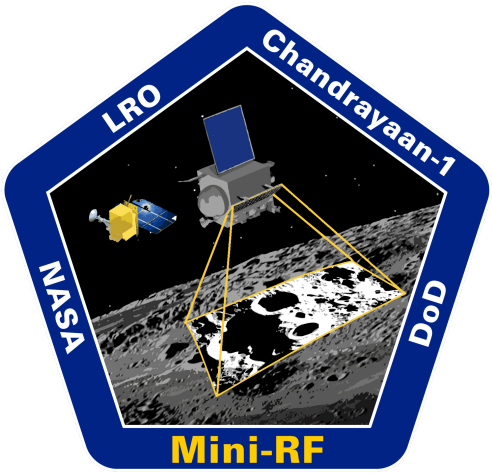
SPECIFICATION NUMBER: MRF-4008
CAGE Code 12934

Created on 2/21/2011

PDS Data Product Software Interface Specification (SIS)

For

Mini-RF Advanced Technologies – Forerunner (Mini-SAR) Payload Operations Center



December January 19, 2011

Prepared by
Mini-RF Program

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RECORD OF CHANGES			
CHANGE NO.	**DATE**	**TITLE OR BRIEF DESCRIPTION**	**ENTERED BY**
0	31 May 07	Initial release	M. Reid
1	11 April 08	Major modifications from peer review.	M. Reid
2	20 May 08	Added descriptions of the Sandia derived scatterometry products to section 6.1.2.	M. Reid
3	08 April 09	Modified descriptions of the Sandia products and resolved remaining TBD items. Added description of the scatterometry settings and parameters file. Table 3: Added data set IDs and names for the Sandia products.	M. Reid
4	30 July 09	Added CENTER_FREQUENCY keyword to level 1 and level 2 product labels.	M. Reid
5	8 Oct 09	Modified product file naming conventions to include band, zoom-mode, and version number. Forerunner data are not collected in zoom-mode. This is included to keep file-naming conventions consistent with those of Mini-RF Forerunner products. Added more information about SPICE kernels and updated their naming conventions. Updated the sample PDS labels for the raw, level 1, and level 2 products. Expanded the keyword definitions and glossary. Updated the signatory list to reflect changes in the project management. Removed references to scatterometry products including Sandia DDRs due to the fact that no scientifically useful scatterometry data were collected prior to the end of the Chandrayaan-1 mission. Added information on SPICE kernels.	M. Reid
6	10 Dec 09	Added file naming conventions for extra calibration data. Fixed error in version number field in Lev 3 product file names. Added data quality and product version fields to labels.	M. Reid
7	17 Dec 09	Modified DATA_QUALITY_DESCR to rang up to 2.	M. Reid

8	17 Aug 10	Updated naming conventions, removed references to scatterometry products, updated references to calibration products, deleted Appendix reference to level-2 products, updated example PDS labels.	M. Reid
9	19 Jan 11	Modified references to mosaics; rewrote references to SPICE kernels; removed references to the Lunar DEM files; added new sample PDS labels; miscellaneous minor editing.	M. Reid

Table of Contents

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1. Purpose and Scope of Document

This Software Interface Specification (SIS) describes the archived Forerunner (also known as "Mini-SAR") instrument science-related data products. Forerunner is an instrument that flew on the Indian Space Research Organisation (ISRO) Chandrayaan-1 lunar orbiting spacecraft. It is a synthetic aperture radar (SAR) that imaged and characterized the lunar surface. The Mini-RF Payload Operations Center (POC) is located at The Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland. The POC supports both this instrument and the similar Mini-RF instrument on the NASA Lunar Reconnaissance Orbiter (LRO) spacecraft. 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.

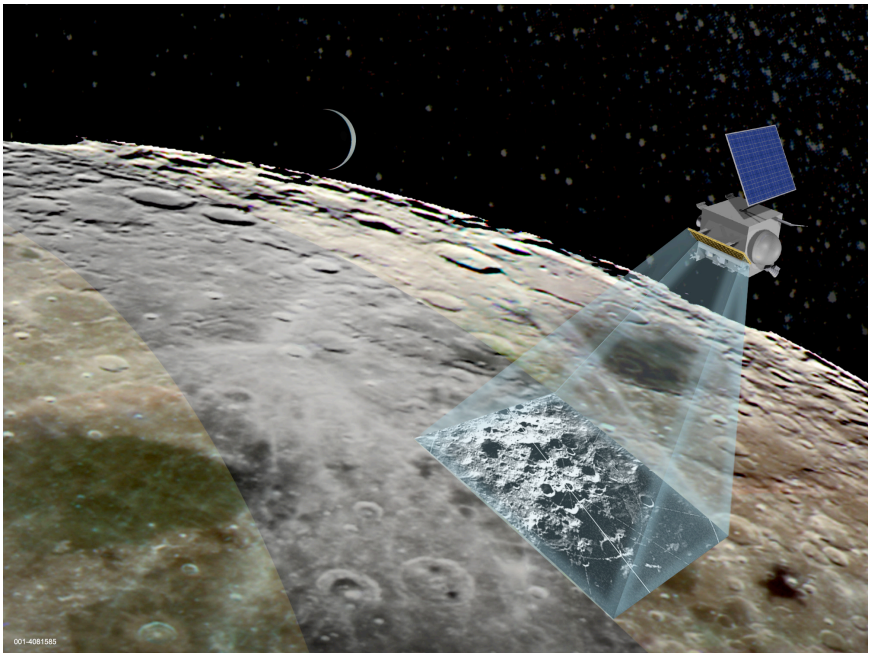

Figure 1: The Chandrayaan-1 spacecraft.

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 Forerunner science data products. The SIS applies to the Forerunner data products produced during the course of Chandrayaan-1 Mission operations.

2. Applicable Documents

The Forerunner 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].

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 *Chandrayaan-1 Project Mini-SAR Instrument Team Data Management and Archive Plan*, Mini-RF program.

4 *Chandrayaan-1 Mini-RF Science Team and PDS Geosciences Node Interface Control Document (ICD)*, Mini-RF program.

5 *Lunar Reconnaissance Orbiter (LRO) Mini-RF Science Team and PDS Geosciences Node Interface Control Document (ICD)*, Mini-RF program.

6 *Data Interface Control Document for Mini-RF Advanced Technologies (Forerunner)* (XMRF-1101), Mini-RF program.

7 *Archive Volume Software Interface Specification (SIS) for Mini-RF Advanced Technologies—Forerunner (Mini-SAR)* (MRF-4010), Mini-RF program.

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, *Forerunner transmit polarization ellipse as observed at Green Bank Radio Telescope on February 28 and March 1, 2009* [DOCUMENT/GB_CAL/MRFFR_GB_CALIB_JENSEN2009].

3. Relationships with other Interfaces

The Forerunner 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 SPICE kernels. Their formats comply with PDS standards. All products will be archived to the PDS Geosciences node.

4. Data Product Characteristics and Environment

4.1 Instrument Overview

Forerunner (Mini-SAR) is an instrument on the Chandrayaan-1 spacecraft. It is capable of active SAR and scatterometer imaging. High-resolution SAR images of the lunar polar regions 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. The instrument will gather data during dedicated observing opportunities. The original operations plan had six approximately 30-day opportunities during the two-year primary mission.

4.1.1 Instrument Description

The Forerunner instrument has the following orbital, operational, and electrical attributes that describe it.

Parameter	SAR	Scatterometer
Orbit	Circular	
Altitude	100 ± 20 km	
Inclination	~90° (1.5° wobble, 14-day period)	
Spacecraft speed	1.63 km/s	
Operation	Alternately from 80° or 85° poleward	
Number of waveforms	936	
Collect Time/Orbit	6 minutes	
Strip length	325 km or 150 km	300 km
Incidence Angle	~35°	Normal
Grazing Angle	55°	90°
Swath Width	8 km	10 km
Looks (S/C Power/SSDR-constrained)	16	128
Peak Data Rate (SSDR-constrained)	187.43 Mbps	
Avg. Data Rate into SSDR During Collect	6.22 Mbps	5.24 Mbps
Azimuth Resolution (Power/SSDR constrained)	150 m	1000 m
Slant Range Resolution (instrument constrained)	≥ 86 m	
Electrical Attributes		
Frequency	2.38 GHz	
Bandwidth	2.1 MHz	
Polarization	Transmit LCP, Receive coherent linear H and V	
End to End Axial Ratio	2.4 dB	
Multiplicative Noise Ratio (best/worst)	–22/–9 dB	
Noise Equivalent Sigma Naught	–30 dB	
Antenna:		
Length	1.37 m	
Width	0.925 m	
Bore-sight Gain	23.3 dBi	
Peak side-lobe level	–9.3 dB	
Transmitter:		
Peak RF Power	40 W	
Transmit Pulse Width	10 μs to 150 μs	
Pulse Repetition Rate	2222 pulses/s to 25000 pulses/s	
Maximum duty factor	33%	
Losses between transmitter & antenna	1.63 dB	
Receiver:		
Number of Channels	2	
System Noise Temperature	620 K	
A/D Sampling Rate	8.2 MHz	
Number of A/D Bits Per Sample	8	

Table 1 Description of the Forerunner instrument.

4.2 Data Processing

There are two modes of data acquisition from the Forerunner instrument on the Chandrayaan-1 spacecraft, SAR and scatterometry mode. SAR mode is referred to in this document as the standard SAR product. Scatterometry mode (also a type of SAR product) is used to create the scatterometry 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 therefore, 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). Only one set of raw scatterometry data are archived at the POC. This data set is useful only for calibration purposes. 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.

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	Nonscience 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)	CH1-ORB-L-MRFFR-1-PDR-V1.0 "CH1-ORB MOON MINI-RF 1 PACKETIZED DATA RECORD V1.0"	Raw	1
Calibrated Data Records (CDR)	CH1-ORB-L-MRFFR-4-CDR-V1.0 "CH1-ORB MOON MINI-RF 4 CALIBRATED DATA RECORD V1.0"	1	4
Map-Projected Calibrated Data Records (CDR)	CH1-ORB-L-MRFFR-5-CDR-MAP-V1.0 "CH1-ORB MOON MINI-RF 5 MAP-PROJ CALIBRATED DATA REC V1.0"	2	5
Polar Mosaics	CH1-ORB-L-MRFFR-5-CDR-MOSAIC-V1.0 "CH1-ORB MOON MINI-RF 5 POLAR MOSAIC CALIBRATED DATA REC V1.0"	3	5
SPICE Kernels	CH1-ORB-L-SPICE-6-V1.0 "MINI-SAR SPICE KERNELS 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.

Keyword	Value
MISSION_NAME	"CHANDRAYAAN-1"
MISSION_ID	CH1
INSTRUMENT_HOST_NAME	"CHANDRAYAAN-1 ORBITER"
INSTRUMENT_HOST_ID	CH1-ORB
INSTRUMENT_NAME	"MINI-RF FORERUNNER"
INSTRUMENT_ID	MRFFR

Table 4 Values of mission and instrument identifying key words. Note that the instrument is also known as "Miniature Synthetic Aperture Radar (Mini-SAR)."

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.

4.2.2.1 Amplitude calibration

The Mini-RF radar data product is comprised of the amplitude (or magnitude squared) of the H and the V channels of the dual-polarized receiver, and also the cross-product of the complex H and V amplitudes. These data are necessary and sufficient to form the 2×2 coherency matrix of the backscattered field, which is alternatively represented by the Stokes parameters, four real

numbers. The first Stokes parameter represents the total backscattered power. This can be scaled to the normalized reflectivity sigma-zero only if the end-to-end transformation of the radar is calibrated absolutely. The starting point for this scaling is the set of pre-flight system data, coupled with in-flight specifics such as incidence and altitude. During the mission, absolute calibration will be updated by imaging a lunar area whose reflectivity is well known from Earth-based radar observatories; however, most lunar science measurements depend on ratios of the Stokes parameters, for which absolute amplitude calibration is not required. Rather, gain balance between the H and the V channels is the key objective. Relative calibration consists of evaluating the corrective scaling constant of the H amplitude relative to the V amplitude. Calibration references (noise, tone, and chirp) are included at the beginning and end of each data take to assist relative amplitude calibration. During the mission, relative calibration will be up-dated by radar coverage of the lunar surface at nadir, from which the observed backscatter should have identical amplitudes seen through both the H and the V channels. Any difference can be inverted to evaluate the relative amplitude calibration constant. In addition, the mission plan calls for relative amplitude calibration through a cooperative transmission and reception between the spacecraft and an Earth-based radar observatory. These data will be posted on the PDS when available. (If more specific information is needed, please consult the Mini-RF Calibration Plan.)

4.2.2.2 Phase calibration

The Mini-RF radar data product is comprised of the amplitude (or magnitude squared) of the H and the V channels of the dual-polarized receiver, and also the cross-product of the complex H and V amplitudes. The cross-product is one representation of the phase to be calibrated. These data are necessary and sufficient to form the 2x2 coherency matrix of the backscattered field, which is alternatively represented by the Stokes parameters, four real numbers. The first Stokes parameter is the total backscattered power (see Amplitude Calibration). Under the operational assumption that the radar transmits circular polarization, the relative phase (in the cross-product) is central to the third and the fourth Stokes parameter. Relative phase calibration consists of evaluating the corrective phase rotation constant of the H complex amplitude relative to the V complex amplitude such that the average phase difference between them is +/-90 degrees (whose sign depends on whether right- or left-circular polarization was transmitted) under the condition that the average reflecting surface is specular. The starting position for relative phase calibration is the set of pre-flight system data, coupled with in-flight measurements based on the radar's calibration references (see Amplitude Calibration). During the mission, relative phase calibration will be up-dated by radar coverage of the lunar surface at nadir, from which the observed averaged backscatter should have known relative phase between the H and the V channels. Any difference can be inverted to evaluate the relative phase rotation calibration constant. In addition, the mission plan calls for relative phase calibration through a cooperative transmission and reception between the spacecraft and an Earth-based radar observatory. Calibration products are included in with the PDS archive volume.

4.2.3 SAR Science Data Processing

There are three levels of SAR Forerunner data products produced while the instrument is in SAR (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
- Level-3 polar mosaic generation

4.2.3.1 Level-0 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 and of 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 SAR Processing

The flow chart for the SAR (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

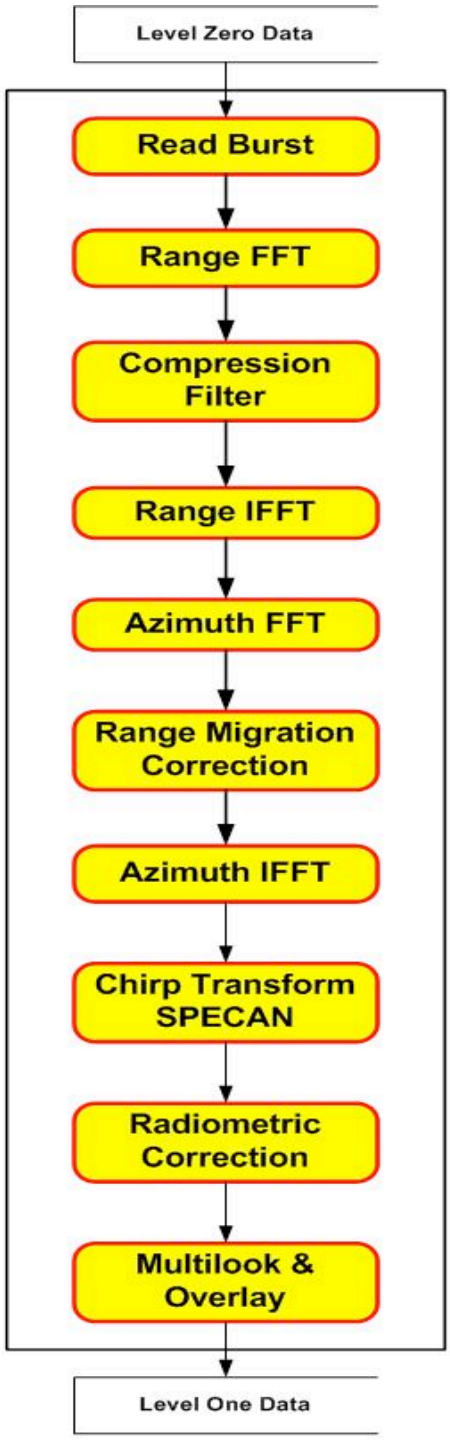

Figure 2 The SAR (burst) mode processor.

4.2.3.3 Level-2 SAR 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 Scatterometry Science Data Processing

Scientifically useful scatterometry data were not acquired due to the premature termination of the Chandrayaan-1 mission; therefore, only a raw scatterometry product that was not collected over a lunar pole and is useful only for calibration purposes is included in the archive.

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 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 received from ISRO 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 real numbers. These data only are provided in big-endian format.

The science data are time-ordered and consist of a set of two-byte samples or interleaved vertical (V) and horizontal (H)-polarization channel data contained within a pulse. The first byte of the sample contains the V-channel value and the second the H-channel value. There can be a

maximum of 1,229 samples per pulse. The formats for the SAR and scatterometry data packets are the same. They differ only in that scatterometry packets have APID 12 (decimal).

The packet CCSDS Secondary Header contains the timestamp for the packet. The Coarse Time field is an MET stored in a 48-bit 1750-format long floating point number. The SCLK kernel provided with the archive will contain the information needed to translate this value.

CCSDS Telemetry Packetes	Paramters		Num Bits	Min	Max	Step Size - EU converter	Zero Offset - EU converter	Comments
CCSDS Primary Header (6 Bytes)	CCSDS Version		3	0				Fixed
	Packet Type		1	0				Fixed
	Secondary Header Flag		1	1				Fixed, 1 =secondary header
	Application ID		11	10	20	1	0	Program by ground command
	Segment Flag		2	3				Fixed
	Sequence Count		14	0	16383	1	0	Packet number, start from 0, set by Receiver
	Packet Length		16	41 + 164 = 205	41 + 4100 = 4141	1	0	Total number of bytes in packet data field-1, set by Rx Includes Secondary & Science Header sizes + Science Data 41 + 2 x SamplesPerPulse
CCSDS Secondary Header (10 Bytes)	Fine Time	ns	32	0	223.478 minutes	3121.95 ns	NA	vernier counter value latched at the start of each burst
	Coarse Time		48	3 16-bit words in 1750 long float foramt				Spacecraft time (from BMU to CP to Receiver, resolution is 125 micro-sec per ISRO)

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	ITEM	UNITS	BITS	MIN	MAX	EU Conversion	EU Units		
Science Header (32 Bytes)	Pulse Repetition Interval (PRI)	counts	16	12,300	41,000	1/0.082	nsec	0	waveform parameters - Note: Range Gate Start is adjusted to be smaller by one or two PRIs, in order to start capturing the background data right away, instead of waiting for the return before starting to open the receive gate. NOTE: SYSCLK = 934,000,000 kHz ChirpRateStepSize=20,000,000
	Tx Pulse Width	counts	16	820	12,300	1/0.082	nsec	0	
	PNP Channel # (Chirp Center Frequency)	counts	16	1,018	1,216	2,400,000 + channel*50 + 75,850	KHz	2,384,150 for S band	
	Rising Delta Tuning Word (Chirp Rate)	counts	32	0	0xFFFFFFFF	RDTW*SYSCLK* SYSCLK / (ChirpRateStepSize + 2^31)	kHz/msec	0	
	Range Gate Start	counts	16	0	41,000	1/0.041	nsec	0	
	Samples Pairs Per Pulse	counts	16	82	2,050	NA	NA	0	
	Inter-Burst Time	counts	32	1	2,214,000,000	1/0.082	nsec	0	
	Number Bursts per Collection	counts	16	1	6,000	1	counts	0	
	Number of Pulses per Burst	counts	16	1	65,535	1	counts	0	Note: Need to make larger than needed to account for the number of pulses in the air. The first 1 or 2 pulses will always be background.
	Experiment ID	NA	8	0	255	1	NA	0	
	Collect Option	NA	8	0x02	0x0C	See MRF_Collect command			
	Waveform Table Index	NA	16	0	1023	NA	NA	NA	
	V-Channel Attenuator Setting	counts	8	0	50	1	dB	0	
	H-Channel Attenuator Setting	counts	8	0	50	1	dB	0	
	Pulse Number within a Burst	counts	16	0	65,534	1	counts	0	pulse number starts from 0
	Burst Number	counts	16	0	5,999	1	counts	0	burst number starts from 0
Science Data	V-Channel ADC Sample Data 1		8	n/a					This format is for Forerunner only
	H-Channel ADC Sample Data 1		8						
	V-Channel ADC Sample Data 2								
	H-Channel ADC Sample Data 2								
	V-Channel ADC Sample Data N		8						N = number of samples per pulse; Max = 1229
	H-Channel ADC Sample Data N		8						

Table 5 Layout of the raw Data PDRs, both SAR and scatterometry modes. Unlike the other data products, the raw PDR files are delivered in big-endian format.

Forerunner 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 ISRO 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".
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: CH1-ORB-L-MRFFR-1-PDR-V*n.n*).

4.3.2 SAR 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 polarmetrically 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.

Forerunner 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 8-byte complex value (one 4-byte floating point real and one 4-byte floating point imaginary value) for a total

Forerunner Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
						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 CDR product.	Geosciences	1	TXT	The level-1 cross-product polarimetric SAR Parameter File.

Table 7 Level-1 SAR data products. IMG and DAT files are binary instrument data and TIF are TIFF (DATASET_ID: CH1-ORB-L-MRFFR-4-CDR-V*n.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 ±79° 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 $S_1 = <|E_{LH}|^2 + |E_{LV}|^2>$, represents the total power or total intensity of the received field.

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

The third and fourth Stokes parameters are defined as $S_3 = 2\ Re< E_{LH}\ E_{LV}^{*}>$ and $S_4 = -2\ Im < E_{LH}\ E_{LV}^{*}>$, 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 $S1$ and $S4$ 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.

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. Science product in oblique cylindrical projection. 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 images between the H & V receive.
Level-2 SAR Parameter File	TEXT	Shared with CDR 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.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
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.
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. These files are used to produce the level-3 mosaic products. Ratio of same sense to opposite sense polarization. These values are dimensionless.

Table 8 Level-2 SAR data products (DATASET_ID: CH1-ORB-L- MRFFR-4-CDR-MAP-V*n.n*).

4.3.3 Level-3 Polar Mosaics

The level-3 products are Derived Data Records (DDRs) generated from multiple level-2 CDRs. They are mosaics that the POC produces by ingesting the level-2 Stokes parameter and circular polarization files into the ISIS software. Two level-3 mosaics are provided for each lunar pole (i.e., regions north of 80° latitude or south of -80° latitude), one constructed from circular polarization ratio data and the other from the stokes 1 parameters data. 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. Each polar mosaic is accompanied by a reduced-size "quick look" JPEG image. These are archived both at the POC and at the PDS.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level-3 CPR North Polar Mosaic	Binary	Full	Geosciences	1	IMG	North polar mosaic constructed from data acquired during multiple orbits from circular polarization data.
Level-3 S1 North Polar Mosaic	Binary	Full	Geosciences	1	IMG	North polar mosaic constructed from data acquired during multiple orbits from stokes 1 parameters data.
Level-3 CPR North Polar Mosaic Quick Look image	Image	None	Geosciences	1	JPG	A JPEG rendering of the CPR north polar mosaic.
Level-3 S1 North Polar Mosaic Quick Look image	Image	None	Geosciences	1	JPG	A JPEG rendering of the S1 north polar mosaic.
Level-3 CPR South Polar Mosaic	Binary	Full	Geosciences	1	IMG	South polar mosaic constructed from data acquired during multiple orbits from circular polarization data.
Level-3 S1 South Polar Mosaic	Binary	Full	Geosciences	1	IMG	South polar mosaic constructed from data acquired during multiple orbits from stokes 1 parameters data.
Level-3 CPR South Polar Mosaic Quick Look image	Image	None	Geosciences	1	JPG	A JPEG rendering of the CPR south polar mosaic.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Level-3 S1 South Polar Mosaic Quick Look image	Image	None	Geosciences	1	JPG	A JPEG rendering of the S1 south polar mosaic.

Table 9 Level-3 mosaic data products produced using the USGS ISIS software (DATA_SET_ID CH1-ORB-L-MRFFR-5-CDR-MOSAIC-V*n.n*).

4.3.4 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.

4.3.4.1 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 10 for a description of the ancillary data product, which contains these data.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Instrument Housekeeping Data	TEXT SPREAD-SHEET	Full	Geosciences	1	CSV	The instrument housekeeping data (engineering data)

Table 10 Instrument Housekeeping data.

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 Green Bank Radio Telescope in West Virginia. These are described in papers referenced in sec. 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 Mini-RF MOC, the Green Bank Radio Telescope consisting of CCSDS packets with primary, secondary, and science headers. CCSDS packet PDR data. Delivered with no supporting materials.
Raw SAR Parameter File	TEXT	Shared with product label	Geosciences	1	TXT	The raw data Parameter File.

Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
Calibration Parameter File	Text file	Minimal	Geosciences	1	TXT	File listing the various parameters and values used in data calibration.

Table 11 Calibration data products.

4.3.6 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 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 Chandrayaan-1 mission and Forerunner (Mini-SAR) instrument will be included in this archive in the GEOMETRY directory.

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) that contains functions that perform computations for space mission-related and astronomical applications. There are several types of SPICE kernel: Attitude and pointing kernels (CK), ephemeris kernels (SPK), planetary constants kernels (PK), frame kernels (FK), leap second kernels (LSK), spacecraft clock coefficients kernels (SCLK), instrument kernels (IK), and error kernels (EK). The Forerunner archive does not include IKs or EKs. Some of these are created by the POC with data supplied by ISRO and JPL, and some are standard generic products provided by NAIF.

SPICE meta-kernels are used for loading other kernels. They contain a list of kernels to be loaded for a given purpose and the order in which they are to be loaded. Meta-kernels are typically provided to the SPICE library *furnsh()* function that loads kernels. They are typically included in the **EXTRAS** directory of an archive volume and do not have associated PDS labels.

SPICE kernels are typically delivered in as separate archive volume to the NAIF PDS node (as is the case with Mini-RF on LRO). Forerunner deviates from this practice in that all kernels are being included in the regular archive volume archived at the Geosciences node.

The standards for archiving SPICE kernels and supporting files at the NAIF PDS node differ somewhat from the general PDS standards. For the kernels only, the NAIF standards are followed. These differ in that all kernels have simultaneously both attached and detached PDS labels; text kernels have Unix-style line-feed <LF> end of line (EOL) terminators, not the PDS-standard PC-style <CR><LF> EOLs (All accompanying files such as detached labels have the PDS-standard EOLs); kernels provided by NAIF have all lower-case file names. NAIF kernels

retain their original file names. Binary kernels, although generated and used at the POC in little-endian byte order form, are converted to big-endian byte order per NAIF standards.

All kernels, except for the metakernel, are stored in subdirectories within the GEOMETRY directory. Each kernel subdirectory contains an *info.txt file that describes the kernel(s) in detail.

CKs constitute the greatest portion of delivered kernels. They contain attitude data obtained primarily from on-board quaternion data that are appended to the end of received Mini-SAR telemetry. The Mini-SAR data processing system converted these data into CKs containing attitude and attitude rates information. There are a few data intervals for which no quaternion-based ephemeris is available. To cover these periods, CKs containing attitude data provided by ISRO and interpolated attitude rates were generated. See the ckinfo.txt file in the GEOMETRY/data/ck/ directory for a description of these files.

Metakernels are provided that load either the predicted or the definitive CKs. They are mutually exclusive.

Product	Kernel Type	File Name	Num Files	File Type	Source	Description
Full-Mission Spacecraft Ephemeris	SPK	CHAN1_SHORT_20081022_00.BSP	1	binary	POC and JPL	Full-mission spacecraft ephemeris. Created by JPL and APL from ranging data and data provided by ISRO.
Planetary ephemeris	SPK	de421.bsp	1	binary	NAIF	Contains ephemeris for the major natural bodies in the Solar System.
Spacecraft Attitude	CK	CHAN1_TLM_<*yyyymmdd*>_<*nn*>.BC	899	binary	POC	Short period spacecraft attitude data covering periods of several days or less. "*yyyymmdd*" is the date of the beginning of the data in the kernel.
Spacecraft Clock Coefficients	SCLK	CHAND1_SCLK_<yyyymmdd>_<nn>.TSC	2	text	POC & M3 Team	Spacecraft clock kernels covering the full mission. "*yyyymmdd*" is the kernel creation date.

Product	Kernel Type	File Name	Num Files	File Type	Source	Description
Leap Seconds	LSK	naif0009.tls	1	text	NAIF	Contains the leap seconds and the values of physical constants required to perform transformations between Universal Time Coordinated (UTC) and Ephemeris time (ET)
Instrument Frames	FK	chand1_v001.tf chand1_vexcel.tf	2	text	POC	Describes the instrument reference frames.
Lunar Frame	FK	moon_080317.tf	1	text	NAIF	Lunar reference frame information.
Planetary Constants	PCK	pck00008.tpc	1	text	NAIF	Contains IAU shape, size, and orientation information for all the major natural bodies in the Solar System.
Lunar Constants	PCK	moon_pa_de421_1900_2050.bpc	1	binary	NAIF	Contains high-precision Lunar orientation data.
Metakernel	MK	ch1_minisar_v01.tm	1	text	POC	Metakernel that lists in loading order all of the other kernels in the archive. This kernel is located in the EXTRAS/mk directory and does not have a PDS label.

Table 12 SPICE kernels delivered with the product sets. Instrument (IK) and error (EK) kernels are not provided for Forerunner.

4.3.7 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.

Forerunner 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.
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 archive.
spice_index.tab	Text Table	Full	Geosciences	1	TAB	A table listing all of the SPICE kernels in the archive.
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.
MRFFR_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.
MRFFR_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.
MRFFR_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.

Forerunner Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
MRFFR_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.
MRFFR_GB_CAL_JENSEN2009.PDF	Adobe PDF	Document	Geosciences	1	PDF	Description of calibration done using data collected by the Green Bank Radio Telescope.
MRFFR_GB-CAL_JENSEN2009.HTM, IMAGE*.GIF or JPG	HTML Text	Document	Geosciences	1	HTM	HTML version of description of calibration done using data collected by the Green Bank Radio Telescope and associated image 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: MRFFR_1_PDR_DS.CAT MRFFR_4_CDR_DS.CAT MRFFR_5_CDR_MAP_DS.CAT MRFFR_5_CDR_MOSAIC_DS.CAT spiceds.cat
INSTHOST.CAT	PVL Text	N/A	Geosciences	1	CAT	Information about the Chandrayaan-1 spacecraft for the PDS catalog.
INST.CAT	PVL Text	N/A	Geosciences	1	CAT	Information about the Mini-RF instrument for the PDS catalog.

Forerunner Product	File Type	Label Type	PDS Node	Num Files	File Name Extension	Description
spice_inst.cat	PVL Text	N/A	Geosciences	1	CAT	Information about the Mini-RF SPICE kernels 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.
GEOMINFO.TXT	Plain Text	Document attached	Geosciences	1	TXT	A description of the contents of the GEOMETRY directory. This directory contains the SPICE kernel files described in section 4.3.6.
ck/ckinfo.txt, fk/fkinfo.txt, lskinfo.txt, pck/pckinfo.txt, Sclk/sclkinfo.txt, spkinfo.txt, mk/mkinfo.txt	Plain Text	Document attached	Geosciences	1	TXT	A description of the contents of the individual kernel directories within the GEOMETRY directory (except for the mkinfo.txt file which is in the EXTRAS directory) as described in Table 12.

Table 13 PDS standard files that contain descriptive and indexing information about the archive.

4.4 Data Product Archiving

The Mini-RF POC is responsible for science data product generation, validation, and archiving. The POC supports and works with the ISRO Chandrayaan-1 mission operations, the Forerunner science team, and the PDS.

4.4.1 Data Flow

Prior to science phase of the Chandrayaan-1 mission, the POC produced sample data products from raw telemetry generated by spacecraft and instrument simulators operated by ISRO. During the mission, the spacecraft control center at ISRO received the science data downlink from the spacecraft on one channel and the housekeeping data on a second channel. ISRO sent the raw data from the Forerunner instrument to the POC through a data link. At the POC, the Vexcel® SAR and Calibration processors processed the raw SAR data through levels 0, 1, and 2. Level-3 mosaics were produced using the ISIS software from the USGS. 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, 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 uniquely identifies each product. The file name may be used for the product ID as long as it is unique.

SPICE kernels are delivered with both attached and detached PDS labels in accordance with NAIF conventions. This applies to both binary and text kernels. It should be noted that the text SPICE kernels themselves do not have the PDS-standard <CR><LF> end of line (EOL) terminators. They have the Unix-type <LF> EOLs. This is also in accordance with NAIF conventions.

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 Forerunner PDS label 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 Forerunner 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 Forerunner data products contain:

1. PDS Label Files describing the specific product (including external data files)
2. SAR or Scatterometry 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. Mission and instrument-specific SPICE kernel files.
7. Documentation.

PDS labels also accompany SPICE kernels.

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*-*dd***T***hh*:*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 Computational Assumptions

Table 14 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")	
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 14 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 delivery of the products, 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.
- The data pipeline is also reviewed as part of the validation process.
- 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 two or three-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 **F** (Forerunner) that is the file designation for all Forerunner 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 4.2.2.

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 _***V***v.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
Z = Zoom
A = Arecibo Radio Telescope Calibration
G = Green Bank Radio Telescope Calibration
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 15.
- **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
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 15 Association of letter-designated bins for pixel resolutions.

u = bit type and scaling
- **U** = Unnormalized floating point
- **F** = Normalized floating point
- **B** = Byte
- **X** = Unspecified

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

In the case of the level-2 products, the latitude and longitude fields in the file names match those of the corresponding level-1 products. Because the level-2 products are map-projected, their center coordinates will sometimes differ from those of the level-1 products from which they derive. For consistency, the coordinate values in the level-2 file names will sometimes differ slightly from the values in their PDS labels.

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 82ºN, 231º, orbit 512, version 1.

FSB_00512_RPD_XJB_82N231_V1.DAT

The following is an example file name of a Mini-RF 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 82ºN, 231º, orbit 617, version 3.

FXZ_00617_2CD_OJU_82N231_V3.IMG

The following is an example file name of a Mini-RF 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 82ºN, 231º, orbit 512, version 2.

FSB_00512_2S3_EJU_82N231_V2.IMG

The following is an example file name of a Mini-RF calibration data product. It is a raw product collected using the Green Bank 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.

FSG_00975_RPD_XXB_XXXXXX_V1.DAT

The following is an example file name of a Mini-RF Forerunner polar mosaic, S-band, level 3, cicular polarization, unnormalized floating point, north pole mosaic product, 2048 ppd, version 1.

FSB_XXXXX_3CP_PJU_90N000_V1.IMG

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

4.7.1.2 File Naming Convention for Calibration Files

Forerunner calibration files contain raw packets and are similar to regular raw science data products. The naming convention is as follows:
Format: **F***fm_yyyyMMddhhmm*_**V***vv.ext*

F = Forerunner

f = Frequency band
- **S** = S-band
- **X** = X-band
- **B** = Both
- **N** = N/A

m = Radar mode
- **A** = Arecibo Radio Telescope Calibration
- **G** = Green Bank Radio Telescope Calibration
- **C** = Other Calibration
- **O** = Other (housekeeping, etc.)

ttt = Product type
- **RPD** = Raw Packetized Data Record
- **RHK** = Instrument Housekeeping file associated with the calibration data file.

yyyy = Year of data collection
MM = month (1…12) of data collection
dd = day of month (1…31) of data collection
hh = hour (0…23) of data collection

mm = minute (0…23) of data collection

ext = Product type (complies with PDS conventions)
DAT = Unformatted binary data (e.g., raw files)
TXT = Unstructured text data (e.g., parameter files)
CSV = Comma Separated Value text files (housekeeping)
LBL = PDS label file

Format: **FSA_RPD**_*yyyyMMddhhmm_vv.ext*
The following is an example file name of a Mini-RF calibration data product collected using the Arecibo Radio Telescope. It is an S-band, raw data, packetized data record collected on January 30, 2009 at 19:44h UTC.

FSA_RPD_200901301944_V01.DAT

4.7.1.3 File Naming Conventions for SPICE Kernels

SPICE kernels filenames do not follow a standard naming convention other than the file name extension indicating the kernel type. The kernel file name extensions follow NAIF conventions. See Table 12 for a listing of the archived kernels and their file names.

4.7.1.3.1 Kernel File Name Extensions

Binary Ephemeris (SPK):
File extension: ***.bsp or *.BSP**

Binary Spacecraft attitude (CK):
File extension: ***.BC**

Text Spacecraft Clock Coefficients Kernel (SCLK):
File extension: ***.TSC**

Text Frame Kernels (FK):
File extension: ***.tf**

Binary Planetary Constants Kernel (PCK):
File extension: ***.bpc**

Text Planetary Constants Kernel (PCK):
File extension: ***.tpc**

Text Leap Seconds Kernel (LSK):
File extension: ***.tls**

Text Metakernel (MK):

File extension: ***.tm**

4.8 Label and Header Descriptions

4.8.1 PDS Label Parameter Descriptions

The key words used in Forerunner data product PDS labels are described in Table 16 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 qube. 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 are interleaved in image lines, or how samples from different bands are arranged sequentially.
CENTER_FREQUENCY	The carrier frequency of the SAR in Gigahertz. Intended for use in calculating Doppler shifts.
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).

Key Word	Description
DATA_QUALITY_DESC	A description of the numeric quality metric given in DATA_QUALITY_ID.
DATA_QUALITY_ID	A numeric indicator (-1,0,1,2) of the quality of the data products. See DATA_QUALITY_DESC.
^DATA_SET_MAP_PROJECTION	Reference to the file which 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.
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.

Key Word	Description
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.
NAME	The common term used to describe the type of data described in the label.
OBLIQUE_PROJ_POLE_LATITUDE	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

Key Word	Description
	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 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).
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 FORERUNNER 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 Mini-RF products that may undergo multiple iterations. For example, RDR products which are regenerated using an updated calibration model or compressed images that are uncompressed using a different scheme.
PUBLICATION_DATE	The date when a published document was issued.
<mission>:RANGE_COEFFICIENT_SET	The Mini-RF instrument-specific ground range to slant range coefficients.
RANGE_RESOLUTION	The image pixel resolution.
RECORD_BYTES	The number of bytes in a physical file record, including record terminators and separators.
RECORD_TYPE	The record format of a file.
REFERENCE_LATITUDE	The zero latitude in a rotated spherical coordinate system that was used in a given map_projection_type.
REFERENCE_LONGITUDE	The zero longitude in a rotated spherical coordinate system that was used in a given map_projection_type.
RELEASE_ID	Identifies the unique identifier associated with a specific release of a data set. All initial releases

Key Word	Description
	should use a RELEASE_ID value of '0001'.
SAMPLE_BITS	The stored number of bits, or units of binary information, contained in a line_sample value.
SAMPLE_FIRST_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_LAST_PIXEL	The sample index for the last pixel that was physically recorded at the end of the image array.
SAMPLE_PROJECTION_OFFSET	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).
SAMPLE_TYPE	The data storage representation of sample value. PC_REAL for Mini-RF images.
SCALED_PIXEL_HEIGHT	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.
SCALED_PIXEL_WIDTH	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.
SECOND_STANDARD_PARALLEL	A required keyword; however, it is not applicable for oblique cylindrical projects. Always “N/A”.
SOFTWARE_NAME	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.
SOFTWARE_VERSION_ID	Version of the software used to generate the products.
SOURCE_PRODUCT_ID	The list of products used as input to create a new product. This can be SPICE kernels, digital elevation model (DEM) files, or other products.
SPACECRAFT_CLOCK_START_COUNT	Clock count of the spacecraft computer at the start of the observation.
SPACECRAFT_CLOCK_STOP_COUNT	Clock count of the spacecraft computer at the end of the observation.
STANDARD_DEVIATION	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 16 The PDS label keywords used in the Mini-RF labels.

4.8.2 Examples of SAR Product PDS Labels

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

```
PDS_VERSION_ID              =  PDS3
LABEL_REVISION_NOTE         =  "JHU/APL Version 1.0"
RECORD_TYPE                 =  UNDEFINED
FILE_NAME                   =  "FSB_01895_RPD_XIB_85S159_V1.DAT"
DATA_SET_ID                 =  "CH1-ORB-L-MRFFR-1-PDR-V1.0"
DATA_SET_NAME               =  "CH1-ORB 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                  =  "FSB_01895_RPD_XIB_85S159_V1"
PRODUCT_VERSION_ID          =  "1.0"
ORIGINAL_PRODUCT_ID         =  "Sar_20090413_230617_20101016_004504.down"
SOFTWARE_VERSION_ID         =  "1.0"
PRODUCT_CREATION_TIME       =  2010-11-24T20:46:31
RELEASE_ID                  =  "0001"
MISSION_NAME                =  "CHANDRAYAAN-1"
INSTRUMENT_HOST_NAME        =  "CHANDRAYAAN-1 ORBITER"
INSTRUMENT_HOST_ID          =  "CH1-ORB"
INSTRUMENT_NAME             =  "MINI-RF FORERUNNER"
INSTRUMENT_ID               =  MRFFR
TARGET_NAME                 =  MOON
MISSION_PHASE_NAME          =  "NOMINAL MISSION"
START_TIME                  =  2009-04-13T23:06:17.147
STOP_TIME                   =  2009-04-13T23:09:48.147
ORBIT_NUMBER                =  0
DESCRIPTION                 =  "Forerunner 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
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                       =  "FSB_01895_RPD_XIB_85S159_V1.TXT"
  RECORD_TYPE                 =  STREAM
  FILE_RECORDS                =  16
  OBJECT                      =  TEXT
    PUBLICATION_DATE            =  2010-11-24
    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 FORERUNNER Level-1 SAR Data Product

```
PDS_VERSION_ID                =  PDS3
LABEL_REVISION_NOTE           =  "JHU/APL Version 1.0"

/* File Identification and Structures. */
RECORD_TYPE                   =  FIXED_LENGTH
RECORD_BYTES                  =  4768
FILE_RECORDS                  =  4054

/* Pointer to data object. */
^IMAGE                        =  "FSB_01895_1CD_XIU_85S159_V1.IMG"

/* Identification Data Elements. */
DATA_SET_ID                   =  "CH1-ORB-L-MRFFR-4-CDR-V1.0"
DATA_SET_NAME                 =  "CH1-ORB 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                    =  "FSB_01895_1CD_XIU_85S159_V1"
PRODUCT_VERSION_ID            =  "1.0"
ORIGINAL_PRODUCT_ID           =  "Sar_20090413_230617_20101016_004504.000.cp"
MISSION_PHASE_NAME            =  "NOMINAL MISSION"
PRODUCT_CREATION_TIME         =  2010-11-24T21:14:52
RELEASE_ID                    =  "0001"
MISSION_NAME                  =  "CHANDRAYAAN-1"
INSTRUMENT_HOST_NAME          =  "CHANDRAYAAN-1 ORBITER"
INSTRUMENT_HOST_ID            =  "CH1-ORB"
INSTRUMENT_NAME               =  "MINI-RF FORERUNNER"
INSTRUMENT_ID                 =  MRFFR
TARGET_NAME                   =  MOON
SOURCE_PRODUCT_ID             =  {
"CHAND1_SCLK_20100924_00.TSC","naif0009.tls"}
START_TIME                    =  2009-04-13T23:06:13.375771
STOP_TIME                     =  2009-04-13T23:09:29.6161
SPACECRAFT_CLOCK_START_COUNT  =  "UNK"
SPACECRAFT_CLOCK_STOP_COUNT   =  "UNK"
ORBIT_NUMBER                  =  1895
INCIDENCE_ANGLE               =  40.67889125 <deg>
CENTER_FREQUENCY              =  2384.15 <GHz>
INSTRUMENT_MODE_ID            =  "BASELINE_S"
INSTRUMENT_MODE_DESC          =  "SAR"
SOFTWARE_NAME                 =  "FOCUS"
SOFTWARE_VERSION_ID           =  "10.0.050"
LOOK_DIRECTION                =  RIGHT
DESCRIPTION                   =  "Mini-RF (Mini-SAR) 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. */
CH1:RANGE_COEFFICIENT_SET     =  (  ("2009-04-13T23:06:13.416",
```

```
112940.475313,  5.189554E-01,  3.430374E-06,  -1.397972E-11),
("2009-04-13T23:06:27.927",  112940.510515,  5.205986E-01,  3.422579E-06,
-1.398071E-11),  ("2009-04-13T23:06:37.600",  112940.540012,  5.216693E-01,
3.417736E-06,  -1.398794E-11),  ("2009-04-13T23:06:47.675",  112940.502073,
5.228096E-01,  3.411598E-06,  -1.397324E-11),  ("2009-04-13T23:06:57.346",
112940.509661,  5.238528E-01,  3.406426E-06,  -1.396850E-11),
("2009-04-13T23:07:07.018",  112940.530493,  5.249184E-01,  3.401490E-06,
-1.397394E-11),  ("2009-04-13T23:07:16.688",  112940.515638,  5.259620E-01,
3.396061E-06,  -1.396443E-11),  ("2009-04-13T23:07:26.493",  112941.406237,
5.268416E-01,  3.403488E-06,  -1.424380E-11),  ("2009-04-13T23:07:36.111",
112941.425855,  5.278454E-01,  3.398728E-06,  -1.424635E-11),
("2009-04-13T23:07:45.728",  112941.429874,  5.288780E-01,  3.393651E-06,
-1.424484E-11),  ("2009-04-13T23:07:55.746",  112941.409010,  5.299426E-01,
3.388003E-06,  -1.423340E-11),  ("2009-04-13T23:08:05.361",  112941.459204,
5.309327E-01,  3.383779E-06,  -1.424731E-11),  ("2009-04-13T23:08:14.976",
112941.420464,  5.319135E-01,  3.378225E-06,  -1.422763E-11),
("2009-04-13T23:08:24.992",  112941.485679,  5.329242E-01,  3.374136E-06,
-1.424901E-11),  ("2009-04-13T23:08:34.433",  112942.633385,  5.335485E-01,
3.403149E-06,  -1.534133E-11),  ("2009-04-13T23:08:43.169",  112942.634054,
5.344041E-01,  3.398814E-06,  -1.533505E-11),  ("2009-04-13T23:08:51.904",
112942.634215,  5.352850E-01,  3.394601E-06,  -1.534213E-11),
("2009-04-13T23:09:01.003",  112942.634145,  5.361938E-01,  3.389862E-06,
-1.533376E-11),  ("2009-04-13T23:09:09.736",  112942.634560,  5.370438E-01,
3.385865E-06,  -1.534612E-11),  ("2009-04-13T23:09:22.836",  112942.633683,
5.383322E-01,  3.379343E-06,  -1.534045E-11)  )

/* Data Object Description. */
OBJECT                        =  IMAGE
  NAME                          =  "MINI-RF SAR DATA"
  CENTER_LONGITUDE              =  159.054136 <deg>
  CENTER_LATITUDE               =  -84.580001 <deg>
  MAXIMUM_LATITUDE              =  -79.922956 <deg>
  MINIMUM_LATITUDE              =  -87.22755 <deg>
  WESTERNMOST_LONGITUDE         =  92.136081 <deg>
  EASTERNMOST_LONGITUDE         =  177.78264 <deg>
  LINES                         =  4054
  LINE_SAMPLES                  =  298
  SAMPLE_TYPE                   =  PC_REAL
  SAMPLE_BITS                   =  32
  MINIMUM                       =  0.000000117
  MAXIMUM                       =  3.441950560
  MEAN                          =  0.178949622
  STANDARD_DEVIATION            =  0.005778851
  SCALED_PIXEL_HEIGHT           =  75.000000000000
  SCALED_PIXEL_WIDTH            =  75.000000000000
  CH1:AZIMUTH_RESOLUTION        =  157.799081
  CH1:RANGE_RESOLUTION          =  144.046570
  LINE_EXPOSURE_DURATION        =  0.048406606719
  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                         =  "FSB_01895_1CD_XIU_85S159_V1.TXT"
  RECORD_TYPE                   =  STREAM
  FILE_RECORDS                  =  2877
  OBJECT                        =  TEXT
    PUBLICATION_DATE              =  2010-11-24
    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 FORERUNNER Level-2 SAR CDR Data Product

```
PDS_VERSION_ID                =  PDS3
LABEL_REVISION_NOTE           =  "2010-JHU/APL Mini-RF CH1 Ver. 1"
^IMAGE                        =  "FSB_01895_2CD_OIU_85S159_V1.IMG"
RECORD_TYPE                   =  FIXED_LENGTH
RECORD_BYTES                  =  5232
FILE_RECORDS                  =  4057
DATA_SET_ID                   =  "CH1-ORB-L-MRFFR-5-CDR-MAP-V1.0"
DATA_SET_NAME                 =  "CH1-ORB MOON MINI-RF 5 MAP-PROJ 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                    =  "FSB_01895_2CD_OIU_85S159_V1"
PRODUCT_VERSION_ID            =  "V1.0"
ORIGINAL_PRODUCT_ID           =  "
Sar_20090413_230617_20101016_004504.000.ortho_OC"
PRODUCT_CREATION_TIME         =  2010-11-24T22:06:14
RELEASE_ID                    =  "0001"
MISSION_NAME                  =  "CHANDRAYAAN-1"
INSTRUMENT_HOST_NAME          =  "CHANDRAYAAN-1 ORBITER"
INSTRUMENT_HOST_ID            =  "CH1-ORB"
INSTRUMENT_NAME               =  "MINI-RF FORERUNNER"
INSTRUMENT_ID                 =  MRFFR
TARGET_NAME                   =  MOON
SOURCE_PRODUCT_ID             =  {
"CHAND1_SCLK_20100924_00.TSC","naif0009.tls"}
START_TIME                    =  2009-04-13T23:06:13.375771
STOP_TIME                     =  2009-04-13T23:09:29.7613
SPACECRAFT_CLOCK_START_COUNT  =  "UNK"
```

```
SPACECRAFT_CLOCK_STOP_COUNT    =  "UNK"
ORBIT_NUMBER                   =  1895
CENTER_FREQUENCY               =  2384150000.00000000 <Hz>
INCIDENCE_ANGLE                =  40.67889125 <deg>
INSTRUMENT_MODE_ID             =  "BASELINE_S"
INSTRUMENT_MODE_DESC           =  "SAR"
SOFTWARE_NAME                  =  "Ortho"
SOFTWARE_VERSION_ID            =  "10.0.085"
LOOK_DIRECTION                 =  RIGHT
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                          =  4057
  LINE_SAMPLES                   =  327
  SAMPLE_TYPE                    =  PC_REAL
  SAMPLE_BITS                    =  32
  MINIMUM                        =  0.000000117
  MAXIMUM                        =  3.441950560
  MEAN                           =  0.178975351
  STANDARD_DEVIATION             =  0.005720154
  SCALED_PIXEL_HEIGHT            =  75.0 <m/pixel>
  SCALED_PIXEL_WIDTH             =  75.0 <m/pixel>
  CH1:AZIMUTH_RESOLUTION         =  157.799081
  CH1:RANGE_RESOLUTION           =  144.046570
  LINE_EXPOSURE_DURATION         =  0.048406606719
  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
  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               =  4057
  SAMPLE_LAST_PIXEL             =  327
  LINE_PROJECTION_OFFSET        =  2132.17274252
  SAMPLE_PROJECTION_OFFSET      =  1064.67276324
  MAP_PROJECTION_TYPE           =  "OBLIQUE CYLINDRICAL"
  MAP_PROJECTION_ROTATION       =  90.0 <deg>
  MAP_RESOLUTION                =  404.311333473 <pix/deg>
  MAP_SCALE                     =  0.0750000010231 <km/pix>
  CENTER_LATITUDE               =  0.0 <deg>
  CENTER_LONGITUDE              =  0.0 <deg>
  REFERENCE_LATITUDE            =  -85.7004370691
  REFERENCE_LONGITUDE           =  -24.3291519991
  MAXIMUM_LATITUDE              =  -79.898019 <deg>
  MINIMUM_LATITUDE              =  -87.300138 <deg>
  WESTERNMOST_LONGITUDE         =  91.849345 <deg>
  EASTERNMOST_LONGITUDE         =  177.781403 <deg>
  OBLIQUE_PROJ_POLE_LATITUDE    =  -0.819834 <deg>
  OBLIQUE_PROJ_POLE_LONGITUDE   =  -76.643089 <deg>
  OBLIQUE_PROJ_POLE_ROTATION    =  355.779179 <deg>
  OBLIQUE_PROJ_X_AXIS_VECTOR    =  (0.068313,-0.030886,-0.997186)
  OBLIQUE_PROJ_Y_AXIS_VECTOR    =  (-0.970554,0.229365,-0.073593)
  OBLIQUE_PROJ_Z_AXIS_VECTOR    =  (0.230993,0.972850,-0.014308)
END_OBJECT                    =  IMAGE_MAP_PROJECTION

/* Metadata Associated with the Image. */
OBJECT                        =  PARAMETER_FILE
  ^TEXT                       =  "FSB_01895_2CD_OIU_85S159_V1.TXT"
  RECORD_TYPE                 =  STREAM
  FILE_RECORDS                =  2934

  OBJECT                      =  TEXT
    PUBLICATION_DATE          =  2010-11-24
    NOTE                      =  "A parameter file generated by the SAR
    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 CH1 Ver. 1"
NOTE                          =  "Mini-RF CH1 circular polarization ratio
product."
^IMAGE                        =  "FSB_01895_2CP_OIU_85S159_V1.IMG"
```

```
RECORD_TYPE                    =  FIXED_LENGTH
RECORD_BYTES                   =  1308
FILE_RECORDS                   =  4057
DATA_SET_ID                    =  "CH1-ORB-L-MRFFR-5-CDR-MAP-V1.0"
DATA_SET_NAME                  =  "CH1-ORB MOON MINI-RF 5 MAP-PROJ 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                     =  "FSB_01895_2CP_OIU_85S159_V1"
PRODUCT_VERSION_ID             =  "1.0"
ORIGINAL_PRODUCT_ID            =  "
Sar_20090413_230617_20101016_004504.000.ortho_OC"
MISSION_PHASE_NAME             =  "NOMINAL MISSION"
PRODUCT_CREATION_TIME          =  2010-11-30T20:31:06
RELEASE_ID                     =  "0001"
MISSION_NAME                   =  "CHANDRAYAAN-1"
INSTRUMENT_HOST_NAME           =  "CHANDRAYAAN-1 ORBITER"
INSTRUMENT_HOST_ID             =  "CH1-ORB"
INSTRUMENT_NAME                =  "MINI-RF FORERUNNER"
INSTRUMENT_ID                  =  MRFFR
TARGET_NAME                    =  MOON
SOURCE_PRODUCT_ID              =  {
"CHAND1_SCLK_20100924_00.TSC","naif0009.tls"}
START_TIME                     =  2009-04-13T23:06:13.375771
STOP_TIME                      =  2009-04-13T23:09:29.7613
SPACECRAFT_CLOCK_START_COUNT   =  "UNK"
SPACECRAFT_CLOCK_STOP_COUNT    =  "UNK"
ORBIT_NUMBER                   =  1895
CENTER_FREQUENCY               =  2384150000.00000000 <Hz>
INCIDENCE_ANGLE                =  40.67889125 <deg>
INSTRUMENT_MODE_ID             =  "BASELINE_S"
INSTRUMENT_MODE_DESC           =  "SAR"
SOFTWARE_NAME                  =  "ISIS"
SOFTWARE_VERSION_ID            =  "3.2.0 | 2010-03-18"
LOOK_DIRECTION                 =  RIGHT
DESCRIPTION                    =  "This dimensionless parameter is the ratio
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                       = 4057
LINE_SAMPLES                = 327
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          = "OBLIQUE CYLINDRICAL"
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             = 0.0 <deg>
LINE_FIRST_PIXEL             = 1
LINE_LAST_PIXEL              = 4057
SAMPLE_FIRST_PIXEL           = 1
SAMPLE_LAST_PIXEL            = 327
OBLIQUE_PROJ_POLE_LATITUDE   = -0.819834 <deg>
OBLIQUE_PROJ_POLE_LONGITUDE  = -76.643089 <deg>
OBLIQUE_PROJ_POLE_ROTATION   = 355.779179 <deg>
OBLIQUE_PROJ_X_AXIS_VECTOR   = (0.068313, -0.030886, -0.997186)
OBLIQUE_PROJ_Y_AXIS_VECTOR   = (-0.970554, 0.229365, -0.073593)
OBLIQUE_PROJ_Z_AXIS_VECTOR   = (0.230993, 0.972850, -0.014308)
MAP_PROJECTION_ROTATION      = 90.0 <deg>
MAP_RESOLUTION               = 404.311333473 <pix/deg>
MAP_SCALE                    = 0.0750000010231 <km/pix>
MAXIMUM_LATITUDE             = -79.898019 <deg>
MINIMUM_LATITUDE             = -87.300138 <deg>
EASTERNMOST_LONGITUDE        = 177.781403 <deg>
WESTERNMOST_LONGITUDE        = 91.849345 <deg>
LINE_PROJECTION_OFFSET       = 2132.1727425199 <pixel>
SAMPLE_PROJECTION_OFFSET     = 1064.67276324 <pixel>
END_OBJECT = IMAGE_MAP_PROJECTION
END
```

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 FORERUNNER Level-3 SAR Data Product

An example of a PDS label for the ISIS-generated polar mosaics is provided below.

```
PDS_VERSION_ID               =  PDS3
LABEL_REVISION_NOTE          =  "2011-JHU/APL Mini-RF CH1 Ver. 1"
NOTE                         =  "Circular Polarization Ratio polar mosaic."
^IMAGE                       =  "FSB_XXXXX_3CP_PJU_90N000_V1.IMG"
RECORD_TYPE                  =  FIXED_LENGTH
```

```
RECORD_BYTES                    =  32428
FILE_RECORDS                    =  8107
DATA_SET_ID                     =  "CH1-ORB-L-MRFFR-5-CDR-MOSAIC-V1.0"
DATA_SET_NAME                   =  "CH1-ORB 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                      =  "FSB_XXXXX_3CP_PJU_90N000_V1"
PRODUCT_VERSION_ID              =  "V1.0"
PRODUCT_CREATION_TIME           =  2011-01-12
RELEASE_ID                      =  "0001"
MISSION_NAME                    =  "CHANDRAYAAN-1"
INSTRUMENT_HOST_NAME            =  "CHANDRAYAAN-1 ORBITER"
INSTRUMENT_HOST_ID              =  "CH1-ORB"
INSTRUMENT_NAME                 =  "MINI-RF FORERUNNER"
INSTRUMENT_ID                   =  MRFFR
TARGET_NAME                     =  MOON
START_TIME                      =  2009-01-07T18:33:32.415636
STOP_TIME                       =  2009-04-15T21:25:01.1903
SPACECRAFT_CLOCK_START_COUNT    =  "N/A"
SPACECRAFT_CLOCK_STOP_COUNT     =  "N/A"
CENTER_FREQUENCY                =  2384150000.0 <Hz>
INSTRUMENT_MODE_ID              =  "BASELINE_S"
INSTRUMENT_MODE_DESC            =  "SAR"
SOFTWARE_NAME                   =  "Ortho"
SOFTWARE_VERSION_ID             =  "10.0.085"
DESCRIPTION                     =  "Circular Polarization Ratio product defined
as the ratio of the same sense circular polarization to the opposite sense
circular polarization (CPR = SC / OS). The Level 3 products are Derived Data
Records (DDRs) generated from multiple Level 2 CDRs.  They are mosaics that
are produced by ingesting the Level 2 Stokes 1 parameter and circular
polarization files into the ISIS software.  The mosaics are produced for each
lunar pole (i.e., regions above 80 deg. latitude).  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."

OBJECT = IMAGE
  LINES                       = 8107
  LINE_SAMPLES                = 8107
  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          = "POLAR STEREOGRAPHIC"
  A_AXIS_RADIUS                = 1737.4 <km>
  B_AXIS_RADIUS                = 1737.4 <km>
  C_AXIS_RADIUS                = 1737.4 <km>
  COORDINATE_SYSTEM_NAME       = PLANETOCENTRIC
  POSITIVE_LONGITUDE_DIRECTION = EAST
  KEYWORD_LATITUDE_TYPE        = PLANETOCENTRIC
  CENTER_LATITUDE              = 90.0 <deg>
  CENTER_LONGITUDE             = 0.0 <deg>
  LINE_FIRST_PIXEL             = 1
  LINE_LAST_PIXEL              = 8107
  SAMPLE_FIRST_PIXEL           = 1
  SAMPLE_LAST_PIXEL            = 8107
  MAP_PROJECTION_ROTATION      = 0.0 <deg>
  MAP_RESOLUTION               = 404.31133898866 <pix/deg>
  MAP_SCALE                    = 0.075 <km/pix>
  MAXIMUM_LATITUDE             = 90.0 <deg>
  MINIMUM_LATITUDE             = 80.0 <deg>
  EASTERNMOST_LONGITUDE        = 360.0 <deg>
  WESTERNMOST_LONGITUDE        = 0.0 <deg>
  LINE_PROJECTION_OFFSET       = 4054.5 <pixel>
  SAMPLE_PROJECTION_OFFSET     = 4054.5 <pixel>
END_OBJECT = IMAGE_MAP_PROJECTION
END
```

5. Applicable Software

5.1 Software Distribution And Update Procedures

The Forerunner delivery to the PDS does not include software.

6. Appendices

6.1 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 FORERUNNER Mini-RF level 1 and 2 products are CDRs.
Chandrayaan-1	The ISRO lunar orbiting spacecraft which hosts the Mini-RF instrument.
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.
Lunar Reconnaissance Orbiter (LRO)	Lunar Reconnaissance Orbiter. A NASA lunar orbiting spacecraft which hosts a similar Mini-RF instrument.
Mini-RF	The synthetic aperture radar instrument hosted on-board the Chandrayaan-1 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. Also called "Mini-SAR."
Mini SAR	Another name for the Mini-RF instrument hosted on-board the Chandrayaan-1 spacecraft.
NAIF	Navigation and Ancillary Information Facility. A facility at NASA/JPL that provides and manages the SPICE library and archives SPICE kernels.
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.
Scatterometer	A term that refers to the Mini-RF instrument when it is operating in nadir-pointing mode.
Scatterometry Mode	One of the two operating modes of the Mini-RF instrument for which science data products are produced. Scatterometry data are gathered when the spacecraft position is such that the radar is nadir-pointing.
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.
Vexcel®	Vexcel Corporation is a subsidiary of Microsoft Corp. and provides part of the software that is used in the POC to process the science data products.

6.2 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
dB	Decibels
DDR	Derived Data Record
EDR	Experimental Data Record
GSFC	Goddard Space Flight Center
kHz	Kilohertz
I&T	Integration and Test
IAU	International Astronomical Union
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
JPL	(The NASA) Jet Propulsion 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
M3	Moon Mineralogy Mapper (instrument)
MET	Mission Elapsed Time
N/A	Not Applicable
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	(Mini-RF) Payload Operations Center (at APL)
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