

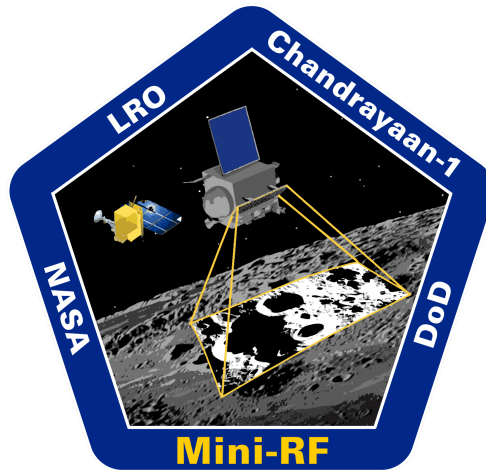
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PDS Data Product Software Interface Specification (SIS)

For

Mini-RF Advanced Technologies – Lunar Reconnaissance Orbiter (LRO) Payload Operations Center



February 25, 2010

Prepared by
Mini-RF Program

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RECORD OF CHANGES

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0	31 May 2007	Initial release.	M. Reid
1	14 Mar 2008	Major revisions based upon external review.	M. Reid
2	20 May 2008	Added Sandia SAR Stereo products to section 6.1.2.	M. Reid
3	8 April 2009	Modified section 6.1.2 description of Sandia products. Resolved remaining TBD items. Table 3: Added data set ID and name for the Sandia SAR Stereo product.	M. Reid
4	30 July 09	Added CENTER_FREQUENCY keyword to Level 1 and Level 2 product labels.	M. Reid
5	30 Nov 09	Updated file naming conventions. Updated reviewers and approvals page.	M. Reid
6	10 Dec 09	Added data quality keywords to labels.	M. Reid
7	17 Dec 09	Redefined data quality description.	M. Reid
8	26 Jan 10	Major revision: Eliminated Level 1 stokes and polarization ratio derived products; eliminated Level 1 browse images; eliminated grid map files, added "quick view" (formerly browse) images derived from Level 2 CDRs; removed Vexcel CALPRO calibration products from archive; added Arecebo and Greenbank calibration data; added new documents describing calibration; changed filenaming convention; moved description of Level 3 Polar Mosaic products from Appendix to sec. 4.3.3. Removed DATA_QUALITY_ID from labels.	M. Reid
9	20 Feb 10	Modified naming convention; added descriptions of daughter products.	M. Reid

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1. Purpose and Scope of Document

This Software Interface Specification (SIS) describes the archived Lunar Reconnaissance Orbiter (LRO) Mini-RF instrument science-related data products. Mini-RF is an instrument that flies on the NASA LRO spacecraft. It is a synthetic aperture radar (SAR), which will image and characterize the lunar surface. The Payload Operations Center (POC) is located at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland. It hosts processing systems, which will generate levels of science data products from the raw telemetry received from the instrument. The raw SAR data are processed within the POC through Level 2 using Microsoft®/Vexcel®'s SAR Processor. This document specifies the format and content of those products and is intended to serve as a guide for producing and using them.



Figure 1: The LRO spacecraft.

This document is intended for scientists and engineers in the planetary science community and others who wish to understand the format and content of the Mini-RF science data products. The SIS applies to the Mini-RF data products produced during the course of LRO Mission operations.

2. Applicable Documents

The LRO Mini-RF SIS references or is applicable to the following documents:

- 1 *Planetary Data System Standards Reference*, NASA/JPL, February 27, 2009, Version 3.8. JPL D-7669, Part-2. Available from <http://pds.jpl.nasa.gov/documents/sr/index.html>. [Accessed: January 26, 2010].

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- 2 *Planetary Data System Archive Preparation Guide*, August 29, 2006, Version 1.1, JPL D-31224, NASA/JPL. Available from <http://pds.jpl.nasa.gov/documents/apg/index.html>. [Accessed: May 8, 2007].
- 3 *Lunar Reconnaissance Orbiter (LRO) Project Instrument Team Data Management and Archive Plan*, Mini-RF program.
- 4 *Lunar Reconnaissance Orbiter (LRO) Mini-RF Science Team and PDS Geosciences Node Interface Control Document (ICD)*, Mini-RF program.
- 5 *Data Interface Control Document for Mini-RF Advanced Technologies – LRO* (MRF-2101), Mini-RF program.
- 6 *Archive Volume Software Interface Specification (SIS) for Mini-RF Advanced Technologies (LRO)* (MRF-4011), Mini-RF program [DOCUMENT/AV_SIS/MRFLRO_AV_SIS].
- 7 *Lunar Reconnaissance Orbiter Data Management and Archive Plan*, 431-PLAN-000182, NASA/GSFC LRO Project.
- 8 P. L. McKerracher, J. R. Jensen, H. B. Sequeira, R. K. Raney, R. C. Schulze, D. B. J. Bussey, B. J. Butler, C. D. Neish, M. Palsetia, G. W. Patterson, P. D. Spudis, B. J. Thomson, F. S. Turner, *Mini-RF calibration, a unique approach to on-orbit synthetic aperture radar system calibration*, 2010 [DOCUMENT/MRF_CAL/MRF_CAL_MCKERRACHER_ET_AL2010].
- 9 J. R. Jensen, *LRO Mini-RF S-band transmit polarization ellipse as observed at Green Bank on August 23, 2009* [DOCUMENT/GB_CAL/MRFLRO_CAL_GBT_JENSEN2010].

3. Relationships with other Interfaces

The LRO data products are produced at the POC and are delivered to the PDS. The products are decompressed radar image files, calibration data, miscellaneous ancillary data, and possibly SPICE kernels. Their formats comply with PDS standards. The image and other files will be archived to the PDS Geosciences node. Any SPICE kernels will be archived at the PDS NAIF node.

4. Data Product Characteristics and Environment

4.1 Instrument Overview

Mini-RF is an instrument on the LRO spacecraft. It is capable of active burst and continuous mode SAR imaging. The continuous mode images are used to create interferometry (also called “InSAR”) products. High-resolution SAR images of Polar Regions of the lunar surface will be obtained. The search for water ice, particularly in the polar regions of the Moon, is its primary science mission, but it will also characterize the surface roughness and thickness of the regolith.

4.1.1 Instrument Description

The LRO Mini-RF instrument has the following parameters, which describe it. The associated values given here are typical, not absolute, and many of them vary.

Parameter	S-Band	X-Band
Altitude	50 km (± 20)	
Inclination	$\sim 90^\circ$ (1.5° wobble, 14-day period)	
Incidence	$\sim 49^\circ$	

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Parameter	S-Band	X-Band
Frequency	2.38 GHz (12.6 cm)	7.14 GHz (4.2 cm)
Polarization	Transmit RCP or LCP, Receive coherent Horizontal & Vertical	
Polarization Purity	Cross-talk: 19 dB, axial ratio: 1.7 dB (end-to-end)	
Spacecraft Velocity	1645 – 1665 m/s	
SAR Swath Width	6 km (baseline)	4 km
Strip length	<400 km	
Antenna Length	1.8 m	
Interferometry Swath Width	3.5 km	
Interferometry Resolution	15 m/pixel	
Antenna Width	0.6 m	
Beam Width	$3.6^{\circ} \times 10.8^{\circ}$	$1.2^{\circ} \times 3.6^{\circ}$
Bore-sight Gain (Two-way)	> 50.6 dB	> 57.5 dB
Noise Equivalent Sigma Naught (Baseline)	-30 dB	-24 dB
Noise Equivalent Sigma Naught (Zoom)	-25 dB	-18 dB
Slant Range Resolution	115 m baseline, 23 m zoom	
Ground Range Resolution	150 m baseline, 15 × 30 zoom	
Looks	16 baseline, 8 zoom	
Azimuth Resolution	150 m baseline, 15 × 30 zoom	
Multiplicative Noise Ratio	-12 dB	
Transmit Pulse Width	50 – 160 μ s	
Chirp Bandwidth	1.6 MHz baseline, 8 MHz zoom	
Peak Power at Transmitter Port	20 W	
Average Transmitted Power	6.4 – 8 W	
PRF	2800 – 5000 Hz	
No samples/pulse	190 – 340 baseline, 1100 – 2000 zoom	
A/D Sampling Frequency	100 Mega-samples per pulse (MSPS)	
Number of A/D Bits Per Sample	12	
Number of Received Channels	2	
Collect Time/Orbit	< 4 minutes	

Table 1 Description of the LRO Mini-RF instrument.

4.2 Data Processing

There are two modes of data acquisition from the Mini-RF instrument on the LRO spacecraft, burst and continuous mode. Burst mode is referred to in this document as the standard SAR product. Continuous mode (also a type of SAR product) is used to create interferometry products. Processed numeric data products are provided in little-endian format.

4.2.1 Data Processing Levels

There are four levels of SAR data products archived at the PDS: raw, Level 1, Level 2, and Level 3 (mosaics). There is a Level 0 processing performed at the POC; however, these are intermediate products that are not scientifically useful and are not archived at the PDS. Additionally, there are ground calibration and ancillary products. All are generated at the POC. Each product will have a unique file name and follow the file naming convention (see File Naming section 4.7.1). Each product file will be associated with a particular data set (see Table 3). A special product, a refined interferometry product, may also be produced. These are described in Appendix section 6.1. The processing levels given in the DATA_SET_IDs are CODMAC levels. All other references to processing levels in this document are NASA processing levels.

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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 1C	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	Non-science data needed to generate calibrated or resampled data sets. Consists of instrument gains, offsets; pointing information for scan platforms, etc.

Table 2 The standard NASA and CODMAC processing levels for science data sets. These are used in defining the data set IDs.

Product Type	Data Set ID DATA_SET_NAME	POC Processing Level	CODMAC Level
Packetized Data Records (PDR)	LRO-L-MRFLRO-1-PDR-V1.0 "LRO MOON MINI-RF 1 PACKETIZED DATA RECORD V1.0"	Raw	1
Calibrated Data Records (CDR)	LRO-L-MRFLRO-4-CDR-V1.0 "LRO MOON MINI-RF 4 CALIBRATED DATA RECORD V1.0"	1	4
Interferometric Calibrated Data Records	LRO-L-MRFLRO-4-CDR-INSAR-V1.0 "LRO MOON MINI-RF 4 INSAR CALIBRATED DATA REC V1.0"	1	4
Map-Projected Calibrated Data Records (CDR)	LRO-L-MRFLRO-5-CDR-MAP-V1.0 "LRO MOON MINI-RF 5 MAP-PROJECTED CALIBRATED DATA REC V1.0"	2	5
Polar Mosaics	LRO-L-MRFLRO-5-CDR-MOSAIC-V1.0 "LRO MOON MINI-RF 5 POLAR MOSAIC CALIBRATED DATA REC V1.0"	3	5
SAR Stereo	LRO-L-MRFLRO-5-CDR-STEREO-V1.0 "LRO MOON MINI-RF 5 SAR STEREO CALIBRATED DATA REC V1.0"	3	5

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Product Type	Data Set ID DATA_SET_NAME	POC Processing Level	CODMAC Level
SPICE Kernels*	LRO-L-SPICE-6-V1.0	N/A	6

Table 3 The archived science data products, their PDS data set IDs and corresponding processing levels. See the description of CODMAC levels in Table 2. *SPICE kernels (optional for the Mini-RF instrument) are archived separately at the NAIF PDS node (VOLUME_ID = LROSP_1000).

Keyword	Value
MISSION_NAME	"LUNAR RECONNAISSANCE ORBITER"
MISSION_ID	LRO
INSTRUMENT_HOST_NAME	" LUNAR RECONNAISSANCE ORBITER "
INSTRUMENT_HOST_ID	LRO
INSTRUMENT_NAME	"MINI-RF LRO"
INSTRUMENT_ID	MRFLRO

Table 4 Values of mission and instrument identifying key words.

4.2.2 Calibration

McKerracher et al (2010) [See Sec. 2, Ref. 8] and Jensen (2010) [See Sec. 2, Ref. 9] describe instrument and data calibration that are applied to the CDRs in documents included in the DOCUMENT directory of the PDS archive. The raw calibration data products are available in the CALIB directory in the accompanying archive. See CALIB/CALINFO.TXT for a listing and discussion of these product files.

4.2.3 Science Data Processing Burst Mode

There are three levels of SAR LRO data products produced while the instrument is in burst mode, which are archived at the PDS Level 1, Level 2, and Level 3 (mosaics). The data are created in the cross-product format in either the baseline or zoom resolution modes with the square pixel spacing aspect ratio. Additionally, there are ground calibration and ancillary products. All are generated at the POC. Each product will have a unique file name and follow the file naming convention given in section 4.7.1. The processed science data products are provided in little-endian format (PC_REAL).

The processing of SAR data into imagery involves the following 3 broad processes.

- Level 0 Processing
- Level 1 Processing
- Level 2 Processing
- Generation of Level 3 mosaics from data from multiple orbits

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4.2.3.1 Level 0 Burst Mode Processing

The Level 0 processing is an intermediate step in the production of deliverable SAR products. The resulting Level 0 products are not scientifically useful in themselves, so **they are not archived**. However, they are mentioned here to aid in the understanding of the deliverable products. The Level 0 Processing steps involve the following:

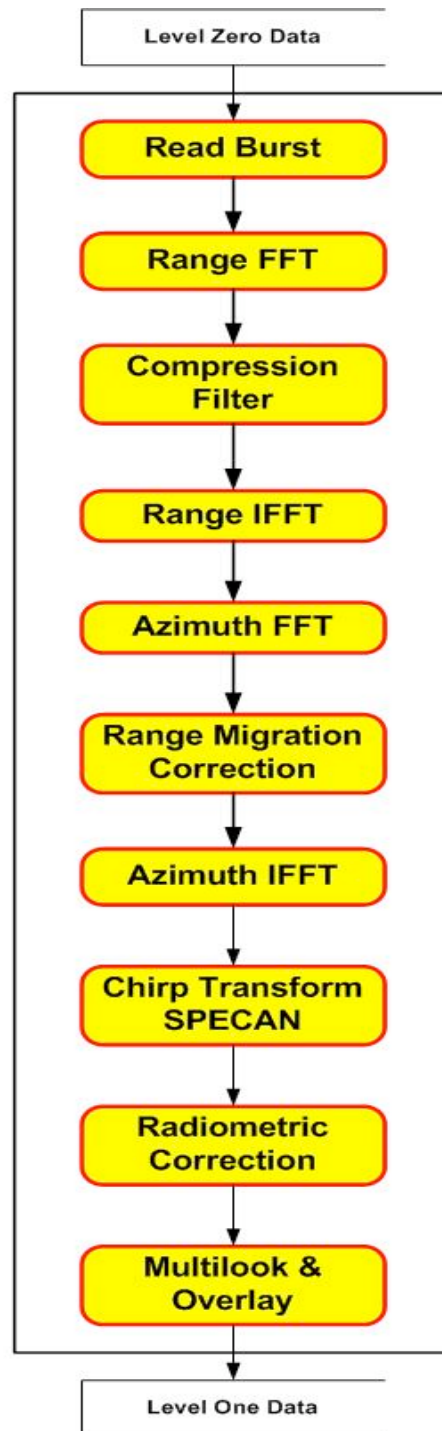
- Telemetry Packets Processing (typically CCSDS format)
- Processing of available on-board calibration and housekeeping data
- Meta-data Extraction (reading of relevant radar parameters from science data header, reading of ephemeris/attitude/time correlation from relevant files)
- Parameter Estimation (Doppler centroid and rate estimation for the data strip, geo-location, range and azimuth spectra, raw data histogram)

4.2.3.2 Level 1 Burst Mode Processing

The level 1 Processing can be carried out in Burst Mode or Continuous Mode depending on the whether the instrument acquired the phase history data in the burst or continuous modes. The flow chart for the Burst Mode processor for data acquired in one polarization only is show in Figure 2 below. The processing consists of the following major steps:

- Range Compression
 - Range FFT
 - Compression Filter
 - Range IFFT
- Azimuth Compression
 - Azimuth FFT
 - Range Migration Curvature Correction
 - Slant Range to Ground Range Conversion
 - Azimuth IFFT
 - Chirp Transform SPECAN
- Radiometric Compensation
 - Range radiometric compensation
 - Azimuth radiometric compensation
- Multi-look Overlay

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Burst Mode Processor Single Polarization

Figure 2 The burst mode processor.

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4.2.3.3 Level 2 Burst Mode Processing

The level 2 processing steps involve the following:

- Generation of the corners of the output Level 2 image in the chosen projection. The corners serve to provide processing bounds for the image strip to be ortho-rectified.
- Image Formation, wherein the L1 image, and optionally an available DEM or GCP file(s) are used to project the image into desired projection.

4.2.4 Science Data Products Continuous (Interferometry) Mode

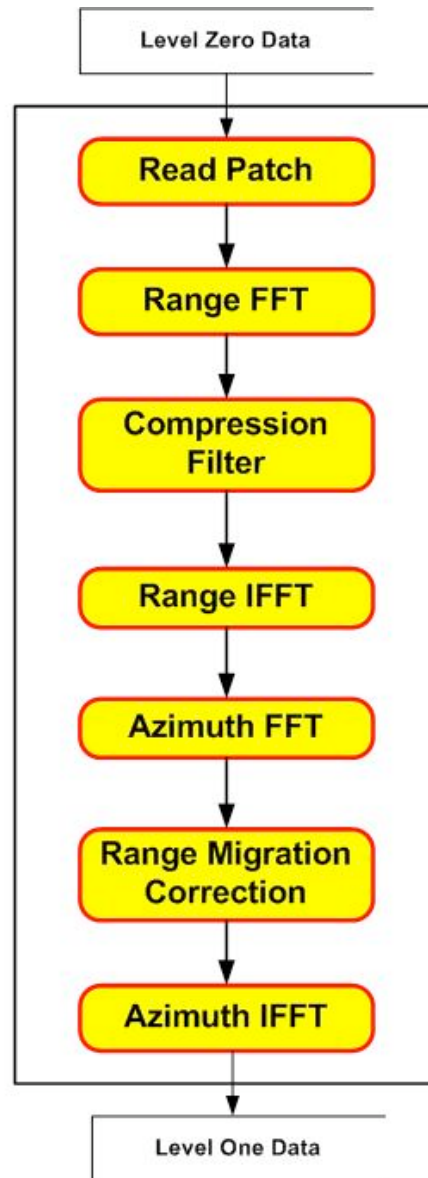
Continuous mode data acquisition is intended for use in producing interferometric (InSAR) data products. There are two levels of continuous mode products archived at the PDS, Level 1 and possibly derived topographic data (Level 3+). There is a Level 0 processing performed at the POC; however, these are intermediate products that are not scientifically useful and are not archived at the PDS. *There are no Level 2 continuous mode products.* All are generated at the POC. Each product will have a unique file name and follow the file naming convention (File Naming, section 4.7.1).

4.2.4.1 Level 1 Continuous Mode Processing

The flow chart for data acquired in continuous mode for a single polarization channel is shown in the Figure 3 below. The processing consists of the following major steps:

- Range Compression
 - Range FFT
 - Compression Filter
 - Range IFFT
- Azimuth Compression
 - Azimuth FFT
 - Range Migration Curvature Correction
 - Azimuth IFFT
- Radiometric Compensation
 - Range radiometric compensation

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Continuous Mode Processor Single Polarization

Figure 3 The continuous mode processor

4.3 Archived Data Products

The format and organization of the archived science, calibration, and ancillary products are described in this section. Metadata accompanies the Raw PDR and CDR data products in a Vexcel[®]-developed human and machine-readable structured text format called “CONI.” These metadata are stored in parameter files of the same name as the data product, except that the file name suffix is **.TXT**. The associated PDS label contains a reference to the parameter file. The

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tables in this section contain detailed descriptions of the product files. The **Num Files** column in the tables indicates the number of files, which make up the specific product.

4.3.1 Raw Data

The Raw Packetized Data Records (PDRs) are in the form of raw binary telemetry in Consultative Committee for Space Data systems (CCSDS) packet format, which have been extracted from frames downlinked from the instrument. PDRs have duplications removed and include any ancillary information needed to understand what is in a given packet. They are retained so that future researchers can reproduce the higher-level products if they so desire. These data will not be reformatted or processed further and are delivered to the PDS with detached minimal PDS labels. Because the higher-level products can be reprocessed as often as desired, there may be a one-to-many relationship a raw data product to a processed data product.

The formats of these packets are identical, but their contents differ. Each of these packets is composed of five segments: the CCSDS Primary Header which contains packet identification information, the CCSDS Secondary Header which contains the packet time stamp, the Science Header which contains associated metadata, the Science Data which contains the data samples, and a trailer ("Other Data") which contains transmission information. Byte values are 8-bits long, Integer values are 32-bits long, short (integers) are 16-bits long, and floating point values are 32-bit IEEE numbers. These data only are provided in big-endian format.

The science data are time-ordered and consist of Vertical (V) or Horizontal (H) polarization channel samples contained within a pulse. The packets will contain either H or V channel data, never both in the same packet. The "V/H Channel Indicator" flag in the Science Header indicates if the data are H or V channel. Data gaps in the derived products or breaks in the sequence count field in the primary CCSDS packet header would indicate missing packets.

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CCSDS Primary Header (6 Bytes)	CCSDS Version	UINT	3	0				Fixed	
	Packet Type	UINT	1	0				Fixed	
	Section Header Flag	UINT	1	1				Fixed, 1 =secondary header	
	Application ID	UINT	11	140	156	1	0	Program by ground command	
	Segment Flag	UINT	2	3				Fixed	
	Sequence Count	UINT	14	0	16383	1	0	Packet number, start from 0, set by Receiver	
	Packet Length	UINT	16	5	4101	1	0	Total number of bytes in packet data field-1, set by Receiver	
CCSDS Secondary Header (6 Bytes)	Spacecraft Seconds	UINT	32	0	4 Billion			Spacecraft time	
	Spacecraft Subseconds	UINT	16	0				Spacecraft time in Fractional seconds	
	Fine Time	UINT	32	0	4 Billion	40	0	vernier counter value latched at the start of each burst	
Science Header (44 Bytes)	Experiment Identifier	UINT	16					waveform parameters	
	Pulse Repetition Interval (PRI)	UINT	16	150,000	500,000	40	0		
	Tx Pulse Width	UINT	16	5,000	20,000	40	0		
	Radar Chirp Start Frequency Offset from MIN VALUE	UINT	16	0	20,000	1	2370000000 for S 7130000000 for X		
	Chirp Rate	SINT	32	-1,500,000	1,500,000	1	0		
	Range Gate Start	UINT	32	0	2,500,000	40	0		
	Rx Pulse Width	UINT	32	5000	1,600,000	40	0		
	Inter-Burst Time	UINT	32	PRI	25,000,000	40	0		
	Number Bursts per Collection	UINT	16	1	10,000	1	0		
	Number of Pulses per Burst	UINT	16	1	30,000	1	0		
		UINT		Defines what cal switches are used and whether transmitter or receiver is used.					
	Collect Option	UINT	8						
	Gain Setting	UINT	8	0	40	1	0		
	Waveform Table ID	UINT	16	0	1,023	1	0		
	Pulse Number within a Burst	UINT	16	0	29,999	1	0		
	Burst Number	UINT	16	0	9,999	1	0		
	Band Select (S / X)	UINT	1	0	1	1	0	S=0, X=1	
	Chirp up / down select	UINT	1	0	1	1	0	UP = 0, Down = 1	
	V / H Channel indicator	UINT	1	0	1	1	0	H =0, V = 1	
	Q:PI Setting	UINT	2	0	2	1	0		
	BAQ Scale Factor	UINT	7	0	127	1	0	Used in Data Processing	

Table 5 Layouts of the Raw Data PDRs. Unlike the other data products, the Raw PDR files are delivered in big-endian format.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Packetized Data Records (PDR) [also referred to as raw data]	CCSDS-formatted binary	Minimal	Geosciences	1	DAT	Raw binary telemetry delivered by the LRO MOC consisting of CCSDS packets with primary, secondary, and science headers. CCSDS packet PDR data. Delivered with no supporting materials. One file for each pass. Also called the "instrument telemetry CCSDS packets". These packets contain data from acquisitions in either continuous or burst mode.
Raw SAR Parameter File	TEXT	Shared with product label	Geosciences	1	TXT	The Raw data SAR Parameter File.

Table 6 Files containing the Raw Data PDRs (DATASET_ID: LRO-L-MRFLRO-1-PDR-Vn.n).

4.3.2 Derived Burst Mode Products

Each pixel in the cross product burst contains like power intensities (HH*, VV*) and the cross power intensity (HV*). The "H" and "V" notation as used here is not to be confused with broadcast and receive polarization.

4.3.2.1 Level 1

The Level 1 data products are Level 1 Calibrated Data Records (CDRs). The POC produces Level 1 SAR CDRs by ingesting the Level 0 EDRs and associated Level 0 ancillary files into the SAR processor (Level 0 data are intermediate products generated from raw (PDR) products. Level 0 data are not archived in PDS.). The Level 1 CDRs are SAR images in range and azimuth orientation with pixel values in beta naught, which have been radiometrically and polarimetrically calibrated. Each cross-product image file contains simple lines of pixels. Each pixel consists of four 4-byte floating-point numbers for a total of 16 bytes. The first two floating-point numbers are the image intensity values for the horizontal (H) and vertical (V) channel receive. The second two numbers are the real and imaginary parts of the single complex number, which gives the cross power intensity image between the H & V receive. H & V represent the complex amplitudes of the horizontal and vertically polarized backscatter respectively. An '*' represents a complex conjugate of H or V. The Level 1 products are the lowest level usable science data products.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 1 Calibrated Data Record (CDR) SAR data.	Binary	Full	Geosciences	1	IMG	The ground range detected cross-product polarimetric image file. Each pixel is represented by two 4-byte floating-point values and an

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
						8-byte complex value (one 4-byte floating point real and one 4-byte floating point imaginary value) for a total of 16 bytes per pixel. The first two numbers are proportionate to HH* and VV* respectively. The next two numbers are proportional to the real and imaginary parts respectively of HV*.
Level 1 SAR Parameter File	TEXT	Shared with product label	Geosciences	1	TXT	The Level 1 cross-product polarimetric SAR Parameter File.

Table 7 Level 1 files. IMG DAT files are binary instrument data and TIF are TIFF images (DATASET_ID: LRO-L-MRFLRO-3-CDR-Vn.n).

4.3.2.2 Level 2

The Level 2 burst mode data products are CDRs that the POC produces by ingesting the Level 1 CDRs into the Level 2 SAR processor. The Level 2 CDRs differ from the Level 1 products in that they are orthorectified and are re-sampled into map projections. Typically, images of regions between $\pm 79^\circ$ of the lunar equator will be rendered into equirectangular projections. Images of regions closer to the lunar poles will be rendered into oblique cylindrical projections. The “equator” of the map projection will correspond to the line of longitude that the subspacecraft point crossed at the equator before the data collection. These will be archived both at the POC and at the PDS. Each pixel is of the same data type as that of the Level 1 image. Seven derived products, sometimes referred to as “daughter products” are included along with each Level 2 CDR. These daughter products include four stokes parameter files, a circular polarization ratio file, a same sense polarization ratio products, and an opposite sense polarization ratio product.

4.3.2.2.1 Stokes Parameters

All Level 2 CDR image products are each accompanied by four Stokes parameters files. Mini-RF transmits a right circular polarized signal, and receives Horizontal and vertical polarized signals, and the phase between the polarizations. The Level 2 file consists of four pieces of information per pixel. The received power on the horizontal polarization (E_{RH}), the received power in the vertical polarization (E_{RV}) and the real and imaginary portions of the cross product between the two polarization signals ($Re E_{RH} E_{RV}^*$ & $Im E_{RH} E_{RV}^*$).

The first Stokes parameter, defined as $S_1 = \langle |E_{LH}|^2 + |E_{LV}|^2 \rangle$, represents the total power or total intensity of the received field.

The second Stokes parameter, defined as $S_2 = \langle |E_{LH}|^2 - |E_{LV}|^2 \rangle$, represents the difference between the horizontally and vertical components of the polarized portion of the received em field.

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The third and fourth Stokes parameters are defined as $S_3 = 2 \operatorname{Re} \langle E_{\text{LH}} E_{\text{LV}}^* \rangle$ and $S_4 = -2 \operatorname{Im} \langle E_{\text{LH}} E_{\text{LV}}^* \rangle$, respectively. They represent respectively the cosine and the sine of the average phase between the horizontally and vertically polarized components of the received field.

4.3.2.2.2 Polarization Products

4.3.2.2.2.1 Same sense circular polarization (SC)

Mini-RF transmits two orthogonal, linearly polarized waves with a phase shift of (nominally) one quarter of the wavelength, and the resulting superposition of these two forms a (nominally) circularly polarized beam. The same sense circular polarization product describes the polarization state of the received field that has an identical polarization to the transmitted beam. This product is calculated as one half of the difference between the Stokes S_1 and S_4 parameters ($SC = 0.5 * S_1 - 0.5 * S_4$).

4.3.2.2.2.2 Opposite sense circular polarization (OC)

The opposite sense circular polarization product describes the polarization state of the received field that has the opposite circular polarization to the transmitted beam. This product is calculated as one half of the sum of the Stokes S_1 and S_4 parameters ($OC = 0.5 * S_1 + 0.5 * S_4$).

4.3.2.2.2.3 Circular polarization ratio (CPR)

This dimensionless parameter is the ratio of the same sense circular polarization to the opposite sense circular polarization ($CPR = SC / OC$). The average CPR value of the entire lunar surface is on the order of 0.3. CPR values for certain types of surface deposits may be either anomalously low (near zero for very smooth terrain) or anomalously high (>1.0 for blocky large-scale rough features). High CPR also is due to volumetric backscattering from thick deposits of frozen volatiles, such as water-ice.

Degree of polarization (m): The fraction of radar backscatter that is polarized is given by the ratio $m = (S_2^2 + S_3^2 + S_4^2)^{1/2} / S_1$. The average value of m at the moon is about 0.6.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 2 SAR Calibrated Data Record (CDR)	Binary	Full	Geosciences	1	IMG	Map-projected calibrated single swath CDR image data. One file for north polar pass and another for the south polar pass. Each pixel is represented by two 4-byte floating-point values and an 8-byte complex value (one 4-byte floating point real and one 4-byte floating point imaginary value) for a total of 16 bytes per pixel. The first two numbers are the intensity images for H and V receive, respectively. The complex value is the cross power intensity image between the H & V receive.
Level 2 SAR Parameter File	TEXT	Shared with product	Geosciences	1	TXT	The Level 2 SAR Parameter File.
Level 2 CDR SAR Stokes Parameters	Binary	Full	Geosciences	4	IMG	Map-projected calibrated single swath CDR image data. Stokes parameters derived from the Level 2 SAR data. One file for each of the four Stokes parameters. These files are used to produce the Level 3 mosaic products. The stokes parameter values are double precision real numbers and are dimensionless.
Level 2 CDR SAR Same-sense polarization image (SSP)	Binary	Full	Geosciences	1	IMG	Map-projected calibrated single swath CDR image data. Single-swath CDR image data. Science product. One file for each pass. Data produced by POC from Level 2 Stokes parameter files. These values are dimensionless.
Level 2 CDR SAR Opposite-sense polarization image (OSP)	Binary	Full	Geosciences	1	IMG	Map-projected calibrated single swath CDR image data. Single-swath CDR image data. Science product. One file for each pass. Data produced by POC from Level 2 Stokes parameter files. These values are dimensionless.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 2 CDR SAR Circular Polarization Ratio	Binary	Full	Geosciences	1	IMG	Map-projected calibrated single swath CDR image data. Single-swath CDR image data. Science product. One file for each pass. Data produced by POC from Level 2 Stokes parameter files. Ratio of same sense to opposite sense polarization. These values are dimensionless.
CPR Quick Look Image	Image	Document	Geosciences	1	JPG	A reduced-size JPEG rendering of the circular polarization ratio (CPR) image.
Stokes 1 Quick Look Image	Image	Document	Geosciences	1	JPG	A reduced-size JPEG rendering of the Stokes 1 parameters image.

Table 8 Level 2 data products (DATASET_ID: LRO-L-MRFLRO-3-CDR-MAP-Vn.n).

4.3.3 Level 3 Polar Mosaics

The Level 3 Burst mode data products are Derived Data Records (DDR)s generated from multiple Level 2 CDRs. They are mosaics that the POC produces by ingesting the Level 2 Stokes parameter files into the ISIS software. Four Level 3 mosaics will be produced of each lunar pole (i.e., regions above 80° latitude) per imaging opportunity. Unlike the lower-level products, these are composed of data sets collected during multiple acquisitions and are produced manually using the ISIS software provided by the Astrogeology branch of the USGS. The final ISIS products are archived at the PDS. Level 3 is the final stage of data processing performed at the POC. These will be archived both at the POC and at the PDS.

LRO Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 3 SAR North Polar Mosaic	Binary	Full	Geosciences	8	IMG	North polar mosaic constructed from data acquired during multiple orbits.
Level 3 SAR North Polar Mosaic Quick Look image	Image	Document	Geosciences	8	JPG	A JPEG rendering of the mosaic.
Level 3 SAR South Polar Mosaic	Binary	Full	Geosciences	8	IMG	South polar mosaic constructed from data acquired during multiple orbits.

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LRO Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 3 SAR South Polar Mosaic Quick Look image	Image	Document	Geosciences	8	JPG	A TIFF rendering of the mosaic.

Table 9 Level 3 Burst Mode SAR Mosaic data products produced using the USGS ISIS software (DATASET_ID: LRO-L-MRFLRO-3-CDR-MOSAIC-V $n.n$).

See Appendix sec. 6.1 for a description of additional derived Level 3+ data products.

4.3.4 Continuous Mode Products

4.3.4.1 Level 1

The continuous mode Level 1 data products are Level 1 Calibrated Data Records (CDRs). These may be used to create refined interferometric products. The POC produces Level 1 SAR CDRs by ingesting the Level 0 EDRs and associated Level 0 ancillary files into the Vexcel® SWATH processor. The Level 1 CDRs are SAR images and interferometry in range and azimuth orientation with pixel values in beta naught. The data are created in single-look complex format with pixel spacing in the native sampling aspect ratios. They are the lowest level usable science data products. There are no additional products produced from interferometry data.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 1 CDR H Polarization Single Look Complex data	Binary	Full	Geosciences	1	IMG	Continuous mode Horizontal channel Interferometry image strips. Each pixel is a complex number consisting of a 4-byte floating-point real and 4-byte floating-point imaginary part for a total of 8-bytes.
Level 1 CDR H Polarization Single Look Complex Parameter File	TEXT	Shared with product	Geosciences	1	TXT	Ancillary metadata listing the various parameters that identify and describe the product.
Level 1 CDR V Polarization Single Look Complex data	Binary	Full	Geosciences	1	IMG	Continuous mode Vertical channel Interferometry image strips. Each pixel is a complex number consisting of a 4-byte floating-point real and 4-byte floating-point imaginary part for a total of 8-bytes.
Level 1 CDR V Polarization Single Look Complex Parameter File	TEXT	Shared with product	Geosciences	1	TXT	Ancillary metadata listing the various parameters that identify and describe the product. Produced in continuous acquisition mode only.

Table 10 Level 1 files (DATASET_ID: LRO-L-MRFLRO-3-CDR-INSAR-V $n.n$).

4.3.5 Calibration Data Products

Calibration data products used in processing consist of raw, packetized data records received from the Mini-RF instrument on-board the spacecraft and produced by calibration activities using the Arecibo Radio Telescope in Puerto Rico and the Greenbank Radio Telescope in West Virginia. These are described in papers referenced in sec. 4.2.2.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Packetized Data Records (PDR) [also referred to as raw data]	CCSDS-formatted binary	Minimal	Geosciences	1	DAT	Raw binary telemetry delivered by the LRO MOC, the Arecibo Radio Telescope, or the Greenbank Radio Telescope consisting of CCSDS packets with primary, secondary, and science headers. CCSDS packet PDR data. Delivered with no supporting materials.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Raw SAR Parameter File	TEXT	Shared with product label	Geosciences	1	TXT	The Raw data Parameter File.
Calibration Parameter File	Text file	Minimal	Geosciences	1	TXT	File listing the various parameters and values used in data calibration.

Table 11 Calibration products. These products are found in the CALIB directory in the archive volume.

4.3.6 Ancillary Data Products

Ancillary data accompanies the science data and are also archived at the POC and the PDS. They too will have detached PDS standard labels.

4.3.6.1 Instrument Housekeeping Data

The Instrument Housekeeping Data contain information about the state of the instrument. The data are provided in comma separated variable (CSV) text files. The exact contents of this may vary depending on data rate and other factors. See Table 12 for a description of the ancillary data product that contains these data.

4.3.6.2 Digital Elevation Model (DEM) Files

The DEM files are produced using both interferometric and SAR stereo techniques. They consist of cartographically projected maps of topography. They will be used by scientists to study the topography of the polar regions.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Digital Elevation Model (DEM) data file	Binary	Full	Geosciences	1	DAT	The Digital Elevation Model used in the SAR processors. A description of these will be provided in a later version of this document.
Digital Elevation Model (DEM) parameter file	TEXT	Shared with product	Geosciences	1	TXT	The Digital Elevation Model parameter file.
Instrument Housekeeping Data	TEXT SPREAD-SHEET	Full	Geosciences	1	CSV	The instrument housekeeping (engineering) data.

Table 12 List of ancillary data files.

4.3.7 SPICE Kernels

The SPICE Kernels are structured parameter files that describe, among other things, the ephemeris and attitude of the spacecraft, the spatial orientation of the instrument, the ephemeris and physical parameters of the Earth, Moon and other natural bodies in the Solar System, the relationship between spacecraft time and time as measured on Earth, and the locations and orientations of ground stations. Some of these files are standard products generated by the NAIF

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team at JPL and are not mission specific. Others are produced specifically for a particular mission or instrument. Some of these files are binary and others are text. The SPICE kernels generated for the overall LRO mission will not be part of the data archive generated by the POC and delivered to the PDS. The LRO project will manage these and provide for their archiving. If SPICE kernels are generated specifically for the Mini-RF instrument, they will be archived separately at the NAIF node of the PDS. These are optional products. The Mini-RF project will determine during the course of the mission if any instrument-specific SPICE kernels are to be created. Their existence and archival at the NAIF node will be noted in the AAREADME.TXT file that accompanies the archive volume.

SPICE Kernel files are intended for use with the SPICE software library. This is a software product from the Navigation and Ancillary Information Facility (NAIF) at the NASA Jet Propulsion Laboratory (JPL), which contains functions that perform computations for space mission-related and astronomical applications. Any SPICE kernels used in product generation will be listed in the SOURCE_PRODUCT_ID field of the accompanying PDS labels.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Instrument Kernel	SPICE IK Kernel	SPICE Kernel label	NAIF	1	ti	Instrument field of view kernel. This is an optional product.

Table 13 SPICE kernels optionally delivered with the product sets.

4.3.8 PDS Archive Files

There is a set of standard files that accompany a data product to be archived at the PDS. These files and some supporting documents are described here. See the Mini-RF LRO Data Archive Volume SIS [sec. 6] document for more information about these files and their locations in the archive.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
AAREADME.TXT	Plain Text	Document attached	Geosciences	1	TXT	Volume content and format information. Includes the location of any instrument-specific SPICE kernels created.
ERRATA.TXT	Plain Text	Document attached	Geosciences	1	TXT	A cumulative listing of comments and updates relating to the Forerunner science data archive.
VOLDESC.CAT	PVL Text	N/A	Geosciences	1	CAT	A description of the contents of the delivered product set.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
INDXINFO.TXT	Plain Text	Document attached	Geosciences	1	TXT	A description of the contents of the Index directory.
INDEX.TAB	Text Table	Full	Geosciences	1	TAB	A table listing all of the data products in the delivery.
MD5.TAB	Text Table	Full	Geosciences	1	TAB	Contains a cumulative set of MD5 checksum values for each file in the archive.
DOCINFO.TXT	Plain Text	Document attached	Geosciences	1	TXT	A description of the contents of the Document directory.
MRFLRO_DP_SIS.PDF	Adobe PDF	Document	Geosciences	1	PDF	The Data Product SIS (this document) in PDF format. The PDS label is shared with the HTML version below.
MRFLRO_DP_SIS.HTM, IMAGE*.GIF, IMAGE*.JPG	HTML Text	Document	Geosciences	8	HTM	This document in HTML format. Associated images will be in JPEG and GIF files.
MRFLRO_AV_SIS.PDF	Adobe PDF	Document	Geosciences	1	PDF	The archive volume SIS document in PDF format. The PDS label is shared with the HTML version below.
MRFLRO_AV_SIS.HTM, IMAGE*.GIF, IMAGE*.JPG	HTML Text	Document	Geosciences	1	HTM	The archive volume SIS document in HTML format. Associated images will be in JPEG and GIF files.
MRF_CAL_MCKERRACHER_ET_AL2010.PDF	Adobe PDF	Document	Geosciences	1	PDF	Mini-RF Calibration white paper in PDF format. The PDS label is shared with the HTML version below.
MRF_CAL_MCKERRACHER_ET_AL2010.HTM, IMAGE*.GIF or JPG	HTML Text	Document	Geosciences	1	HTM	Mini-RF Calibration white paper in HTML format. Associated images will be in JPEG and/or GIF files.
MRFLRO_CAL_GBT_JEN SEN2009.PDF	Adobe PDF	Document	Geosciences	1	PDF	Mini-RF Calibration white paper in PDF format. The PDS label is shared with the HTML version below.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
MRFLRO_CAL_GBT_JEN SEN2009.HTM, IMAGE*.GIF or JPG	HTML Text	Document	Geosciences	1	HTM	Mini-RF Calibration white paper in HTML format. Associated images will be in JPEG and/or GIF files.
CATINFO.TXT	Plain Text	Document attached	Geosciences	1	TXT	A description of the contents of the Catalog directory.
*_DS.CAT	PVL Text	N/A	Geosciences	1	CAT	Data set information for the PDS catalog. These will have the following file names: MRFLRO_1_PDR_DS. CAT MRFLRO_4_CDR_DS. CAT MRFLRO_4_CDR_INS AR_DS.CAT MRFLRO_5_CDR_MAP _DS.CAT MRLRO_5_CDR_MOS AIC_DS.CAT
INSTHOST.CAT	PVL Text	N/A	Geosciences	1	CAT	Information about the LRO spacecraft for the PDS catalog.
INST.CAT	PVL Text	N/A	Geosciences	1	CAT	Information about the Mini-RF instrument for the PDS catalog.
MISSION.CAT	PVL Text	N/A	Geosciences	1	CAT	Information about the overall mission for the PDS catalog.
PERSON.CAT	PVL Text	N/A	Geosciences	1	CAT	Information about key personnel involved in the Forerunner project for the PDS catalog.
REF.CAT	PVL Text	N/A	Geosciences	1	CAT	References mentioned in other *.CAT files.
CALINFO.TXT	Plain Text	Document attached	Geosciences	1	TXT	A description of the contents of the Calibration directory. This directory contains the calibration files referenced in section 4.2.2.

Table 14 PDS standard files that contain descriptive and indexing information about the archive.

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4.4 Data Product Archiving

The LRO Mini-RF POC is responsible for science data product generation, validation, and archiving. The POC supports and works with the LRO mission operations, the LRO Mini-RF science team, and the PDS.

4.4.1 Data Flow

Prior to science phase of the LRO mission, the POC produces sample data products from raw telemetry generated by spacecraft and instrument simulators located at GSFC. During the mission, the spacecraft control center receives the science data downlink from the spacecraft on one channel and the housekeeping data on a second channel. The MOC sends the raw data from the Mini-RF instrument to the POC through a data link. At the POC, the Vexcel[®] SAR and Calibration processors process the raw SAR data through levels 0, 1, and 2. Level 3 mosaics are produced using the ISIS software from the USGS. Interferometry data are processed through a separate processor. Software applications developed specifically for and running only at the POC facilitate this processing and package the data for later archiving at the PDS.

The Vexcel[®] SAR processors consist of the SKY Level 0 processor (products not archived), the SWATH Level 1 processor, and the ORTHO Level 2 processor. Each processor's output products are the input to the next level's processor. Calibration is performed by the Vexcel[®] CALPRO processor.

4.4.2 Labeling and Identification

With the exception of the Raw data, all data products described in this document which are to be delivered to the PDS are accompanied by full PDS standard labels. Detached minimal labels accompany the Raw data. The PDS labels are detached text files, which describe the associated product file. There will be one label file for each product file. These labels conform to the PDS version 3 standards. A product ID in its PDS label will uniquely identify each product. The file name may be used for the product ID as long as it is unique.

The PDS label describes and provides ancillary information about the data product. They are written in a structured text language called "Object Description Language (ODL)." Examples of a LRO Mini-RF PDS labels are given in section 4.8.2. Note that not all of the keywords are necessarily present in a given PDS label.

4.5 Standards Used in Generating Data Products

4.5.1 PDS Standards

The LRO Mini-RF science and calibration data products are constructed according to the data object concepts developed by the PDS. By adopting the PDS format, the data products are consistent in content and organization with other planetary image collections. In the PDS standard, the data product file is grouped into objects with PDS labels describing the objects. All PDS labels are written in ODL, a subset of the Parameter Value Language (PVL), which is a structured text format (Applicable Document 1). The LRO Mini-RF data products contain:

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1. PDS Label Files describing the specific product (including external data files)
2. SAR or Interferometry image data files.
3. Stokes parameter files.
4. Calibration data files.
5. Ancillary files containing housekeeping data, lunar geometric data, and metadata in an ASCII table format.
6. Documentation.

The image data will be delivered in an uncompressed form.

4.5.2 Time Standards

All time values in the PDS labels shall be given in Coordinated Universal Time (UTC). The time in UTC shall be represented in ISO calendar format standard: *yyyy-mm-ddThh:mm:ss.ss* eg 2006-08-14T15:02:10.12.

The spacecraft time in Mission Elapsed Time (MET) shall also be given in the science product labels in the form of SPICE spacecraft clock (SCLK) strings. An SCLK string has the form “<partition>/<MET seconds>:<MET subseconds>”, where partition is the current spacecraft clock partition, *MET seconds* is the mission elapsed time in seconds, and *MET subseconds* is the vernier counter representing a fraction of a second. An example of an SCLK string is “1/123456789:123456”.

4.5.3 Coordinate Systems

Table 11 lists the computational assumptions for the geometric and viewing data provided in the PDS label. There are two reference frames (coordinate systems) in use: 1) the International Celestial Reference Frame (ICRF), also frequently called the J2000 or the E.M.E. 2000 frame, used for target and spacecraft position and velocity vectors, and instrument pointing and 2) a lunar body-fixed reference frame, used for specifying certain viewing geometry vectors and target location. The lunar body-fixed frame used by the Mini-RF investigation is the Mean Earth/Polar Axis frame (commonly abbreviated as ME), as realized using NASA’s SPICE products (Frames Kernel).

Item	Assumption	Comment
Geometric Elements	The mid-point time of observation is used for the geometric element computations.	
Label Parameters	The label parameters reflect the observed, not the true geometry. Therefore, light-time and stellar aberration corrections are used as appropriate.	
Inertial Reference Frame	The inertial reference frame is J2000 (also called “EME2000”)	

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Item	Assumption	Comment
Coordinate System	Latitudes and longitudes are given in the Mean Earth/Polar Axis (ME) coordinate system.	LRO project teams may optionally use the Principal Axis (PA) coordinate system internally, but will always use the ME coordinate system for data archived at the PDS.
Sub-Point	The "sub-point" of a body on a target is defined by the surface intercept of the body-to-target-center vector. This is not the closest point on the body to the observer. This definition gives sub-point latitude and longitude that are independent of the reference ellipsoid.	
Units	Distances are in km, speeds in km/sec, angles in degrees, and angular rates in degrees/sec unless otherwise noted.	
Angular Ranges	Angle ranges are 0 to 360 degrees for azimuths and local hour angles. Longitudes range from 0 to 360 degrees (positive to the East). Latitudes range from -90 to 90 degrees.	
Geometric Parameters	SPICE kernel files are used to store the geometric parameters.	

Table 15 Computational assumptions.

4.5.4 Archiving Standard

The science data products will be archived by orbit number and the complete archive will consist of approximately 720 orbits.

4.5.5 Data Storage Conventions

All text files are of standard ASCII format and in accordance with PDS standards, each line in a text file terminates with a carriage return (ASCII 13) and line feed (ASCII 10) end of line (EOL) marker (i.e., <CR><LF>).

4.6 Data Validation

Basic data validation is performed at the POC and consists of the following:

- POC staff check the data products for conformance to this document and the Archive Volume SIS, and for valid science content.
- Generation of data products and volumes, together with validation are completed within the required validation period of six months from the availability of processing input data.
- Prior to the first delivery of the products to the PDS, PDS representatives and other interested parties review a sample product set generated by the POC and may request changes to the product set as necessary to conform to the SIS.
- The data pipeline is also reviewed as part of the validation process.

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- In accordance with PDS requirements, the design of the data products as described by this Data Product SIS, and as shown by a set of sample products, undergoes a peer review prior to the beginning of processing. A review committee made up of a few scientists who are knowledgeable in the area along with representatives from the POC and the PDS evaluate the products. They may produce a list of liens against the product set that will be resolved prior to PDS archiving.

4.7 Data Product Structure and Organization

4.7.1 File Naming

The file names developed for any PDS archive are restricted to a maximum 27-character base name and 2 or 3 character extension name with a period separating the file and extension names. Also known as the “27.3” format, this is compliant with the ISO 9660 Level 2 specification, which is required by PDS. All file names for products archived at the PDS contain only capital letters, numerals, and underscores (except for the one period ‘.’ which separates the file basename from the file extension). All files begin with the one character instrument identifier **L** (LRO) which is the file designation for all LRO Mini-RF files. In accordance with PDS standards, all file names are in capital letters. The three-character file extension for each type of product file is given in the File Extension column of each product description table in section 4.2.1.

4.7.1.1 File Naming Conventions for the Orbit-Based Science Data Products

The following table describes the detailed naming convention used for the Raw, Level 1, Level 2, and Level 3 data products. The Vexcel[®] processors produce the Level 1 and Level 2 products.

Format: *Mfm_ooooo_ltt_abu_ccdeee_Vv.ext*

M = Indicates the instrument.

L = LRO

F = Forerunner

B = Both

f = Frequency band

S = S-band

X = X-band

B = Both

N = N/A

m = Radar mode

B = Baseline SAR

I = Interferometry

S = Scatterometry

Z = Zoom

A = Arecibo Radio Telescope Calibration

G = Greenbank Radio Telescope Calibration

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C = Other Calibration
O = Other (housekeeping, etc.)

ooooo = The orbit number in which the data acquisition began. Numeric, range 00001...99999.

l = Processing level

R = Raw PDR
1 = Level 1
2 = Level 2
3 = Level 3

tt = File type

PD = Packetized Data Records
CD = Calibrated Data Records
S1 = Stokes Parameter 1 File
S2 = Stokes Parameter 2 File
S3 = Stokes Parameter 3 File
S4 = Stokes Parameter 4 File
SC = Same-Sense Polarization Image File
OC = Opposite-Sense Polarization Image File
CP = Circular Polarization Ratio image File
HK = Instrument Housekeeping data (Associated with RAW data only)

a = projection

O = Oblique cylindrical
E = Equirectangular
P = Polar stereographic
X = N/A (for Raw, Level 1, Housekeeping, cal, etc.)

b = pixel resolution bin scale in pixels per degree (ppd)

A = 1 ppd
B = 2 ppd
C = 4 ppd
See Table 16.
X = N/A (calibration or housekeeping data)

Designator	Pixels/Degree (ppd)	Meters/Pixel (mpd)
A	1	30323
B	2	15162
C	4	7581
D	8	3790
E	16	1895
F	32	948

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G	64	474
H	128	237
I	256	118
J	512	59
K	1024	29.6
L	2048	14.8
M	4096	7.4
N	8192	3.7
O	16384	1.9
X	N/A	N/A

Table 16 Association of letter-designated bins for pixel resolutions.

u = bit type and scaling

U = Unnormalized floating point

F = Normalized floating point

B = Byte

cc = Lunar center latitude to nearest whole degree

Numeric value range 00...90.

XX = N/A or Unknown

d = hemisphere of latitude

N = North latitude

S = South latitude

X = N/A

eee = Lunar center longitude to nearest whole degree

Numeric value range 000...359.

XXX = N/A or Unknown

v = Product version number. Numeric range 1...9.

ext = Product type (complies with PDS conventions)

IMG = Processed image file

DAT = Unformatted binary data (e.g., raw files)

JPG = JPEG formatted browse images

TXT = Unstructured text data (e.g., parameter files)

CSV = Comma Separated Value text files
(housekeeping)

LBL = PDS label file

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The following is an example file name of a Mini-RF SAR mode raw data product. It is baseline SAR, S-band, raw data, packetized data record, byte format, no projection, 75 m/pixel resolution, center coordinates 82°N, 231°, orbit 512, version 1.

LSB_00512_RPD_XJB_82N231_V1.DAT

The following is an example file name of a Mini-RF LRO SAR mode level 2 CDR data product. It is zoom mode, X-band, level 2 processed, calibrated data record, oblique cylindrical projection, 512 pixels/degree resolution, unnormalized floating point format, center coordinates 82°N, 231°, orbit 617, version 3.

LXZ_00617_2CD_OJU_82N231_V3.IMG

The following is an example file name of a Mini-RF LRO SAR mode level 2 stokes 3 data product. It is baseline SAR mode, S-band, level 2 processed, stokes parameter, simple cylindrical projection, unnormalized floating point format, 512 pixels/degree resolution, center coordinates 82°N, 231°, orbit 512, version 2.

LSB_00512_2S3_EJU_82N231_V2.IMG

The following is an example file name of a Mini-RF LRO calibration data product. It is a raw product collected using the Arecibo Radio Telescope. The spacecraft orbit number is 975, it is a raw packetized data record product, bit type is binary, the location on the Moon is not specified, and it is version 1.

LSA_00975_RPD_XXB_XXXXXX_V1.DAT

4.7.1.2 File Naming Conventions for the Level 3 Polar Mosaics

The following table describes the detailed naming convention for this dataset. These products are mosaics. They contain data from multiple orbits. The file names of the polar mosaics follow the same naming convention as the other science products, except that the center latitude and longitude given in their file names are that of the center of the mosaic and the orbit number is that of the highest orbit number product among the lower-level products used in the mosaic.

The following is an example file name of a Mini-RF LRO polar mosaic, zoom, SAR, S-band, level 3, same-sense polarization, unnormalized floating point, north pole mosaic product, 2048 ppd, version 01. The highest orbit number data that was used was orbit 752.

LSZ_00752_3SC_PLU_90N000_V1.IMG

All files have a corresponding PDS label of the same name except for a suffix ending **.LBL**.

4.7.1.3 File Naming Conventions for SPICE Kernels

The Mini-RF instrument kernel is the only LRO kernel, which might be created, by the POC and therefore, the only one discussed here. The creation of this product is optional. The LRO project

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creates other SPICE kernels for the mission, but they are created and archived separately and not discussed here. The file naming convention for the sole Mini-RF SPICE kernels is **lro_mrf_vv.ti** where *nn* is the version number and the “.ti” suffix indicates that it is an instrument kernel. The kernel filename is in all lower-case per PDS NAIF node standards.

Instrument kernel (IK):

Format: **lro_mrf_vnn.ti**

Label: **lro_mrf_vnn.lbl**

4.7.1.4 File Naming Conventions for the Digital Elevation Model (DEM) File

The DEM naming convention and that of its associated parameter file are given below. *yyyymmdd* is the date that they were released. If provided, the DEM files will be included in the EXTRAS directory within the archive volume and will not have associated PDS labels.

Format: **LUNAR_DEM_yyyyymmdd_vv.DAT**

Format : **LUNAR_DEM_yyyyymmdd_vv.TXT**

4.8 Label and Header Descriptions

4.8.1 PDS Label Parameter Descriptions

The key words used in LRO Mini-RF data product PDS labels are described in Table 17 below.

Key Word	Description
A_AXIS_RADIUS	The a_axis_radius element provides the value of the semimajor axis of the ellipsoid that defines the approximate shape of a target body. 'A' is usually in the equatorial plane.
B_AXIS_RADIUS	The b_axis_radius element provides the value of the intermediate axis of the ellipsoid that defines the approximate shape of a target body. 'B' is usually in the equatorial plane.
C_AXIS_RADIUS	The c_axis_radius element provides the value of the semiminor axis of the ellipsoid that defines the approximate shape of a target body. 'C' is normal to the plane defined by 'A' and 'B'.
AZIMUTH_RESOLUTION	The radar image line resolution.
BANDS	The BANDS element indicates the number of bands in the image.
BAND_NAME	BAND_NAME is the name given to a single band in a multi-band image or image cube. These identify the components of the radar image pixel.
BAND_STORAGE_TYPE	The band_storage_type element indicates the storage sequence of lines, samples and bands in an image. The values describe, for example, how different samples

Key Word	Description
	are interleaved in image lines, or how samples from different bands are arranged sequentially.
CENTER_FREQUENCY	The carrier frequency of the SAR in Hertz.
CENTER_LATITUDE	The center_latitude element provides a reference latitude for the map projections (always 0 for oblique cylindrical) and a center point for Level 1 images.
CENTER_LONGITUDE	The center_longitude element provides a reference longitude for the map projections (always 0 for oblique cylindrical) and a center point for Level 1 images.
CHECKSUM	A CRC checksum value for the data file produced by the Posix cksum utility.
COORDINATE_SYSTEM_NAME	The coordinate_system_name element provides the full name of the coordinate system to which the state vectors are referenced.
COORDINATE_SYSTEM_TYPE	There are three basic types of coordinate systems: body-fixed rotating, body-fixed non-rotating and inertial. A body-fixed coordinate system is one associated with a body (e.g., the Moon).
^DATA_SET_MAP_PROJECTION	Reference to the file that describes the oblique cylindrical map projection.
DATA_SET_ID	Uniquely identifies the data sets available on the volume. The EDR collection is made up of a single data set.
DATA_SET_NAME	The full name given to the data set.
DESCRIPTION	A narrative description of an object described in the label.
EASTERNMOST_LONGITUDE	The maximum numerical value of longitude unless it crosses the Prime Meridian.
FIRST_STANDARD_PARALLEL	A required keyword; however, it is not applicable for oblique cylindrical projects. Always "N/A".
^IMAGE	The file name of the image data product being described.
INCIDENCE_ANGLE	The sensor beam incidence angle. The angle between the local vertical and the spacecraft direction.
INSTRUMENT_HOST_ID	The unique identifier for the spacecraft which carries the instrument.
INSTRUMENT_HOST_NAME	The full name of the spacecraft which carries the instrument.
INSTRUMENT_MODE_DESC	Describes the instrument mode which is identified by the instrument_mode_id element.
INSTRUMENT_MODE_ID	The instrument-dependent designation of operating mode.
INSTRUMENT_NAME	The FULL name of the instrument. Note that the associated INSTRUMENT_ID element provides an abbreviated name or acronym for the instrument.
INSTRUMENT_ID	Abbreviated name or acronym which identifies the instrument.

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Key Word	Description
KEYWORD_LATITUDE_TYPE	Identifies the type of latitude (planetocentric) used in the labels, e.g., for the maximum, minimum, center, reference, and standard-parallel latitudes.
LINE_FIRST_PIXEL	The line index of the first pixel that was physically recorded at the beginning of the image array.
LINE_LAST_PIXEL	The line index of the last pixel that was physically recorded at the end of the image array.
LINE_PROJECTION_OFFSET	The line offset value of the map projection origin position from the line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array).
LINES	The total number of data instances along the vertical axis of an image.
LINE_SAMPLES	The total number of data instances along the horizontal axis of an image.
FILE_NAME	The name of the product data file described by the label.
FILE_RECORDS	The number of physical file records, including both label records and data records.
LABEL_REVISION_NOTE	Indicates the revision date and authorship of the current label.
LINE_EXPOSURE_DURATION	The time elapsed during the acquisition of one image line of data.
LOOK_DIRECTION	The value (RIGHT or LEFT) indicates the side of the spacecraft groundtrack to which the antenna is pointed for data acquired within a synthetic aperture radar (SAR) image.
MAP_PROJECTION_ROTATION	The clockwise rotation, in degrees, of the line and sample coordinates with respect to the map projection origin. Always 90 for oblique cylindrical projections.
MAP_PROJECTION_TYPE	Identifies the type of projection characteristic of a given map, always oblique cylindrical in this case.
MAP_RESOLUTION	The scale of the map in pixels/degree. The scale is defined as the ratio of the actual distance between two points on the surface of the target body to the distance between the corresponding points on the map.
MAP_SCALE	The scale of the map in kilometers/pixel. The scale is defined as the ratio of the actual distance between two points on the surface of the target body to the distance between the corresponding points on the map.
MAXIMUM	Indicates the largest pixel value in the image.
MAXIMUM_LATITUDE	The northern most latitude represented in the image.
MD5_CHECKSUM	A checksum value using the MD5 algorithm.
MEAN	The mean value of the pixels in the image.
MINIMUM	Indicates the smallest pixel value in the image.
MINIMUM_LATITUDE	The southern most latitude represented in the image.
MISSION_NAME	Identifies the mission.

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Key Word NAME	Description
OBLIQUE_PROJ_POLE_LATITUDE	The common term used to describe the type of data described in the label. One of the three angles defining the oblique coordinate system used in the OBLIQUE CYLINDRICAL projection. This is the ordinary latitude in degrees of the pole (Z axis) of the oblique system.
OBLIQUE_PROJ_POLE_LONGITUDE	One of the three angles defining the oblique coordinate system used in the OBLIQUE CYLINDRICAL projection. This is the ordinary longitude in degrees of the pole (Z axis) of the oblique system.
OBLIQUE_PROJ_POLE_ROTATION	One of the three angles defining the oblique coordinate system used in the OBLIQUE CYLINDRICAL projection. This is a rotation in degrees around the polar (Z) axis of the oblique system that completes the transformation from standard to oblique coordinates.
OBLIQUE_PROJ_X_AXIS_VECTOR	The X vector is the unit vector to the spacecraft at closest approach.
OBLIQUE_PROJ_Y_AXIS_VECTOR	The Y vector is the unit vector parallel to the velocity at this time.
OBLIQUE_PROJ_Z_AXIS_VECTOR	The Z vector is the cross product of the X and Y vectors.
ORBIT_NUMBER	Indicates the number of the observational pass around the Moon.
ORIGINAL_PRODUCT_ID	The temporary product identifier that was assigned to a product during active flight operations, which was eventually replaced by a permanent id (see product_id). This may not end up being used.
PDS_VERSION_ID	The version number of the PDS standards documents that is valid when a data product label is created. PDS3 is used for the LRO Mini-RF Data products.
POSITIVE_LONGITUDE_DIRECTION	Identifies the direction of longitude (e.g. EAST, WEST) for a planet. This is EAST for the Moon.
PRODUCER_FULL_NAME	The full_name of the individual mainly responsible for the production of a data set.
PRODUCER_ID	The short name or acronym for the producer or producing team/group of a dataset.
PRODUCER_INSTITUTION_NAME	The organization responsible for developing the data products.
PRODUCT_CREATION_TIME	The time in UTC when the product was created.
PRODUCT_ID	The permanent, unique identifier assigned to a data product by its producer. In the PDS, the value assigned to product_id must be unique within its data set.
PRODUCT_TYPE	The type of product, e.g. PDR, CDR, Mosaic, etc.
PRODUCT_VERSION_ID	The version of an individual product within a data set. This will be used for LRO Mini-RF products that may undergo multiple iterations. For example, RDR products, which are regenerated using an

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Key Word	Description
PUBLICATION_DATE	updated calibration model or compressed images that are uncompressed using a different scheme.
<mission>:RANGE_COEFFICIENT_SET	The date when a published document was issued.
RANGE_RESOLUTION	The Mini-RF instrument-specific ground range to slant range coefficients.
RECORD_BYTES	The image pixel resolution.
RECORD_TYPE	The number of bytes in a physical file record, including record terminators and separators.
REFERENCE_LATITUDE	The record format of a file.
REFERENCE_LONGITUDE	The zero latitude in a rotated spherical coordinate system that was used in a given map_projection_type.
RELEASE_ID	The zero longitude in a rotated spherical coordinate system that was used in a given map_projection_type.
SAMPLE_BITS	Identifies the unique identifier associated with a specific release of a data set. All initial releases should use a RELEASE_ID value of '0001'.
SAMPLE_FIRST_PIXEL	The stored number of bits, or units of binary information, contained in a line_sample value.
SAMPLE_LAST_PIXEL	The sample index for the first pixel that was physically recorded at the beginning of the image array. Always 1 for Mini-RF images.
SAMPLE_PROJECTION_OFFSET	The sample index for the last pixel that was physically recorded at the end of the image array.
SAMPLE_TYPE	The sample offset value of the map projection origin position from line and sample 1,1 (line and sample 1,1 is considered the upper left corner of the digital array).
SCALED_PIXEL_HEIGHT	The data storage representation of sample value. PC_REAL for Mini-RF images.
SCALED_PIXEL_WIDTH	The height on the surface of the target of the projection of a pixel onto the surface. This is the line spacing in Mini-RF images.
SECOND_STANDARD_PARALLEL	The width on the surface of the target of the projection of a pixel onto the surface. This is the pixel spacing in Mini-RF images.
SOFTWARE_NAME	A required keyword; however, it is not applicable for oblique cylindrical projects. Always "N/A".
SOFTWARE_VERSION_ID	The name of the software system that created the data products. The version number of the software is identified by the SOFTWARE_VERSION_ID keyword.
SOURCE_PRODUCT_ID	Version of the software used to generate the products.
SPACECRAFT_CLOCK_START_COUNT	The list of products used as input to create a new product. This will be SPICE kernels and digital elevation model (DEM) files.
SPACECRAFT_CLOCK_STOP_COUNT	Clock count of the spacecraft computer at the start of the observation.
	Clock count of the spacecraft computer at the end

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Key Word	Description
STANDARD_DEVIATION	of the observation. The standard deviation (sigma value) of the pixel values in the image array.
START_TIME	The date and time for the start of the observation in UTC system format.
STOP_TIME	The date and time for the end of the observation in UTC system format.
TARGET_NAME	Identifies the target of the instrument, i.e., the Moon or N/A (for calibration targets)
^TEXT	The name of a referenced text file.
WESTERNMOST_LONGITUDE	The minimum numerical value of longitude unless it crosses the Prime Meridian.

Table 17 The PDS label keywords used in the Mini-RF labels.

4.8.2 Examples of SAR PDS Labels

4.8.2.1 Example PDS Minimal Label for a LRO Raw PDR Data Product

```

PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2010-JHU/APL Mini-RF LRO Ver. 1"
RECORD_TYPE              = UNDEFINED
FILE_NAME                = "LSZ_01408_RPD_XKB_32N355_V1.DAT"
DATA_SET_ID              = "LRO-L-MRFLRO-1-PDR-V1.0"
DATA_SET_NAME            = "LRO MOON MINI-RF 1 PACKETIZED DATA RECORD
V1.0"
PRODUCER_ID              = "JHUAPL"
PRODUCER_FULL_NAME       = "MINI-RF POC TEAM"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS
LABORATORY"
PRODUCT_ID               = "LSZ_01408_RPD_XKB_32N355_V1"
PRODUCT_VERSION_ID       = "1.0"
ORIGINAL_PRODUCT_ID       = "
PacketsFrom2009290_20091017_142550_20100115_214904.down"
SOFTWARE_VERSION_ID       = "1.0"
PRODUCT_CREATION_TIME     = 2010-02-05T04:39:01
RELEASE_ID                = "0001"
MISSION_NAME              = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_NAME      = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID        = LRO
INSTRUMENT_NAME           = "MINI-RF LRO"
INSTRUMENT_ID             = MRFLRO
TARGET_NAME               = MOON
MISSION_PHASE_NAME        = "NOMINAL MISSION"
START_TIME                = 2009-10-17T14:25:50.922
STOP_TIME                 = 2009-10-17T14:32:57.921
ORBIT_NUMBER              = 0
DESCRIPTION                = "LRO SAR Packetized Data Record (PDR) file.
The Raw Packetized Data Records (PDRs) are in the form of raw binary
telemetry received in CCSDS packet format, which have been extracted from
frames downlinked from the instrument. PDRs have duplicates removed and
include any ancillary information needed to understand what is in a given

```

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packet. They are retained so that future researchers can reproduce the higher-level products if they so desire."

```
/* Metadata Associated with the Image. */
OBJECT                      =  PARAMETER_FILE
  ^TEXT                     =  "LSZ_01408_RPD_XKB_32N355_V1.TXT"
  RECORD_TYPE               =  STREAM
  FILE_RECORDS              =  16
  OBJECT                    =  TEXT
    PUBLICATION_DATE        =  2010-02-05
    NOTE                     =  "A parameter file generated by the raw data
    processor."
  END_OBJECT                =  TEXT
END_OBJECT                  =  PARAMETER_FILE

END
```

4.8.2.2 Example PDS label for a LRO Level 1 SAR Data Product

```
PDS_VERSION_ID              =  PDS3
LABEL_REVISION_NOTE         =  "2010-JHU/APL Mini-RF LRO Ver. 1"

/* File Identification and Structures. */
RECORD_TYPE                 =  FIXED_LENGTH
RECORD_BYTES                =  26032
FILE_RECORDS                =  23308

/* Pointer to data object. */
^IMAGE                      =  "LSZ_01408_1CD_XKU_32N355_V1.IMG"

/* Identification Data Elements. */
DATA_SET_ID                 =  "LRO-L-MRFLRO-4-CDR-V1.0"
DATA_SET_NAME                =  "LRO MOON MINI-RF 4 CALIBRATED DATA RECORD
V1.0"
PRODUCER_ID                 =  "JHUAPL"
PRODUCER_FULL_NAME          =  "MINI-RF POC TEAM"
PRODUCER_INSTITUTION_NAME   =  "JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS
LABORATORY"
PRODUCT_ID                  =  "LSZ_01408_1CD_XKU_32N355_V1"
PRODUCT_VERSION_ID          =  "1.0"
ORIGINAL_PRODUCT_ID         =  ""
PacketsFrom2009290_20091017_142550_20100115_214904.000.cp"
MISSION_PHASE_NAME          =  "NOMINAL MISSION"
PRODUCT_CREATION_TIME       =  2010-02-05T22:05:17
RELEASE_ID                  =  "0001"
MISSION_NAME                 =  "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_NAME        =  "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID          =  "LRO"
INSTRUMENT_NAME              =  "MINI-RF LRO"
INSTRUMENT_ID               =  MRFLRO
TARGET_NAME                  =  MOON
SOURCE_PRODUCT_ID           =  {"LRO_SCLK_20100202_00.TSC","naif0009.tls"}
START_TIME                  =  2009-10-17T14:25:53.362224
```

SPECIFICATION NUMBER: MRF-4009
CAGE Code 12934

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STOP_TIME = 2009-10-17T14:27:40.799
SPACECRAFT_CLOCK_START_COUNT = "UNK"
SPACECRAFT_CLOCK_STOP_COUNT = "UNK"
ORBIT_NUMBER = 1408
INCIDENCE_ANGLE = 53.61261526<deg>
CENTER_FREQUENCY = 2380.00008611<GHz>
INSTRUMENT_MODE_ID = "ZOOM_S"
INSTRUMENT_MODE_DESC = "SAR"
SOFTWARE_NAME = "FOCUS"
SOFTWARE_VERSION_ID = "9.0.320"
LOOK_DIRECTION = LEFT
DESCRIPTION = "Mini-RF Level 1 SAR Calibrated Data Record
(CDR) file. The Level 1 data product is the lowest level of processed data
product that is scientifically useable. It consists of a calibrated, but not
georectified SAR image."

/* The ground range/slant range coefficients. */
LRO:RANGE_COEFFICIENT_SET = (("2009-10-17T14:25:53.386",
62716.470892, 7.696415E-01, 3.368160E-06, -3.310459E-11),
("2009-10-17T14:26:01.206", 62716.471172, 7.692234E-01, 3.373354E-06,
-3.313990E-11), ("2009-10-17T14:26:06.319", 62716.471997, 7.689241E-01,
3.377114E-06, -3.316900E-11), ("2009-10-17T14:26:11.733", 62716.470219,
7.685646E-01, 3.381498E-06, -3.319549E-11), ("2009-10-17T14:26:16.846",
62716.469516, 7.682650E-01, 3.385265E-06, -3.322443E-11),
("2009-10-17T14:26:22.259", 62716.471800, 7.679047E-01, 3.389759E-06,
-3.325698E-11), ("2009-10-17T14:26:27.372", 62716.470879, 7.676055E-01,
3.393422E-06, -3.327958E-11), ("2009-10-17T14:26:32.786", 62716.470899,
7.672450E-01, 3.397908E-06, -3.331208E-11), ("2009-10-17T14:26:37.899",
62716.468868, 7.669451E-01, 3.401656E-06, -3.333879E-11),
("2009-10-17T14:26:43.312", 62716.471006, 7.665846E-01, 3.406134E-06,
-3.337045E-11), ("2009-10-17T14:26:48.425", 62716.469268, 7.662236E-01,
3.410591E-06, -3.340105E-11), ("2009-10-17T14:26:53.839", 62716.470149,
7.658628E-01, 3.415113E-06, -3.343629E-11), ("2009-10-17T14:26:58.952",
62716.467871, 7.655629E-01, 3.418765E-06, -3.345736E-11),
("2009-10-17T14:27:04.366", 62716.469982, 7.651406E-01, 3.424016E-06,
-3.349598E-11), ("2009-10-17T14:27:09.479", 62716.469638, 7.648401E-01,
3.427802E-06, -3.352542E-11), ("2009-10-17T14:27:14.892", 62716.467454,
7.644179E-01, 3.432936E-06, -3.355662E-11), ("2009-10-17T14:27:20.005",
62716.467937, 7.640558E-01, 3.437508E-06, -3.359395E-11),
("2009-10-17T14:27:25.419", 62716.468774, 7.636945E-01, 3.441921E-06,
-3.362111E-11), ("2009-10-17T14:27:30.532", 62716.468191, 7.633325E-01,
3.446382E-06, -3.365133E-11), ("2009-10-17T14:27:38.341", 62716.468455,
7.627890E-01, 3.453189E-06, -3.370367E-11))

/* Data Object Description. */
OBJECT = IMAGE
NAME = "MINI-RF SAR DATA"
CENTER_LONGITUDE = -4.716889<deg>
CENTER_LATITUDE = 32.260219<deg>
MAXIMUM_LATITUDE = 35.146284<deg>
MINIMUM_LATITUDE = 29.373404<deg>
WESTERNMOST_LONGITUDE = 354.934983<deg>
EASTERNMOST_LONGITUDE = 355.606469<deg>
LINES = 23308
LINE_SAMPLES = 1627

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```

SAMPLE_TYPE           = PC_REAL
SAMPLE_BITS           = 32
MINIMUM               = 0.000000000
MAXIMUM               = 7.224467278
MEAN                  = 0.294750041
STANDARD_DEVIATION    = 0.011127740
SCALED_PIXEL_HEIGHT   = 7.500000000000
SCALED_PIXEL_WIDTH     = 7.500000000000
LRO:AZIMUTH_RESOLUTION = 15.674092
LRO:RANGE_RESOLUTION  = 30.486847
LINE_EXPOSURE_DURATION = 0.004609439305
BANDS                 = 4
BAND_STORAGE_TYPE     = SAMPLE_INTERLEAVED
BAND_NAME              = ("H RECEIVE INTENSITY", "V RECEIVE
INTENSITY", "CROSS POWER INTENSITY (REAL)", "CROSS POWER INTENSITY
(IMAGINARY)")
DESCRIPTION            = "The ground range detected cross-product
polarimetric image file. Each pixel is represented by two 4-byte floating
point values and an 8-byte complex value (one 4-byte floating point real
and one 4-byte floating point imaginary component) for a total of 16 bytes
per pixel. The first two numbers are the intensity images for H and V
receive, respectively. The complex value is the cross power intensity
image between the H and V receive."
END_OBJECT             = IMAGE

/* Metadata Associated with the Image. */
OBJECT                 = PARAMETER_FILE
^TEXT                  = "LSZ_01408_1CD_XKU_32N355_V1.TXT"
RECORD_TYPE            = STREAM
FILE_RECORDS           = 1815
OBJECT                 = TEXT
PUBLICATION_DATE       = 2010-02-05
NOTE                   = "A parameter file generated by the SAR
data processor."
END_OBJECT             = TEXT

END_OBJECT             = PARAMETER_FILE

END

```

4.8.2.3 Example PDS label for a LRO Level 2 SAR Data Product

```

PDS_VERSION_ID        = PDS3
LABEL_REVISION_NOTE    = "2010-JHU/APL Mini-RF LRO Ver. 1"
^IMAGE                 = "LSZ_01408_2CD_OKU_32N355_V1.IMG"
RECORD_TYPE            = FIXED_LENGTH
RECORD_BYTES           = 27312
FILE_RECORDS           = 23616
DATA_SET_ID            = "LRO-L-MRFLRO-5-CDR-MAP-V1.0"
DATA_SET_NAME          = "LRO MOON MINI-RF 5 MAP-PROJECTED CALIBRATED
DATA REC V1.0"
PRODUCER_ID            = "JHUAPL"
PRODUCER_FULL_NAME     = "MINI-RF POC TEAM"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS

```

SPECIFICATION NUMBER: MRF-4009
CAGE Code 12934

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```
LABORATORY"
PRODUCT_ID                = "LSZ_01408_2CD_OKU_32N355_V1"
PRODUCT_VERSION_ID        = "1.0"
ORIGINAL_PRODUCT_ID        = ""
PacketsFrom2009290_20091017_142550_20100115_214904.000.ortho_OC"
MISSION_PHASE_NAME         = "NOMINAL MISSION"
PRODUCT_CREATION_TIME      = 2010-02-05T14:19:17
RELEASE_ID                 = "0001"
MISSION_NAME               = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_NAME       = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID         = LRO
INSTRUMENT_NAME            = "MINI-RF LRO"
INSTRUMENT_ID              = MRFLRO
TARGET_NAME                = MOON
SOURCE_PRODUCT_ID          = {"LRO_SCLK_20100202_00.TSC","naif0009.tls"}
START_TIME                 = 2009-10-17T14:25:53.362224
STOP_TIME                  = 2009-10-17T14:27:42.2187
SPACECRAFT_CLOCK_START_COUNT = "UNK"
SPACECRAFT_CLOCK_STOP_COUNT = "UNK"
ORBIT_NUMBER               = 1408
CENTER_FREQUENCY           = 2380000086.11031818<Hz>
INCIDENCE_ANGLE            = 53.61261526<deg>
INSTRUMENT_MODE_ID         = "ZOOM_S"
INSTRUMENT_MODE_DESC       = "SAR"
SOFTWARE_NAME              = "Ortho"
SOFTWARE_VERSION_ID        = "9.0.320"
LOOK_DIRECTION             = LEFT
DESCRIPTION                 = "Mini-RF Level 2 SAR Calibrated Data Record
(CDR) file. The Level 2 data products are orthorectified and are re-sampled
into oblique cylindrical map projected SAR images."
```

/* Data Object Description. */

```
OBJECT                    = IMAGE
NAME                     = "MINI-RF SAR DATA"
LINES                   = 23616
LINE_SAMPLES            = 1707
SAMPLE_TYPE             = PC_REAL
SAMPLE_BITS             = 32
MINIMUM                 = 0.000000000
MAXIMUM                 = 7.224467278
MEAN                    = 0.294667579
STANDARD_DEVIATION      = 0.010913741
SCALED_PIXEL_HEIGHT     = 7.4<m/pixel>
SCALED_PIXEL_WIDTH      = 7.4<m/pixel>
LRO:AZIMUTH_RESOLUTION  = 15.674092
LRO:RANGE_RESOLUTION    = 30.486847
LINE_EXPOSURE_DURATION  = 0.004609439305
BANDS                   = 4
BAND_STORAGE_TYPE       = SAMPLE_INTERLEAVED
BAND_NAME               = ("H RECEIVE INTENSITY", "V RECEIVE
INTENSITY", "CROSS POWER INTENSITY (REAL)","CROSS POWER INTENSITY
(IMAGINARY)")
DESCRIPTION              = "This image contains multi-valued pixels.
The ground range detected cross-product polarimetric image file resampled
into an oblique cylindrical map projection. Each pixel is represented by
```

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two 4-byte floating point values and an 8-byte complex value (one 4-byte floating point real and one 4-byte floating point imaginary component) for a total of 16 bytes per pixel. The first two numbers are the intensity images for H and V receive, respectively. The complex value is the cross power intensity image between the H and V receive."

END_OBJECT = IMAGE

/* Map Projection Information. */

OBJECT = IMAGE_MAP_PROJECTION

^DATA_SET_MAP_PROJECTION = "DSMAP.CAT"

POSITIVE_LONGITUDE_DIRECTION = "EAST"

KEYWORD_LATITUDE_TYPE = "PLANETOCENTRIC"

COORDINATE_SYSTEM_NAME = "PLANETOCENTRIC"

COORDINATE_SYSTEM_TYPE = "BODY-FIXED ROTATING"

LINE_FIRST_PIXEL = 1

SAMPLE_FIRST_PIXEL = 1

FIRST_STANDARD_PARALLEL = "N/A"

SECOND_STANDARD_PARALLEL = "N/A"

A_AXIS_RADIUS = 1737.4<km>

B_AXIS_RADIUS = 1737.4<km>

C_AXIS_RADIUS = 1737.4<km>

LINE_LAST_PIXEL = 23616

SAMPLE_LAST_PIXEL = 1707

LINE_PROJECTION_OFFSET = 11600.9521456

SAMPLE_PROJECTION_OFFSET = -6310.44370744

MAP_PROJECTION_TYPE = "OBLIQUE CYLINDRICAL"

MAP_PROJECTION_ROTATION = 90.0<deg>

MAP_RESOLUTION = 4096.08934062<pix/deg>

MAP_SCALE = 0.0074030002528<km/pix>

CENTER_LATITUDE = 0.0<deg>

CENTER_LONGITUDE = 0.0<deg>

REFERENCE_LATITUDE = 32.2468226517

REFERENCE_LONGITUDE = -178.075208329

MAXIMUM_LATITUDE = 35.146367<deg>

MINIMUM_LATITUDE = 29.373408<deg>

WESTERNMOST_LONGITUDE = 354.917237<deg>

EASTERNMOST_LONGITUDE = 355.623363<deg>

OBLIQUE_PROJ_POLE_LATITUDE = -0.572471<deg>

OBLIQUE_PROJ_POLE_LONGITUDE = -92.285964<deg>

OBLIQUE_PROJ_POLE_ROTATION = 122.248627<deg>

OBLIQUE_PROJ_X_AXIS_VECTOR = (-0.845280,-0.028407,0.533568)

OBLIQUE_PROJ_Y_AXIS_VECTOR = (0.532833,0.029727,0.845698)

OBLIQUE_PROJ_Z_AXIS_VECTOR = (-0.039885,0.999154,-0.009991)

END_OBJECT = IMAGE_MAP_PROJECTION

/* Metadata Associated with the Image. */

OBJECT = PARAMETER_FILE

^TEXT = "LSZ_01408_2CD_OKU_32N355_V1.TXT"

RECORD_TYPE = STREAM

FILE_RECORDS = 1872

OBJECT = TEXT

PUBLICATION_DATE = 2010-02-05

NOTE = "A parameter file generated by the SAR"

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```

    data processor."
END_OBJECT                      = TEXT

END_OBJECT                      = PARAMETER_FILE

END

```

The above example is for a Level 2 map product in oblique cylindrical projection. Polar images are in this projection. Non-polar images are provided in equirectangular projection and have a slightly different label.

4.8.2.4 Example PDS Daughter Product Label

```

PDS_VERSION_ID                 = PDS3
LABEL_REVISION_NOTE            = "2010-JHU/APL Mini-RF LRO Ver. 1"
NOTE                           = "Mini-RF LRO circular polarization ratio
product."
^IMAGE                         = "LSZ_01408_2CP_EKU_32N355_V1.IMG"
RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 5788
FILE_RECORDS                   = 11823
DATA_SET_ID                    = "LRO-L-MRFLRO-5-CDR-MAP-V1.0"
DATA_SET_NAME                  = "LRO MOON MINI-RF 5 MAP-PROJECTED CALIBRATED
DATA REC V1.0"
PRODUCER_ID                    = "JHUAPL"
PRODUCER_FULL_NAME             = "MINI-RF POC TEAM"
PRODUCER_INSTITUTION_NAME     = "JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS
LABORATORY"
PRODUCT_ID                     = "LSZ_01408_2CP_EKU_32N355_V1"
PRODUCT_VERSION_ID             = "1.0"
ORIGINAL_PRODUCT_ID            = "
PacketsFrom2009290_20091017_142550_20100115_214904.000.ortho_OC"
MISSION_PHASE_NAME             = "NOMINAL MISSION"
PRODUCT_CREATION_TIME          = 2010-02-19T21:49:34
RELEASE_ID                     = "0001"
MISSION_NAME                   = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_NAME           = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID             = LRO
INSTRUMENT_NAME                = "MINI-RF LRO"
INSTRUMENT_ID                  = MRFLRO
TARGET_NAME                    = MOON
SOURCE_PRODUCT_ID              = TBD
START_TIME                     = 2009-10-17T14:25:53.362224
STOP_TIME                      = 2009-10-17T14:27:42.2187
SPACECRAFT_CLOCK_START_COUNT   = "UNK"
SPACECRAFT_CLOCK_STOP_COUNT    = "UNK"
ORBIT_NUMBER                   = 1408
CENTER_FREQUENCY               = 2380000086.11031818<Hz>
INCIDENCE_ANGLE                = 53.61261526<deg>
INSTRUMENT_MODE_ID             = "ZOOM_S"
INSTRUMENT_MODE_DESC           = "SAR"
SOFTWARE_NAME                  = "ISIS"
SOFTWARE_VERSION_ID            = "3.1.21 | 2009-09-16"
LOOK_DIRECTION                 = LEFT
DESCRIPTION                     = "This dimensionless parameter is the ratio

```

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of the same sense circular polarization to the opposite sense circular polarization (CPR = SC / OS). The average CPR value of the entire lunar surface is on the order of 0.3. Certain types of surface deposits can have either anomalously low (near zero) or anomalously high (>1.0) values."

/* Data Object Description. */

OBJECT = IMAGE

LINES = 11823
 LINE_SAMPLES = 1447
 BANDS = 1
 BAND_STORAGE_TYPE = BAND_SEQUENTIAL
 OFFSET = 0.0
 SCALING_FACTOR = 1.0
 SAMPLE_BITS = 32
 SAMPLE_BIT_MASK = 2#11111111111111111111111111111111#
 SAMPLE_TYPE = PC_REAL
 CORE_NULL = 16#FF7FFFFB#
 CORE_LOW_REPR_SATURATION = 16#FF7FFFFC#
 CORE_LOW_INSTR_SATURATION = 16#FF7FFFFD#
 CORE_HIGH_REPR_SATURATION = 16#FF7FFFFF#
 CORE_HIGH_INSTR_SATURATION = 16#FF7FFFFE#
 END_OBJECT = IMAGE

OBJECT = IMAGE_MAP_PROJECTION

^DATA_SET_MAP_PROJECTION = "DSMAP.CAT"
 COORDINATE_SYSTEM_TYPE = "BODY-FIXED ROTATING"
 MAP_PROJECTION_TYPE = "EQUIRECTANGULAR"
 A_AXIS_RADIUS = 1737.4 <km>
 B_AXIS_RADIUS = 1737.4 <km>
 C_AXIS_RADIUS = 1737.4 <km>
 FIRST_STANDARD_PARALLEL = "N/A"
 SECOND_STANDARD_PARALLEL = "N/A"
 COORDINATE_SYSTEM_NAME = PLANETOCENTRIC
 POSITIVE_LONGITUDE_DIRECTION = EAST
 KEYWORD_LATITUDE_TYPE = PLANETOCENTRIC
 CENTER_LATITUDE = 0.0 <deg>
 CENTER_LONGITUDE = 180.0 <deg>
 LINE_FIRST_PIXEL = 1
 LINE_LAST_PIXEL = 11823
 SAMPLE_FIRST_PIXEL = 1
 SAMPLE_LAST_PIXEL = 1447
 MAP_PROJECTION_ROTATION = 0.0 <deg>
 MAP_RESOLUTION = 2048.0 <pix/deg>
 MAP_SCALE = 14.806323449292 <m/pixel>
 MAXIMUM_LATITUDE = 35.146367 <deg>
 MINIMUM_LATITUDE = 29.373408 <deg>
 EASTERNMOST_LONGITUDE = 355.623363 <deg>
 WESTERNMOST_LONGITUDE = 354.917237 <deg>
 LINE_PROJECTION_OFFSET = 71980.499999997 <pixel>
 SAMPLE_PROJECTION_OFFSET = -358229.5 <pixel>
 END_OBJECT = IMAGE_MAP_PROJECTION
 END

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The above example is for a circular polarization ratio (CPR) product. SSP, OSP, and stokes parameter product labels are similar.

4.8.2.5 Example PDS label for a LRO Level 3 SAR Data Product

An example of a PDS label for the ISIS-generated mosaics is provided below. Right or left looking is relative to north. ORBIT_NUMBER contains the number of the first image used to make the mosaic.

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE     = "2008-JHU/APL Sample to PDS March 2008"

/* File Identification and Structures. */
RECORD_TYPE             = FIXED_LENGTH
RECORD_BYTES            = 32444
FILE_RECORDS            = 8111

/* Pointer to data object. */
^IMAGE                  = "LSZ_3SC_PLU_90N000_00752_V1.IMG"

/* Identification Data Elements. */
DATA_SET_ID             = "LRO-L-MRFLRO-5-CDR-MOSAIC-V1.0"
DATA_SET_NAME           = "LRO MOON MINI-RF 5 POLAR MOSAIC CALIBRATED
DATA_REC V1.0"
PRODUCER_ID             = "JHUAPL"
PRODUCER_FULL_NAME      = "MINI-RF POC TEAM"
PRODUCER_INSTITUTION_NAME = "JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS
LABORATORY"
PRODUCT_ID              = "LSZ_3SC_PLU_90N000_00752_V1"
PRODUCT_VERSION_ID      = "1.0"
PRODUCT_CREATION_TIME   = 2008-01-02T20:37:30
RELEASE_ID              = "0001"
MISSION_NAME            = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_NAME    = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID      = LRO
INSTRUMENT_NAME         = "MINI-RF LRO"
INSTRUMENT_ID           = MRFLRO
TARGET_NAME             = MOON
START_TIME              = 2007-10-31T17:52:06.798338
STOP_TIME               = 2007-10-31T17:53:22.3410
SPACECRAFT_CLOCK_START_COUNT = "1/1234567:123"
SPACECRAFT_CLOCK_STOP_COUNT  = "1/1234567:123"
ORBIT_NUMBER            = 300
INCIDENCE_ANGLE         = "N/A"
INSTRUMENT_MODE_ID      = "N/A"
INSTRUMENT_MODE_DESC    = "N/A"
SOFTWARE_NAME           = "ISIS"
SOFTWARE_VERSION_ID     = "3.1.14"
LOOK_DIRECTION          = "N/A"
DESCRIPTION              = "
Polar mosaic made from Mini-RF Level 2 SAR Calibrated Data Record (CDR)
files."

/* Data Object Description. */
```

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```

OBJECT                                =  IMAGE
  NAME                                =  "MINI-RF SAR DATA"
  LINES                              =  8111
  LINE_SAMPLES                        =  8111
  SAMPLE_TYPE                         =  PC_REAL
  SAMPLE_BITS                         =  32
  MINIMUM                             =  "N/A"
  MAXIMUM                             =  "N/A"
  MEAN                                =  "N/A"
  STANDARD_DEVIATION                  =  "N/A"
  SCALED_PIXEL_HEIGHT                 =  "N/A"
  SCALED_PIXEL_WIDTH                  =  "N/A"
  AZIMUTH_RESOLUTION                  =  "N/A"
  RANGE_RESOLUTION                    =  "N/A"
  BANDS                               =  1
  BAND_STORAGE_TYPE                   =  BAND_SEQUENTIAL
  BAND_NAME                           =  "SAME SENSE POLARIZATION"
  DESCRIPTION                         =  "
    This mosaic covers the north polar region of the Moon and
    consists of strips of same sense polarization data."
END_OBJECT                            =  IMAGE

```

```

OBJECT = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION            =  "DSMAP.CAT"
  COORDINATE_SYSTEM_TYPE               =  "BODY-FIXED ROTATING"
  MAP_PROJECTION_TYPE                  =  "POLAR STEREOGRAPHIC"
  A_AXIS_RADIUS                        =  1738.100000 <KM>
  B_AXIS_RADIUS                        =  1738.100000 <KM>
  C_AXIS_RADIUS                        =  1738.100000 <KM>
  FIRST_STANDARD_PARALLEL              =  "N/A"
  SECOND_STANDARD_PARALLEL             =  "N/A"
  COORDINATE_SYSTEM_NAME               =  PLANETOCENTRIC
  POSITIVE_LONGITUDE_DIRECTION         =  EAST
  KEYWORD_LATITUDE_TYPE                =  PLANETOCENTRIC
/* NOTE:  CENTER_LATITUDE and CENTER_LONGITUDE describe */
/* the location of the center of projection, which is not */
/* necessarily equal to the location of the center point */
/* of the file. */

```

```

  CENTER_LATITUDE                     =  90.000000 <DEG>
  CENTER_LONGITUDE                     =  0.000000 <DEG>
  REFERENCE_LATITUDE                   =  "N/A"
  REFERENCE_LONGITUDE                  =  "N/A"
  LINE_FIRST_PIXEL                     =  1
  LINE_LAST_PIXEL                      =  8111
  SAMPLE_FIRST_PIXEL                   =  1
  SAMPLE_LAST_PIXEL                    =  8111
  MAP_PROJECTION_ROTATION               =  0.000000
  MAP_RESOLUTION                       =  404.474236 <PIX/DEG>
  MAP_SCALE                            =  0.075000 <KM/PIX>
  MAXIMUM_LATITUDE                     =  90.000000 <DEG>
  MINIMUM_LATITUDE                     =  80.000000 <DEG>
  EASTERNMOST_LONGITUDE                 =  360.000000 <DEG>
  WESTERNMOST_LONGITUDE                 =  0.000000 <DEG>
  LINE_PROJECTION_OFFSET                =  4055.000000

```

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```
SAMPLE_PROJECTION_OFFSET      = 4055.000000  
END_OBJECT = IMAGE_MAP_PROJECTION  
  
END
```

5. Applicable Software

5.1 Software Distribution And Update Procedures

The LRO Mini-RF delivery to the PDS does not include software.

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6. Appendices

6.1 Level 3+ Derived Data Record (DDR) Products

Sandia National Laboratories will produce a tool that generates topography from the continuous mode SAR data to be acquired by Mini-RF on LRO. They will use as input the SAR strips that have been processed by the Vexcel SAR processor. Additionally Sandia will need to provide the viewing geometry limits that are needed in order for their tool to be able to generate topography. This will affect targeting, as APL will need to acquire strips that are applicable for SAR stereo processing.

The output from the SAR stereo processor will be strips showing lunar topography. These strips will have pixel values that either show lunar radius, or an altitude relative to a stated datum. The strips will be in a polar stereographic projection for regions poleward of 80°. If any equatorial data is acquired then the topographic strips will be in a simple cylindrical projection. Table 18 below describes these products.

Sandia will deliver both the processing tool as well as generate the image products and deliver them too. It is envisioned that some training will be required on how to use the tool.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 3 Reduced Data Record (RDR) SAR Stereo image.	Binary	Full	Geosciences	1	IMG	The lunar topographic profile image file. These products are created from data collected during two separate orbits. The images are strips provided in polar stereographic map projection. Each pixel is represented by one 4-byte floating-point value. Each value is an altitude in meters above the 1,737.4 km radius lunar sphere model. The precision of each pixel is given to the nearest whole meter (although not necessarily to that accuracy). The image file is of fixed-record length with absent data on either side of the image filled with null pixels. A null pixel is defined as one having a value of -65,000.0.

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Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level 3 SAR Stereo Parameter file	Text	Full	Geosciences	1	TAB	Ancillary metadata listing the various parameters, which identify and describe the product. This file shall consist of a two-column table with parameter name and value columns. The columns shall be delimited by commas. The records are of fixed-length with numeric values left-justified to the comma delimiter and character or string values enclosed in double quotes. The quoted values shall fill the column space and text shall be left-justified within the text string and any remaining space padded with white space. Each record shall be terminated by a <CR><LF> end-of-line (EOL) marker.

Table 18 The SAR Stereo product file description (DATASET_ID: LRO-L-MRFLRO-5-CDR-STEREO-V n.n).

Table 19 below describes the SAR Stereo Parameter file. This file shall be an ASCII text file where the text is in a parameter name-value comma-separated value form. The columns shall be comma delimited and the records are of fixed-length.

Name	Data Type	Units	Description
Product ID	string	N/A	An identifier of the product.
Version Num.	integer	N/A	The version of this product file (usually 1).
Product Creation Time	string	ISO Time field	The time that this version of the product was generated. This field is only accurate to the nearest minute. ISO Format: (yyyy-dd-mmThh:mm).
First Orbit Number	integer	N/A	The first orbit number during which the data were collected.
Second Orbit Number	integer	N/A	The second orbit number during which the data were collected.
Source Product ID 1	string	N/A	The product ID of the first (earlier orbit) Level 1 product strip from which this product was made.
Source Product ID 2	string	N/A	The product ID of the second (later orbit) Level 1 product strip from which this product was made.
Center Latitude	float	degrees	The lunar latitude of the center pixel in the image.
Center Longitude	float	degrees	The lunar longitude of the center pixel in the image.

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Name	Data Type	Units	Description
Scale	integer	meters	The amount of lunar surface represented by one pixel in the image in meters per pixel.
Line Length	integer	N/A	The number of pixels in a line of data in the image (corresponds to the cross-track dimension).
Number of Lines	integer	N/A	The number of data lines in the image (corresponds to the along-track dimension).

Table 19 The contents of the SAR Stereo Parameter file. The size of the image file in bytes should equal: (Line Length) * (Number of Lines) * (4 bytes/pixel).

"Product ID	",	"LIN_STR_LV3_06612_06616_A01"	
"Version	",		1
"Creation Time	",	"2010-04-07T22:38	"
"First Orbit Number	"		6612
"Second Orbit Number	",		6616
"Source Product ID 1	",	"LSR_CDR_LV1_06612_A01	"
"Source Product ID 2	",	"LSR_CDR_LV1_06616_A01	"
"Center Latitude (deg)	",		-81.473826
"Center Longitude (deg)"	",		122.412897
"Scale (m/pixel)	",		60.281
"Line Length	",		2976
"Number of Lines	",		6089

Table 20 Sample contents of a Sandia SAR Stereo parameter file. Note that all string values are quoted and space-padded for constant field length.

6.1.1.1 SAR Stereo File Naming

The following table describes the detailed naming convention for this dataset. These products are composed of two strips. They contain data from two orbits.

The filenames of these products will follow the convention described in sec. 4.7.1 except that the center latitude and longitude given in their file names are that of the center of the image and the orbit number is that of the highest orbit number product among the lower-level products used in the product :

The following is an example file name of a Mini-RF LRO SAR stereo product, S-band, interferometric, level 3, calibrated data record, 512 ppd resolution, unnormalized floating point format, center coordinates 82°N, 231°, highest orbit number 617, version 1.

LSI_3CD_XLU_82N231_00617_V1.IMG

It would be accompanied by the following metadata parameter file:

LSI_3CD_XLU_82N231_00617_V1.CSV

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6.2 Glossary

Archive	An archive consists of one or more data sets along with all the documentation and ancillary information needed to understand and use the data. An archive is a logical construct independent of the medium on which it is stored.
Burst Mode	One of the two operating modes of the Mini-RF instrument for which science data products are produced. This is also called "SAR Mode."
Calibrated Data Record (CDR)	Data that have undergone gain and bias adjustments and have units. These are generated by the Vexcel® SWATH and ORTHO processors. The LRO Mini-RF level 1 and 2 products are CDRs.
Chandrayaan-1	An ISRO lunar orbiting spacecraft which hosts a similar Mini-RF instrument.
Continuous Mode	One of the two operating modes of the Mini-RF instrument for which science data products are produced. This is also called "Interferometry Mode" or "InsAR."
Cross Track	The linear direction on the ground as seen by the instrument perpendicular to the direction of the spacecraft's orbit.
Data Product	A labeled grouping of data resulting from a scientific observation, usually stored in one file. A product label identifies, describes, and defines the structure of the data.
Data Set	An accumulation of data products. A Data set together with supporting documentation and ancillary files is an archive.
Derived Data Records (DDR)	Data records that have been processed from lower-level data products.
Experiment Data Record (EDR)	NASA Level 0 data for a given instrument. These are generated by the Vexcel® SKY Processor.

InSAR Another name for the Continuous Mode.

Lunar Reconnaissance Orbiter (LRO) The NASA lunar orbiting spacecraft which hosts the Mini-RF instrument.

Mini-RF The synthetic aperture radar instrument hosted on-board the LRO lunar orbiting spacecraft and producing data from which the products described by this document are produced. Also, the name of the project which developed and manages that instrument.

Packetized Data Record (PDR)	Data items received from the spacecraft and contained within CCSDS packets that have not undergone any formatting or calibration.
Sandia	Sandia National Laboratories, Albuquerque, New Mexico.
Standard data product	A data product that has been defined during the proposal and selection process and that is contractually promised by the PI as part of the investigation. Standard data products are generated in a predefined way, using well-understood procedures, and processed in "pipeline" fashion.
Synthetic Aperture Radar (SAR)	A type of radar. The Mini-RF instrument is a side-looking synthetic aperture imaging radar instrument.
Swath	The area along the ground visible to the instrument during a given section of an orbit. The combination of track and cross track define the swath.
Track	The linear direction on the ground as seen by the instrument parallel to the direction of the spacecraft's orbit.

6.3 Acronyms

APL	(The Johns Hopkins University) Applied Physics Laboratory
ASCII	American Standard Code for Information Interchange
CCSDS	Consultative Committee for Space Data Systems
CDR	Calibrated Data Record
CK	Camera-Matrix Kernel (SPICE)
CLM	Chandrayaan-1 Lunar Module
CODMAC	Committee on Data Management and Computation
CPR	Circular Polarization Ratio
CSV	Comma-Separated Values
DEM	Digital Elevation Model

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dB	Decibels
DDR	Derived Data Record
EDR	Experimental Data Record
GSFC	Goddard Space Flight Center
kHz	Kilohertz
I&T	Integration and Test
IK	Instrument Measurement Kernel (SPICE)
ISIS	Integrated Software for Imaging Spectrometers
ISRO	Indian Space Research Organisation
JHU/APL	The Johns Hopkins University Applied Physics Laboratory
K	Kelvin
km	Kilometers
LCP	Left Circular Polarized
LSK	Leap seconds Kernel (SPICE)
m	Meters
m/s	Meters per second
μs	Microseconds (10^{-6} seconds)
LRO	Lunar Reconnaissance Orbiter
MET	Mission Elapsed Time
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NAWC	Naval Air Warfare Center
ns	Nanoseconds (10^{-9} seconds)
ODL	Object Description Language
OSP	Opposite Sense Polarization
PDF	(Adobe) Portable Document Format
PDR	Packetized Data Records
PDS	(NASA) Planetary Data System
POC	Payload Operations Center
PVL	Parameter Value Language
RCP	Right Circular Polarized
RDR	Reduced Data Records
SAR	Synthetic Aperture Radar
SCLK	Spacecraft Clock Kernel (SPICE)
SSP	Same Sense Polarization
STF	(Vexcel [®]) SKY Telemetry Format
SPICE	Spacecraft, Planet, Instrument, C-matrix Events
SPK	Spacecraft and Planets Kernel (SPICE)
TIFF	Tagged Image File Format
ULCN2005	Unified Lunar Control Network 2005
USGS	United States Geological Survey
UTC	Coordinated Universal Time
W	Watts