LROC EDR/CDR
DATA PRODUCT
SOFTWARE INTERFACE SPECIFICATION

Version 1.14 (DRAFT)
November 11, 2009

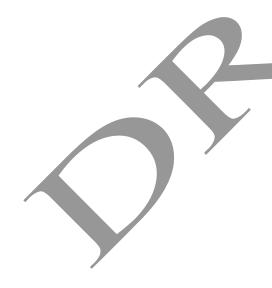ASU SCHOOL OF EARTH & SPACE EXPLORATION

ARIZONA STATE UNIVERSITY

Signature Page

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DOCUMENT CHANGE LOG

Date	Change	Affected Portions
2008/03/17	First draft for PDS review	all
2008/03/28	Incorporated comments/suggestions from Eric Eliason and Stan Scott.	Sections 1.1, 2.2, 2.3.2, 2.3.4, 2.4.2, 3.1
2008/05/20	Incorporated comments/suggestions from SIS review panel	Sections 2.1, 2.3, 2.3.3, 2.3.4, 2.5, 3.2, 3.3, Appendix B
2008/05/26	Incorporated comments/suggestions from Stuart Sides (SIS Review panel)	Minor edits in multiple sections.
2008/12/01	Added keyword for recording temperatures at beginning, middle, and end of a WAC image series.	Sections 3.2.3, 3.2.4 and 3.3
2009/02/24	Updated numbers; major review	all
2009/02/26	Updated numbers; major review	all
2009/05/04	Added missing label keywords and correcting information on keyword description.	Sections 3.2.1, 3.2.2, 3.2.3 and 3.2.4
2009/06/01	Minor edits throughout document, NAC orientation, CDR data storage type, and header updates.	Sections 2.1, 2.2, 3.2., 3.3
2009/06/04	Minor edits throughout document, added keywords to labels	Sections 2.1, 3.2, 3.3, Appendix B
2009/06/08	Minor edit of NAC companding table	Appendix B
2009/06/11	Minor edit correcting maximum WAC file size Minor edit adding partition to sclk value description Minor correcting location of PDS UNITS keyword in labels	Section 2.2 Section 2.4.2 Sections 3.2.1, 3.2.2, 3.2.3, 3.2.4
2009/06/25	Acronym addition, minor edits, quotation fixes	Acronyms & Abbreviations, labels and keyword descriptions
2009/11/11	Updates to reflect new EDR/CDR header keywords and values	Sections 3.2-3.3

TBD/TBR ITEMS

Section	Description	Person

DRAFT

Acronyms and Abbreviations

ASCII	American Standard Code for Information Interchange
ASU	Arizona State University
CDR	Calibrated Data Record
CD-ROM	Compact Disk – Read-Only Memory
CD-WO	Compact Disk – Write Once
CODMAC	Committee on Data Management, Archiving, and Computing
DN	Digital Number
EDR	Experiment Data Record
GSFC	Goddard Space Flight Center
I/F	See Appendix A – Glossary
ISIS	Integrated Software for Imagers and Spectrometers
ISO	International Standards Organization
JPL	Jet Propulsion Laboratory
LDWG	LRO Data Working Group
LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
MD5	Message Digest algorithm 5
ME	Mean Earth
MET	Mission Elapsed Time
Mini-RF	Mini-Radio Frequency Technology Demonstration
MOC	Mission Operations Center
MTF	Modulation Transfer Function
NAC	Narrow Angle Camera
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NSSDC	National Space Science Data Center
PDS	Planetary Data System
PSG	Project Science Group
SDVT	Science Data Validation Team
SIS	Software Interface Specification
SNR	Signal-to-Noise Ratio
SOC	Science Operations Center
SPICE	S – Spacecraft ephemeris, P – Planet, satellite, comet, or asteroid ephemeredes, I – Instrument description kernel, C – C-matrix pointing kernel, E – Events kernel
SSH	Secure Shell
TBD	To Be Determined
TBR	To Be Reviewed
UV	UltraViolet
VIS	Visible
WAC	Wide Angle Camera

1. Introduction

1.1. Purpose and Scope

This Software Interface Specification (SIS) outlines the generation of Lunar Reconnaissance Orbiter Camera (LROC) NAC and WAC EDR (CODMAC Level 2) and CDR (CODMAC Level 3) data products with a detailed description of the products and a description of how the products are generated, including data sources and destinations. The EDR products contain panchromatic NAC image data, monochromatic WAC image data, and seven band WAC image data, while the CDR products contain calibrated panchromatic NAC image data, calibrated monochromatic WAC image data, and seven band calibrated WAC image data.

This SIS is intended to provide enough information to enable users to read and understand the data products.

1.2. Applicable Documents

The following documents are applicable to the development and execution of this document:
1. Lunar Reconnaissance Orbiter Project Data Management and Archive Plan, 431-PLAN-00182. Check with the LRO Project Configuration Management Office to ensure the document is the most current version prior to use.
2. LROC Data Management and Archive Plan, LROC_SOC_PLAN_0001.
3. LROC EDR Archive Volume SIS, LROC_SOC_SPEC_0002.

This SIS is also consistent with the following Planetary Data System documents:
4. *Planetary Data System Archive Preparation Guide*, August 29, 2006, Version 1.1, JPL D-31224.
5. *Planetary Data System Standards Reference*, March 20, 2006, Version 3.7. JPL D-7669, Part 2.
6. *Planetary Data System Data Dictionary Document*, August 28, 2002, JPL D-7116, Rev. E

1.3. Relationships with Other Interfaces

The LROC EDR and CDR Archive Volume SIS describes how the data products specified by this document will be cataloged and made available through the LROC PDS Data Node.

2. Data Product Characteristics and Environment

2.1. Instrument Overview

The LROC consists of two Narrow-Angle Cameras (NACs), a Wide-Angle Camera (WAC), and a common Sequence and Compressor System (SCS).

Each NAC (see Figure 2.1) has a 700 mm focal length Cassegrain (Ritchey-Chretien) telescope that images onto a 5064-pixel CCD line-array providing a cross-track field-of-view (FOV) of 2.85°. The NAC readout noise is better than 101 e⁻ and the data are sampled at 12-bits. These 12-bit pixel values are companded to 8-bit pixels using one of several selectable piecewise linear mappings during readout from the CCD. The NAC internal buffer holds 256 MB of uncompressed data, enough for a full-resolution image 52,224 lines long. NAC specifications are summarized in Table 2.1.

The WAC electronics is a copy of those flown on cameras on Mars Climate Orbiter, Mars Polar Lander, Mars Odyssey, and Mars Reconnaissance Orbiter. The WAC (see Figure 2.2) has two lenses imaging onto the same 1024 x 1024 pixel, electronically shuttered CCD area-array, one imaging in the visible/near infrared (VIS), and the other in the Ultraviolet (UV). *In monochrome mode, 1024 x 14 pixels are read out in one visible band (645 nm). In color mode, only the center 704 x 14 visible pixels and 512 x 16 UV pixels binned to 128 x 4 pixels, are read out for each band.* The VIS optics have a cross-track FOV of 91.7° (monochrome) and 61.4° (color), and the UV optics a 58.96° FOV. From the nominal 50-km orbit, the WAC will provide a nadir ground sample distance of 74.9 m/pixel in the visible, and a swath width of 104.6 km (visible monochrome), 59.6 km (visible color) and 56.8 km (UV color). The seven-band color capability of the WAC is provided by a color filter array (see Figure 2.3) mounted directly over the detector, providing different sections of the CCD with different filters. Consequently the instrument has no moving parts; it acquires data in the seven channels in a "pushframe" mode, with scanning of the WAC FOV provided by motion of the spacecraft and target. Continuous color coverage of the lunar surface is possible by repeated imaging such that each of the narrow framelets of each color band overlap. The WAC has a readout noise less than 66 e⁻ and, pixel values are digitized to 11-bits and are then companded to 8-bit values through a square-root-like lookup table. WAC specifications are summarized in Table 2.2 and the spectral transmissivity of all seven WAC filters are displayed in figure 2.4. The two UV bands (320 and 360 nm) undergo 4x4 pixel on-chip analog summing before digitization to achieve better signal-to-noise ratio. Thus, UV pixels are recorded at reduced 383.5 m/pixel sampling but have improved signal properties. Only the center 704 pixels for the VIS are digitized when all seven bands are being acquired. WAC band passes are arranged first UV then VIS (320, 360, 415, 565, 605, 645, 690), but the order is reversed after LRO performs a 180° yaw maneuver to align the solar panels with the sun.

The two NACs and the WAC interface with the Sequencing and Compressor System (SCS), the third element of the LROC (see Figure 2.5). As the name implies, the SCS commands individual image acquisition by the NACs and WAC from a stored sequence, and losslessly compresses the NAC and WAC data as they are read out and passed to the spacecraft data system. The SCS provides a single command and data interface between the LROC and the LRO spacecraft data system through a spacewire interface.

The NACs are mounted on the spacecraft such that the CCDs are perpendicular to the spacecraft's X-axis. The NAC-L is off-pointed ~2.85° from the NAC-R so that the footprints of the two images overlap ~130 pixels. The NAC-R is also mounted 0.106° forward of the NAC-L. The NACs are mounted such that pixel 0 for the NAC-L is at the –Y (in spacecraft coordinates) end of its CCD and pixel 0 for the NAC-R is at the +Y end of its CCD. This orientation requires that one of the NAC frames from a NAC-L and NAC-R paired observation must be transformed such that both images have the same ground orientation

The mass of both the NACs combined is 16.4 kg, the WAC is 0.9 kg, and the SCS is 1.2 kg, for a total LROC mass of 18.5 kg. The peak and average power consumption for each NAC is 9.3 W and 6.4 W the WAC is 2.7 W and 2.6 W, and the SCS is 4.5 W and 4.0 W, for a total LROC power dissipation of 16.5 W and 13 W, respectively.
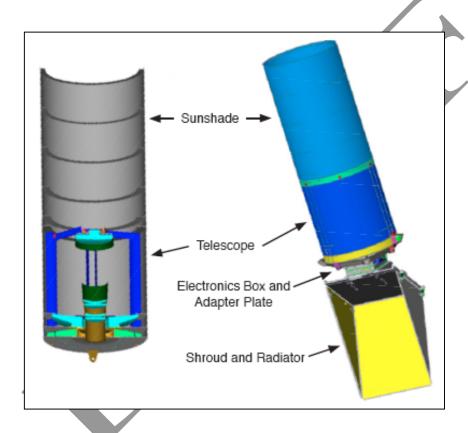

Figure 2.1 - LROC Narrow Angle Camera

	NAC-L	NAC-R
FOV	2.8502°	2.8412°
IFOV	10.0042 μrad	9.9764 μrad
Image scale at 50 km altitude	0.5 m/pixel	
Maximum image size at 50 km altitude	2.49 x 26 km	2.48 x 26.1 km
f/# (Ritchey-Chretien)	3.577	3.590
Effective focal length	699.62 ± 0.08 mm	701.57 ± 0.09 mm
Distortion coefficient	0.0000181 ± 0.0000005	0.0000183 ± 0.0000005
Optical center location	sample 2548 ± 8	sample 2568 ± 8
Primary mirror diameter	198 mm	
MTF (Nyquist)	0.23	
Gain	90.5 ± 2.6 e$^-$/DN	92.5 ± 1.5 e$^-$/DN
Noise	101 ± 7 e$^-$	97 ± 2 e$^-$
Detector Fullwell	334,000 ± 31,000 e$^-$	352,000 ± 4100 e$^-$
SNR (400-750 nm)	> 52	> 49
Detector digitization	12-bit, encoded to 8-bits	
Lossless compression ratio	1.7:1	
Structure + baffle	Graphite-cyanate composite	
Detector	Kodak KLI-5001G	
Pixel format	1 x 5,064*	
Analog/digital converter	Honeywell ADC9225	
FPGA	Actel RT54SX32-S	
Voltage	28 ± 7V DC	
Peak power	9.3 W	
Orbit average power	6.4 W	
Mass (both NACs)	16.4 kg	
Volume (length x diameter)	118 cm x 27 cm (incl. radiator)	

Table 2.1 – NAC Specificationss. * Of the 5064 pixels, 39 masked pixels on the right and 21 masked pixels on the left are used for dark reference.
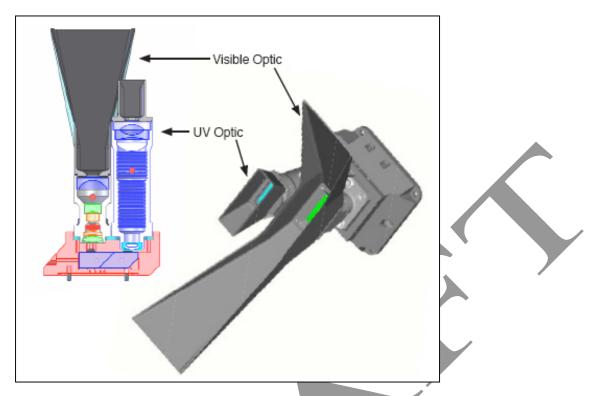
Figure 2.2. - LROC Wide Angle Camera

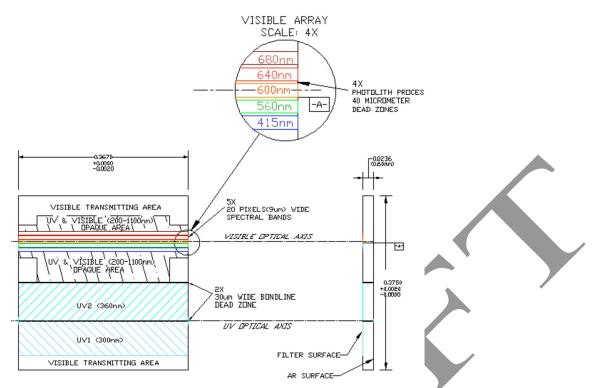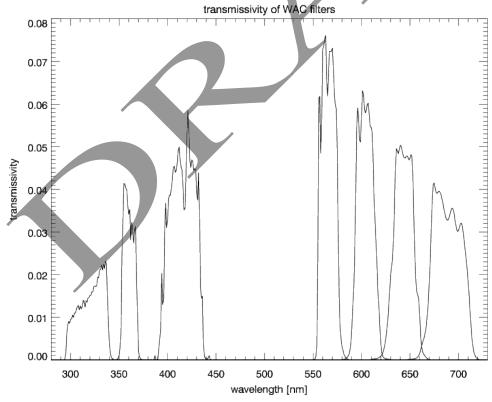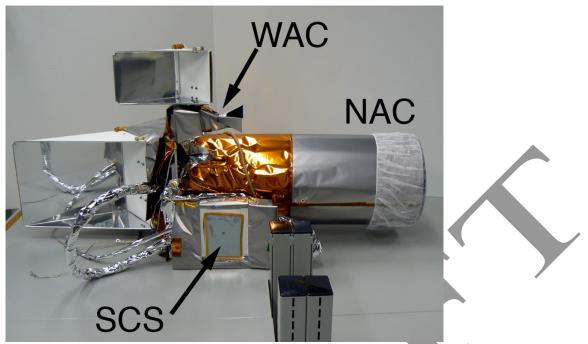|	Visible		UV	
FOV (monochrome / color)	91.7° / 61.4°		58.96°	
IFOV	1.498 mrad		7.67 mrad (4x4 binned)	
Image scale (nadir, 50 km altitude)	74.9 m/pixel		383.5 m/pixel (binned)	
Image frame width monochrome	104.6 km		-	
Image frame width 7-band color	59.6 km		56.8 km	
Image format monochrome	1024 samples x 14 lines		-	
Image format color (each band)	704 samples x 14 lines		128 samples x 4 lines (binned)	
f/#	5.052		5.65	
Effective focal length	6.013 mm		4.693 mm	
Entrance pupil diameter	1.19 mm		0.85 mm	
System MTF (Nyquist)	0.37			
Gain	25.9 ± 0.7 e$^-$/DN			
Noise	66 ± 4 e$^-$			
Detector fullwell	46,100 ± 3600 e$^-$			
Band | λ$_{eff}$ | FWHM	320 nm		321 nm	32.3 nm
	360 nm		360 nm	14.9 nm
	415 nm		415 nm	36.1 nm
	565 nm		566 nm	20.1 nm
	605 nm		604 nm	20.4 nm
	645 nm		643 nm	22.5 nm
	690 nm		689 nm	38.6 nm
SNR (at 1000 DN)	> 150			
Detector digitization	11-bit, encoded to 8-bits			
Lossless compression ratio	1.7:1			
Electronics	4 circuit boards			
Detector	Kodak KLI-1001			
Pixel format	1,024 x 1,024			
Voltage	28±7 V DC			
Peak Power	2.7 W			
Orbit average power	2.6 W			
Mass	0.9 kg			
Volume (width x length x height)	15.8 cm x 23.2 cm x 32.3 cm (incl. radiator)			

Table 2.2 – WAC Specifications

Figure 2.3 - Diagram of LROC Wide Angle Camera filter assembly.

Figure 2.4 - The spectral transmissivity of the 7 WAC filters. The values of the y-axis represent the relative system throughput.

Figure 2.5 - LROC components include the WAC, NAC, and Sequence and Compressor System (SCS).

2.2. Data Product Overview

LROC EDR data products are comprised of the following files:

    a. NAC panchromatic image corresponding to a single observation (either full resolution or summed), with Digital Number (DN) counts in 8-bit format, companded from 12-bit in the instrument. The NAC EDR file size will be a maximum of 256 MB for the full resolution 52,224 lines or summed 104,448 lines. NAC EDR file sizes will be smaller when fewer lines are acquired.

    b. WAC image corresponding to a series of framelets, with DN counts in 8-bit format, companded from 11-bit in the instrument. Each framelet is in row-major order. The WAC EDR file size will not exceed 26.6 MB, which corresponds to observing 18.5º of latitude in multispectral mode. The WAC exposure and/or interframe gap parameters will be modified approximately every 10º of latitude, resulting in an average file size of 14.4 MB. It is important to note that the WAC EDR stores multispectral framelets in single band, not as separate bands within the EDR file.

LROC CDR data products are comprised of the following files:

    a. NAC DNs will be decompanded and images will be radiometrically calibrated to radiance (i.e. star observations) or I/F (i.e. lunar observations). Radiance images will be archived as floating point values (4 bytes per pixel) and I/F images as scaled signed-integer values (2 bytes per pixel). The I/F values will be multiplied by 32767 before being converted to signed-integer. The NAC CDR file size will be approximately 1,000 MB for full resolution 52,224 line or summed 104,448 line radiance images (I/F images will be half as large). NAC CDR file sizes will be smaller when fewer lines are acquired.

b. WAC image corresponding to a series of framelet images, with decompanded DNs, radiometrically calibrated to radiance or I/F. The WAC CDR file size will not exceed a maximum of 256 MB, which corresponds to observing 80º of latitude in multispectral mode. The WAC exposure and/or interframe gap parameters will be modified approximately every 10º of latitude, resulting in an average file size of 28.8 MB. It is important to note that the WAC EDR stores multispectral framelets in single band, not as separate bands in the CDR file. The WAC CDR file will require further processing to separate framelets into their respective bands and to align the bands, in order to be viewed as a standard mutli-band image.

2.3. Data Processing

Post acquisition data processing for WAC and NAC images begins upon delivery of the images to SOC from the MOC. The SOC is designed to handle 440 Gbits per day of data downlink, not including ancillary products generated by the MOC. Owing to the large volume of data, the SOC has been designed with a high degree of automation in all aspects of the data processing.

Data are pushed to the SOC using the SSH protocol, with delivery status being checked using MD5 checksums for each file. Failed transfers will be automatically re-initiated by the MOC. Stored housekeeping (spacecraft and LROC instrument), predict and definitive SPICE kernels, and command load reports are also delivered to the SOC, some of which are used during data processing. Upon receipt by the SOC, all files are handled by automated processing routines being run within the Rector framework, to allow for scalable growth as processing needs grow or recede. At each stage of the automated processing, quality assurance tests are performed, either before processing or after processing occurs, to insure valid products are flowing down-stream through the pipelines. Meta-data for each EDR and CDR file that is processed will be recorded into a PostgreSQL database, which then directs the generation of each archive delivery. Archive deliveries are pushed from our production storage array onto a data node storage array, where the data are accessible (in read-only mode) by the LROC PDS data node (http://lroc.sese.asu.edu).

NAC and WAC data should not experience missing data under nominal downlink conditions, owing to the use of the CCSDS File Delivery Protocol (CFDP). Should downlink conditions be degraded such that PDU data packets are missed/lost, the MOC will identify missing PDU data packets, record the start and end bytes values in the Meta-file, and fill the missing bytes with zero values. This strategy will allow the SOC to reconstruct the majority of observations with missing data.

2.3.1. Data Processing Level

The EDR product contains individual NAC and WAC framelet images, and associated engineering data, corresponding to NASA processing Level 0 (CODMAC Level 2).

The CDR product contains individual NAC and WAC framelet images, and associated engineering data, corresponding to NASA processing Level 1a (CODMAC Level 3).

2.3.2. **Data Product Generation**

The processing pipeline can be run through multiple iterations to account for software updates that affect the output data, updates to SPICE information, or if the calibration of the instruments is updated or modified. In either case it is expected the data will be reprocessed as calibration files are updated.

All LRO data will be transmitted from the LRO Orbiter to the MOC. The MOC and Flight Dynamics Facility will generate LRO SPICE data files for distribution to the SOCs. LROC image files, as delivered from the MOC, are coupled with engineering data and other previously recorded information in the LROC operations database, to create an EDR product. Valid EDR files are then used as input to the process that performs additional processing to generate CDR files.

NAC raw image data (hereafter referred to as science files) consist of 8-bit companded pixels as read out from the camera. The image file is composed first of the even pixels from each line (with a 20 byte CTX heritage header every 1 MB; MB = 1024×1024 bytes) and padded to a 1 MB boundary, followed by the odd pixels in the same style. The EDR file generation process extracts the odd and even pixels, interleaving them to reconstruct original scan lines. If compression was enabled at image acquisition, the data stream is first de-compressed before the interleaving is performed. Information from the meta-file, housekeeping, and the SOC database are combined to generate the PDS label with the binary data to compose the EDR file.

NAC EDR files are calibrated using routines developed in the SOC and archived as Calibrated Data Records (CDR).

WAC science files consist of frames in row-major order with a 4 byte validity marker separating each frame. If compression was enabled at image acquisition, the data stream is first de-compressed before further processing is performed. Information from the meta-file, housekeeping, and the SOC database are combined to generate the PDS label that combined with the binary data to produce the EDR file.

WAC EDR files are calibrated using routines developed in the SOC and archived as CDRs.

2.3.3. **Data Flow**

Each NAC image file is uniquely named to distinguish between the two NACs (see Section 2.3.4). LROC WAC observations are stored as a series of framelets, with each framelet corresponding to one or more of the seven available bands on the detector. LROC observation and housekeeping files are downlinked through the Ka-band antenna at Whites Sands, N.M., then sent to LRO MOC at Goddard Space Flight Center (GSFC). Real-time telemetry is downlinked via S-band antenna at various locations and also transferred to the MOC. Once observation and housekeeping files are processed by the MOC, including identification of any missing data segments, the observation files and housekeeping files are transferred to the LROC SOC at ASU via Secure Shell (SSH) file copy protocol. Real-time telemetry is streamed to the LROC SOC as it is received at the MOC (with no processing).

The MOC also sends to the LROC SOC numerous products generated by the GSFC Flight Dynamics group, including predictive and definitive NAIF SPICE kernels. Once all necessary files are received, observations can be ingested into product generation pipelines to produce EDR and CDR PDS products. The pipeline process includes validation of the EDR and CDR products compliance with PDS label and format standards.

At intervals specified in the LROC Data and Management Archive document [*Applicable Documents* 2], EDR and CDR products will be delivered to the PDS, which is the LROC Data Node (http://lroc.sese.asu.edu) hosted at ASU.

2.3.4. Labeling and Identification

LROC EDR and CDR products are identified by a unique name and each file has a header that records salient information regarding each product. Data product names follow the convention as defined in the LROC EDR Archive Volume SIS [*Applicable Documents* 3].

The product header (as described in section 3.2) contains information regarding the processing and generation of the product. Should products be reprocessed, the version number in the header section will be updated to reflect the new product.

2.4. Standards Used in Generating Data Products

2.4.1. PDS Standards

The LROC EDR data product complies with Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference [*Applicable Documents* 5].

2.4.2. Time Standards

LROC EDR and CDR products comply with Planetary Data Systems standards for time, as well as complying with the LRO project agreement on time stamping of data. This includes UTC and S-clock recorded observation times in EDR and CDR product labels.

The LRO spacecraft clock (SCLK) time stamp consists of three fields: P/SSSSSSSSSS:FFFFF. The P field represents the clock partition, the SSSSSSSSSS field represents the count of on-board seconds and the FFFFF field represents the count of fractions of a second with one fraction being 1/65536 of a second. Converting between SCLK and other time formats is performed using the MOC provided LRO SCLK kernel and NAIF SPICE toolkit.

2.4.3. Data Storage Conventions

All binary files are arranged with fixed-length records, stored in most-significant-byte-first (big-endian) format. In text files each record is terminated with a carriage return (ASCII code 13) followed by a line feed (ASCII code 10).

2.5. Data Validation

All LROC EDR and CDR products will be validated by the LROC SOC Team and the PDS Imaging Node for compliance with PDS archive standards [*Applicable Documents* 5].

3. Detailed Data Product Specifications

3.1. Data Product Structure and Organization

LROC data products are organized according to the directory structure defined in the LROC EDR Archive Volume SIS [*Applicable Documents* 3]. Data product names follow the convention defined in the LROC EDR Archive Volume SIS [*Applicable Documents* 3].

3.2. Data Format Descriptions

Final label content and format will be validated by PDS Engineering and Imaging Nodes. Resulting changes should of course be reflected within all label descriptions.

3.2.1. Example label for LROC NAC EDR product:

```
PDS_VERSION_ID                       = PDS3

/* FILE CHARACTERISTICS */
RECORD_TYPE                          = FIXED_LENGTH
RECORD_BYTES                         = 5064
FILE_RECORDS                         = 52225
LABEL_RECORDS                        = 1
^IMAGE                               = 2

/* DATA IDENTIFICATION */
DATA_SET_ID                          = "LRO-L-LROC-2-EDR-V1.1"
ORIGINAL_PRODUCT_ID                  = nacl000017a9
PRODUCT_ID                           = M102658937LE
MISSION_NAME                         = "LUNAR RECONNAISSANCE ORBITER"
MISSION_PHASE_NAME                   = "COMMISSIONING"
INSTRUMENT_HOST_NAME                 = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID                   = LRO
INSTRUMENT_NAME                      = "LUNAR RECONNAISSANCE ORBITER CAMERA"
INSTRUMENT_ID                        = LROC
LRO:PREROLL_TIME                     = 2009-07-19T16:07:49.362
START_TIME                           = 2009-07-19T16:07:50.004
STOP_TIME                            = 2009-07-19T16:08:22.787
LRO:SPACECRAFT_CLOCK_PREROLL_COUNT   = "1/269712469:21626"
SPACECRAFT_CLOCK_START_COUNT         = "1/269712469:63752"
```

```
SPACECRAFT_CLOCK_STOP_COUNT          = "1/269712502:49514"
ORBIT_NUMBER                         = 302
PRODUCER_ID                          = LRO LROC TEAM
PRODUCT_CREATION_TIME                = 2009-12-05T11:55:45
PRODUCER_INSTITUTION_NAME            = "ARIZONA STATE UNIVERSITY"
PRODUCT_TYPE                         = EDR
PRODUCT_VERSION_ID                   = "v1.1"
UPLOAD_ID                            = "SC_2009200_0200_B_V03.txt"

/* DATA DESCRIPTION */
TARGET_NAME                          = "MOON"
CROSSTRACK_SUMMING                   = 1
RATIONALE_DESC                       = "TARGET OF OPPORTUNITY"
FRAME_ID                             = "LEFT"
DATA_QUALITY_ID                      = "0"
DATA_QUALITY_DESC                    = "The DATA_QUALITY_ID is set to an 8-bit
value th
at encodes the
   following data quality information for the observation. For each bit
   a value of 0 means FALSE and a value of 1 means TRUE. More
   information about the data quality ID can be found in the LROC
   EDR/CDR SIS, section 3.3 'Label and Header Descriptions'.
      Bit 1: Temperature of focal plane array is out of bounds.
      Bit 2: Threshold for saturated pixels is reached.
      Bit 3: Threshold for under-saturated pixels is reached.
      Bit 4: Observation is missing telemetry packets.
      Bit 5: SPICE information is bad or missing.
      Bit 6: Observation or housekeeping information is bad or missing.
      Bit 7: Spare.
      Bit 8: Spare."

/*ENVIRONMENT*/
LRO:TEMPERATURE_SCS                  = 1.99 <degC>
LRO:TEMPERATURE_FPA                  = 17.22 <degC>
LRO:TEMPERATURE_FPGA                 = -13.87 <degC>
LRO:TEMPERATURE_TELESCOPE            = 6.12 <degC>
LRO:TEMPERATURE_SCS_RAW              = 2854
LRO:TEMPERATURE_FPA_RAW              = 2138
LRO:TEMPERATURE_FPGA_RAW             = 3468
LRO:TEMPERATURE_TELESCOPE_RAW        = 2665

/*IMAGING PARAMETERS*/
CROSSTRACK_SUMMING                   = 1
BANDWIDTH                            = 300 <nm>
CENTER_FILTER_WAVELENGTH             = 600 <nm>
LINE_EXPOSURE_DURATION               = 0.627733 <ms>
LRO:LINE_EXPOSURE_CODE               = 34
LRO:DAC_RESET_LEVEL                  = 198
LRO:CHANNEL_A_OFFSET                 = 43
LRO:CHANNEL_B_OFFSET                 = 108
LRO:COMPAND_CODE                     = 0
LRO:LINE_CODE                        = 51
LRO:BTERM                            = (0,8,25,59,128)
LRO:MTERM                            = (0.5,0.25,0.125,0.0625,0.03125)
```

8

```
LRO:XTERM                        = (0,32,136,543,2207)
LRO:COMPRESSION_FLAG             = 1
LRO:MODE                         = 7

/*DATA OBJECT*/
OBJECT                  = IMAGE
    LINES                        = 52224
    LINE_SAMPLES                 = 5064
    SAMPLE_BITS                  = 8
    SAMPLE_TYPE                  = LSB_INTEGER
    UNIT                         = "RAW_INSTRUMENT_COUNT"
    MD5_CHECKSUM                 = "780fb38e328c8df1bd6279645e98134a"
END_OBJECT
END
```

3.2.2. Example label for LROC NAC CDR product:

```
/* FILE CHARACTERISTICS */
RECORD_TYPE                      = FIXED_LENGTH
RECORD_BYTES                     = 5064
FILE_RECORDS                     = 52225
LABEL_RECORDS                    = 1
^IMAGE                           = 2

/* DATA IDENTIFICATION */
DATA_SET_ID                      = "LRO-L-LROC-3-CDR-V1.1"
ORIGINAL_PRODUCT_ID              = nacl000017a9
PRODUCT_ID                       = M102658937LC
MISSION_NAME                     = "LUNAR RECONNAISSANCE ORBITER"
MISSION_PHASE_NAME               = "COMMISSIONING"
INSTRUMENT_HOST_NAME             = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID               = LRO
INSTRUMENT_NAME                  = "LUNAR RECONNAISSANCE ORBITER CAMERA"
INSTRUMENT_ID                    = LROC
LRO:PREROLL_TIME                 = 2009-07-19T16:07:49.362
START_TIME                       = 2009-07-19T16:07:50.004
STOP_TIME                        = 2009-07-19T16:08:22.787
LRO:SPACECRAFT_CLOCK_PREROLL_COUNT = "1/269712469:21626"
SPACECRAFT_CLOCK_START_COUNT     = "1/269712469:63752"
SPACECRAFT_CLOCK_STOP_COUNT      = "1/269712502:49514"
ORBIT_NUMBER                     = 302
PRODUCER_ID                      = LRO LROC TEAM
PRODUCT_CREATION_TIME            = 2009-12-05T11:55:45
PRODUCER_INSTITUTION_NAME        = "ARIZONA STATE UNIVERSITY"
PRODUCT_TYPE                     = CDR
PRODUCT_VERSION_ID               = "v1.1"
UPLOAD_ID                        = "SC_2009200_0200_B_V03.txt"

/* DATA DESCRIPTION */
TARGET_NAME                      = "MOON"
CROSSTRACK_SUMMING               = 1
RATIONALE_DESC                   = "TARGET OF OPPORTUNITY"
```

```
FRAME_ID                              = "LEFT"
DATA_QUALITY_ID                       = "0"
DATA_QUALITY_DESC                     = "The DATA_QUALITY_ID is set to an 8-bit
value th
at encodes the
   following data quality information for the observation. For each bit
   a value of 0 means FALSE and a value of 1 means TRUE. More
   information about the data quality ID can be found in the LROC
   EDR/CDR SIS, section 3.3 'Label and Header Descriptions'.
       Bit 1: Temperature of focal plane array is out of bounds.
       Bit 2: Threshold for saturated pixels is reached.
       Bit 3: Threshold for under-saturated pixels is reached.
       Bit 4: Observation is missing telemetry packets.
       Bit 5: SPICE information is bad or missing.
       Bit 6: Observation or housekeeping information is bad or missing.
       Bit 7: Spare.
       Bit 8: Spare."

/*ENVIRONMENT*/
LRO:TEMPERATURE_SCS                   = 1.99 <degC>
LRO:TEMPERATURE_FPA                   = 17.22 <degC>
LRO:TEMPERATURE_FPGA                  = -13.87 <degC>
LRO:TEMPERATURE_TELESCOPE             = 6.12 <degC>
LRO:TEMPERATURE_SCS_RAW               = 2854
LRO:TEMPERATURE_FPA_RAW               = 2138
LRO:TEMPERATURE_FPGA_RAW              = 3468
LRO:TEMPERATURE_TELESCOPE_RAW         = 2665

/*IMAGING PARAMETERS*/
CROSSTRACK_SUMMING                    = 1
BANDWIDTH                             = 300 <nm>
CENTER_FILTER_WAVELENGTH              = 600 <nm>
LINE_EXPOSURE_DURATION                = 0.627733 <ms>
LRO:LINE_EXPOSURE_CODE                = 34
LRO:DAC_RESET_LEVEL                   = 198
LRO:CHANNEL_A_OFFSET                  = 43
LRO:CHANNEL_B_OFFSET                  = 108
LRO:COMPAND_CODE                      = 0
LRO:LINE_CODE                         = 51
LRO:BTERM                             = (0,8,25,59,128)
LRO:MTERM                             = (0.5,0.25,0.125,0.0625,0.03125)
LRO:XTERM                             = (0,32,136,543,2207)
LRO:COMPRESSION_FLAG                  = 1
LRO:MODE                              = 7

/* DATA OBJECT */
OBJECT                                = IMAGE
  LINES                               = 52224
  LINE_SAMPLES                        = 5064
  SAMPLE_BITS                         = 16
  SAMPLE_TYPE                         = LSB_INTEGER
  SCALING_FACTOR                      = 32767
  UNIT                                = "W / (m**2 micrometer sr)" or "Scaled
I/F"
```

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```
    MD5_CHECKSUM                          = "5ae7138e328c8df1bd6279645e982f44"
END_OBJECT
END
```

3.2.3. Example label for LROC WAC EDR product:

```
PDS_VERSION_ID                = PDS3

/*FILE CHARACTERISTICS*/
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 704
FILE_RECORDS                  = 19276
LABEL_RECORDS                 = 10
^IMAGE                        = 11

/*DATA IDENTIFICATION*/
DATA_SET_ID                   = "LRO-L-LROC-2-EDR-V1.1"
ORIGINAL_PRODUCT_ID           = wac000017b9
PRODUCT_ID                    = M102686980CE
MISSION_NAME                  = "LUNAR RECONNAISSANCE ORBITER"
MISSION_PHASE_NAME            = "COMMISSIONING"
INSTRUMENT_HOST_NAME          = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID            = LRO
INSTRUMENT_NAME               = "LUNAR RECONNAISSANCE ORBITER CAMERA"
INSTRUMENT_ID                 = LROC
START_TIME                    = 2009-07-19T23:55:12.604
STOP_TIME                     = 2009-07-20T00:02:05.557
SPACECRAFT_CLOCK_START_COUNT  = "1/269740512:37355"
SPACECRAFT_CLOCK_STOP_COUNT   = "1/269740925:34283"
ORBIT_NUMBER                  = 306
PRODUCT_CREATION_TIME         = 2009-12-05T12:22:21
PRODUCER_ID                   = LRO_LROC_TEAM
PRODUCER_INSTITUTION_NAME     = "ARIZONA STATE UNIVERSITY"
PRODUCT_TYPE                  = EDR
PRODUCT_VERSION_ID            = "v1.1"
UPLOAD_ID                     = "SC_2009200_0200_B_V03.txt"

/*DATA DESCRIPTION*/
TARGET_NAME                   = "MOON"
RATIONALE_DESC                = "GLOBAL COVERAGE"
DATA_QUALITY_ID               = "0"
DATA_QUALITY_DESC                 = "The DATA_QUALITY_ID is set to an 8-bit
value that e
ncodes the
   following data quality information for the observation. For each bit
   a value of 0 means FALSE and a value of 1 means TRUE. More
   information about the data quality ID can be found in the LROC
   EDR/CDR SIS, section 3.3 'Label and Header Descriptions'.
       Bit 1: Temperature of focal plane array is out of bounds.
       Bit 2: Threshold for saturated pixels is reached.
       Bit 3: Threshold for under-saturated pixels is reached.
       Bit 4: Observation is missing telemetry packets.
```

```
        Bit 5: SPICE information is bad or missing.
        Bit 6: Observation or housekeeping information is bad or missing.
        Bit 7: Spare.
        Bit 8: Spare."


/*ENVIRONMENT*/
LRO:BEGIN_TEMPERATURE_SCS       = 2.11 <degC>
LRO:MIDDLE_TEMPERATURE_SCS      = 2.01 <degC>
LRO:END_TEMPERATURE_SCS         = 2.08 <degC>
LRO:BEGIN_TEMPERATURE_FPA       = -23.43 <degC>
LRO:MIDDLE_TEMPERATURE_FPA      = -23.15 <degC>
LRO:END_TEMPERATURE_FPA         = -22.80 <degC>
LRO:BEGIN_TEMPERATURE_SCS_RAW   = 2850
LRO:MIDDLE_TEMPERATURE_SCS_RAW  = 2853
LRO:END_TEMPERATURE_SCS_RAW     = 2850
LRO:BEGIN_TEMPERATURE_FPA_RAW   = 3727
LRO:MIDDLE_TEMPERATURE_FPA_RAW  = 3719
LRO:END_TEMPERATURE_FPA_RAW     = 3711


/*IMAGING PARAMETERS*/
EXPOSURE_DURATION               = 50.0 <ms>
LRO:EXPOSURE_CODE               = 500
INTERFRAME_DELAY                = 1671.875 <ms>
INSTRUMENT_MODE_ID              = "COLOR"
FILTER_NUMBER                   = ("1", "2", "3", "4", "5", "6", "7")
CENTER_FILTER_WAVELENGTH        = (321 <nm>, 360 <nm>, 415 <nm>, 566 <nm>, 604
<nm>, 643 <nm>, 689 <nm>)
BANDWIDTH                       = (32 <nm>, 15 <nm>, 36 <nm>, 20 <nm>, 20 <nm>,
23 <nm>, 39 <nm>)
LRO:LOOKUP_TABLE_TYPE           = STORED
LRO:LOOKUP_CONVERSION_TABLE                 =     ((0,1),(2,2),(3,3),(-9998,-
9998),(4,4),(5,5),(-9998,-
9998),(6,6),(7,7),(8,8),(9,9),(10,10),(11,11),(12,13),(14,14),(15,15),(16,17)
,(18,18),(19,19),(20,21),(22,23),(24,24),(25,26),(27,28),(29,30),(31,32),(33,
33),(34,36),(37,38),(39,40),(41,42),(43,44),(45,47),(48,49),(50,51),(52,54),(
55,56),(57,59),(60,62),(63,64),(65,67),(68,70),(71,73),(74,76),(77,79),(80,82
),(83,85),(86,88),(89,92),(93,95),(96,98),(99,102),(103,105),(106,109),(110,1
13),(114,116),(117,120),(121,124),(125,128),(129,132),(133,136),(137,140),(14
1,144),(145,148),(149,152),(153,156),(157,161),(162,165),(166,170),(171,174),
(175,179),(180,183),(184,188),(189,193),(194,198),(199,203),(204,208),(209,21
3),(214,218),(219,223),(224,228),(229,233),(234,238),(239,244),(245,249),(250
,255),(256,260),(261,266),(267,271),(272,277),(278,283),(284,289),(290,295),(
296,301),(302,307),(308,313),(314,319),(320,325),(326,331),(332,337),(338,344
),(345,350),(351,357),(358,363),(364,370),(371,376),(377,383),(384,390),(391,
397),(398,404),(405,411),(412,418),(419,425),(426,432),(433,439),(440,446),(4
47,454),(455,461),(462,468),(469,476),(477,483),(484,491),(492,499),(500,506)
,(507,514),(515,522),(523,530),(531,538),(539,546),(547,554),(555,562),(563,5
70),(571,579),(580,587),(588,595),(596,604),(605,612),(613,621),(622,630),(63
1,638),(639,647),(648,656),(657,665),(666,674),(675,683),(684,692),(693,701),
(702,710),(711,719),(720,728),(729,738),(739,747),(748,756),(757,766),(767,77
6),(777,785),(786,795),(796,805),(806,814),(815,824),(825,834),(835,844),(845
,854),(855,864),(865,874),(875,885),(886,895),(896,905),(906,916),(917,926),(
927,937),(938,947),(948,958),(959,969),(970,979),(980,990),(991,1001),(1002,1
012),(1013,1023),(1024,1034),(1035,1045),(1046,1056),(1057,1068),(1069,1079),
```

```
(1080,1090),(1091,1102),(1103,1113),(1114,1125),(1126,1136),(1137,1148),(1149
,1160),(1161,1171),(1172,1183),(1184,1195),(1196,1207),(1208,1219),(1220,1231
),(1232,1243),(1244,1255),(1256,1268),(1269,1280),(1281,1292),(1293,1305),(13
06,1317),(1318,1330),(1331,1342),(1343,1355),(1356,1368),(1369,1380),(1381,13
93),(1394,1406),(1407,1419),(1420,1432),(1433,1445),(1446,1458),(1459,1472),(
1473,1485),(1486,1498),(1499,1512),(1513,1525),(1526,1538),(1539,1552),(1553,
1566),(1567,1579),(1580,1593),(1594,1607),(1608,1621),(1622,1635),(1636,1648)
,(1649,1663),(1664,1677),(1678,1691),(1692,1705),(1706,1719),(1720,1734),(173
5,1748),(1749,1762),(1763,1777),(1778,1791),(1792,1806),(1807,1821),(1822,183
5),(1836,1850),(1851,1865),(1866,1880),(1881,1895),(1896,1910),(1911,1925),(1
926,1940),(1941,1955),(1956,1971),(1972,1986),(1987,2001),(2002,2017),(2018,2
032),(2033,2047))
LRO:COMPRESSION_FLAG          = 0
LRO:MODE                      = 0
LRO:NFRAMES                   = 247
LRO:BAND_CODE                 = 127
LRO:INTERFRAME_GAP_CODE       = 82
LRO:COMPAND_CODE              = 0
LRO:BACKGROUND_OFFSET         = 56

/* DATA OBJECT */
OBJECT                        = IMAGE
LINES                       = 19266
    LINE_SAMPLES              = 704
    SAMPLE_BITS               = 8
    SAMPLE_TYPE               = LSB_INTEGER
    UNIT                      = "RAW_INSTRUMENT_COUNT"
    MD5_CHECKSUM              = "dee3088477b54635963ae2518a4bdf1e"
END_OBJECT
END
```

3.2.4. Example label for LROC WAC CDR product:

```
PDS_VERSION_ID                = PDS3

/* FILE CHARACTERISTICS */
RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 704
FILE_RECORDS                  = 19276
LABEL_RECORDS                 = 10
^IMAGE                        = 11

/*DATA IDENTIFICATION*/
DATA_SET_ID                   = "LRO-L-LROC-3-CDR-V1.1"
ORIGINAL_PRODUCT_ID           = wac000017b9
PRODUCT_ID                    = M102686980CC
MISSION_NAME                  = "LUNAR RECONNAISSANCE ORBITER"
MISSION_PHASE_NAME            = "COMMISSIONING"
INSTRUMENT_HOST_NAME          = "LUNAR RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID            = LRO
INSTRUMENT_NAME               = "LUNAR RECONNAISSANCE ORBITER CAMERA"
INSTRUMENT_ID                 = LROC
```

```
START_TIME                    = 2009-07-19T23:55:12.604
STOP_TIME                     = 2009-07-20T00:02:05.557
SPACECRAFT_CLOCK_START_COUNT  = "1/269740512:37355"
SPACECRAFT_CLOCK_STOP_COUNT   = "1/269740925:34283"
ORBIT_NUMBER                  = 306
PRODUCT_CREATION_TIME         = 2009-12-05T12:22:21
PRODUCER_ID                   = LRO_LROC_TEAM
PRODUCER_INSTITUTION_NAME     = "ARIZONA STATE UNIVERSITY"
PRODUCT_TYPE                  = CDR
PRODUCT_VERSION_ID            = "v1.1"
UPLOAD_ID                     = "SC_2009200_0200_B_V03.txt"

/*DATA DESCRIPTION*/
TARGET_NAME                   = "MOON"
RATIONALE_DESC                = "GLOBAL COVERAGE"
DATA_QUALITY_ID               = "0"
DATA_QUALITY_DESC             = "The DATA_QUALITY_ID is set to an 8-bit value
that encodes the
   following data quality information for the observation. For each bit
   a value of 0 means FALSE and a value of 1 means TRUE. More
   information about the data quality ID can be found in the LROC
   EDR/CDR SIS, section 3.3 'Label and Header Descriptions'.
      Bit 1: Temperature of focal plane array is out of bounds.
      Bit 2: Threshold for saturated pixels is reached.
      Bit 3: Threshold for under-saturated pixels is reached.
      Bit 4: Observation is missing telemetry packets.
      Bit 5: SPICE information is bad or missing.
      Bit 6: Observation or housekeeping information is bad or missing.
      Bit 7: Spare.
      Bit 8: Spare."

/*ENVIRONMENT*/
LRO:BEGIN_TEMPERATURE_SCS      = 2.11 <degC>
LRO:MIDDLE_TEMPERATURE_SCS     = 2.01 <degC>
LRO:END_TEMPERATURE_SCS        = 2.08 <degC>
LRO:BEGIN_TEMPERATURE_FPA      = -23.43 <degC>
LRO:MIDDLE_TEMPERATURE_FPA     = -23.15 <degC>
LRO:END_TEMPERATURE_FPA        = -22.80 <degC>
LRO:BEGIN_TEMPERATURE_SCS_RAW  = 2850
LRO:MIDDLE_TEMPERATURE_SCS_RAW = 2853
LRO:END_TEMPERATURE_SCS_RAW    = 2850
LRO:BEGIN_TEMPERATURE_FPA_RAW  = 3727
LRO:MIDDLE_TEMPERATURE_FPA_RAW = 3719
LRO:END_TEMPERATURE_FPA_RAW    = 3711

/*IMAGING PARAMETERS*/
EXPOSURE_DURATION             = 50.0 <ms>
LRO:EXPOSURE_CODE             = 500
INTERFRAME_DELAY              = 1671.875 <ms>
INSTRUMENT_MODE_ID            = "COLOR"
FILTER_NUMBER                 = ("1", "2", "3", "4", "5", "6", "7")
CENTER_FILTER_WAVELENGTH      = (321 <nm>, 360 <nm>, 415 <nm>, 566 <nm>, 604
<nm>, 643 <nm>, 689 <nm>)
```

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```
BANDWIDTH                       = (32 <nm>, 15 <nm>, 36 <nm>, 20 <nm>, 20 <nm>,
23 <nm>, 39 <nm>)
LRO:LOOKUP_TABLE_TYPE           = STORED
LRO:LOOKUP_CONVERSION_TABLE              =      ((0,1),(2,2),(3,3),(-9998,-
9998),(4,4),(5,5),(-9998,-
9998),(6,6),(7,7),(8,8),(9,9),(10,10),(11,11),(12,13),(14,14),(15,15),(16,17)
,(18,18),(19,19),(20,21),(22,23),(24,24),(25,26),(27,28),(29,30),(31,32),(33,
33),(34,36),(37,38),(39,40),(41,42),(43,44),(45,47),(48,49),(50,51),(52,54),(
55,56),(57,59),(60,62),(63,64),(65,67),(68,70),(71,73),(74,76),(77,79),(80,82
),(83,85),(86,88),(89,92),(93,95),(96,98),(99,102),(103,105),(106,109),(110,1
13),(114,116),(117,120),(121,124),(125,128),(129,132),(133,136),(137,140),(14
1,144),(145,148),(149,152),(153,156),(157,161),(162,165),(166,170),(171,174),
(175,179),(180,183),(184,188),(189,193),(194,198),(199,203),(204,208),(209,21
3),(214,218),(219,223),(224,228),(229,233),(234,238),(239,244),(245,249),(250
,255),(256,260),(261,266),(267,271),(272,277),(278,283),(284,289),(290,295),(
296,301),(302,307),(308,313),(314,319),(320,325),(326,331),(332,337),(338,344
),(345,350),(351,357),(358,363),(364,370),(371,376),(377,383),(384,390),(391,
397),(398,404),(405,411),(412,418),(419,425),(426,432),(433,439),(440,446),(4
47,454),(455,461),(462,468),(469,476),(477,483),(484,491),(492,499),(500,506)
,(507,514),(515,522),(523,530),(531,538),(539,546),(547,554),(555,562),(563,5
70),(571,579),(580,587),(588,595),(596,604),(605,612),(613,621),(622,630),(63
1,638),(639,647),(648,656),(657,665),(666,674),(675,683),(684,692),(693,701),
(702,710),(711,719),(720,728),(729,738),(739,747),(748,756),(757,766),(767,77
6),(777,785),(786,795),(796,805),(806,814),(815,824),(825,834),(835,844),(845
,854),(855,864),(865,874),(875,885),(886,895),(896,905),(906,916),(917,926),(
927,937),(938,947),(948,958),(959,969),(970,979),(980,990),(991,1001),(1002,1
012),(1013,1023),(1024,1034),(1035,1045),(1046,1056),(1057,1068),(1069,1079),
(1080,1090),(1091,1102),(1103,1113),(1114,1125),(1126,1136),(1137,1148),(1149
,1160),(1161,1171),(1172,1183),(1184,1195),(1196,1207),(1208,1219),(1220,1231
),(1232,1243),(1244,1255),(1256,1268),(1269,1280),(1281,1292),(1293,1305),(13
06,1317),(1318,1330),(1331,1342),(1343,1355),(1356,1368),(1369,1380),(1381,13
93),(1394,1406),(1407,1419),(1420,1432),(1433,1445),(1446,1458),(1459,1472),(
1473,1485),(1486,1498),(1499,1512),(1513,1525),(1526,1538),(1539,1552),(1553,
1566),(1567,1579),(1580,1593),(1594,1607),(1608,1621),(1622,1635),(1636,1648)
,(1649,1663),(1664,1677),(1678,1691),(1692,1705),(1706,1719),(1720,1734),(173
5,1748),(1749,1762),(1763,1777),(1778,1791),(1792,1806),(1807,1821),(1822,183
5),(1836,1850),(1851,1865),(1866,1880),(1881,1895),(1896,1910),(1911,1925),(1
926,1940),(1941,1955),(1956,1971),(1972,1986),(1987,2001),(2002,2017),(2018,2
032),(2033,2047))
LRO:COMPRESSION_FLAG            = 0
LRO:MODE                        = 0
LRO:NFRAMES                     = 247
LRO:BAND_CODE                   = 127
LRO:INTERFRAME_GAP_CODE         = 82
LRO:COMPAND_CODE                = 0
LRO:BACKGROUND_OFFSET           = 56

/* DATA OBJECT */
OBJECT                          = IMAGE
  LINES                         = 10452
  LINE_SAMPLES                  = 704
  SAMPLE_BITS                   = 32
  SAMPLE_TYPE                   = PC_REAL
  UNIT                          = "W / (m**2 micrometer sr)" or "Scaled I/F"
```

```
  MD5_CHECKSUM                        = "3c234ada4401c044edde0190c1211fe2"
END_OBJECT

END
```

3.3. Label and Header Descriptions

PDS_VERSION_ID
> The PDS version number for the header format; always PDS3.

RECORD_TYPE
> The record type for this file; always FIXED_LENGTH.

RECORD_BYTES
> The number of bytes per record.

FILE_RECORDS
> The total number of records in this file.

LABEL_RECORDS
> The total number of records used for the header data.

^IMAGE
> A pointer to the starting record of the image object.

DATA_SET_ID
> For EDR products, set to "LRO-L-LROC-2-EDR-V1.1". For CDR products, set to "LRO-L-LROC-3-CDR-V1.1".

ORIGINAL_PRODUCT_ID
> Filename of this image as received from the LRO MOC. For NAC observations, the filename is either *nacl00000000* or *nacr00000000* (NAC-LEFT or NAC-RIGHT respectively). For WAC observations, the filename is *wac00000000*.

PRODUCT_ID
> Unique identifier for this LROC NAC and WAC EDR/CDR product. Example [TARGET][MET][INSTRUMENT][PRODUCT] where [TARGET] is a single character denoting the observation target [(M)oon, (E)arth, (C)alibration or (S)tar, [MET] is a nine digit number reflecting the MET of acquisition (with a single digit for partition), [INSTRUMENT] is a single character denoting the instrument [(R)ight NAC, (L)eft NAC, (M)onochrome WAC, (C)olor WAC, (U)V only WAC, (V)isible only WAC, and [PRODUCT] is a single character denoting an (E)DR product or (C)DR product.

MISSION_NAME
> Always "LUNAR RECONNAISSANCE ORBITER".

MISSION_PHASE_NAME
> Name of the mission phase; "COMMISSIONING", "NOMINAL MISSION" or "EXTENDED MISSION".

INSTRUMENT_HOST_NAME
> Always "LUNAR RECONNAISSANCE ORBITER".

INSTRUMENT_HOST_ID
> Always LRO.

INSTRUMENT_NAME
> Always "LUNAR RECONNAISSANCE ORBITER CAMERA".

INSTRUMENT_ID

Always LROC.

LRO:PREROLL_TIME

The UTC time and date at the start of the image acquisition command, corresponding to the acquisition of 1024 lines at the given exposure prior to the actual image acquisition.

START_TIME

The UTC time and date at the start of the image acquisition.

STOP_TIME

The UTC time and date at the end of the image acquisition.

LRO:SPACECRAFT_CLOCK_PREROLL_COUNT

Set to the sclk string for the start of an observation preroll acquisition.

SPACECRAFT_CLOCK_START_COUNT

Set to the sclk string for the start of an observation.

SPACECRAFT_CLOCK_STOP_COUNT

Set to the sclk string for the stop of an observation.

ORBIT_NUMBER

Set to the LRO orbit revolution on which this image was acquired.

PRODUCT_CREATION_TIME

Set to time and date for the creation of this PDS product file, in the form of CCYY-MM-DDThh:mm:ss.sss.

PRODUCER_ID

Always set to LRO LROC TEAM.

PRODUCER_INSTITUTION_NAME

Always set to "ARIZONA STATE UNIVERSITY".

PRODUCT_TYPE

What kind of PDS product this file represents. Can be either EDR or CDR.

PRODUCT_VERSION_ID

The product version of this file, currently "v1.1".

UPLOAD_ID

The string identifier for the ATS command report which corresponds to the ATS command load used to acquire this image.

TARGET_NAME

Set to the target body: "MOON" for any nominal lunar imaging, "EARTH" for any observations of the Earth, "CAL" for any non-STAR calibration images, and "STAR" for star calibration images.

RATIONALE_DESC

For NAC observations, set to one of the following: the keywords recorded in the REACT ROI, the appropriate NAC campaign, or set to the string "TARGET OF OPPORTUNITY". For WAC observations, set to either the appropriate campaign or "GLOBAL_COVERAGE".

FRAME_ID

For NAC, records if the image was acquired from the "LEFT" or "RIGHT" NAC.

DATA_QUALITY_ID

Set to an 8-bit value that encodes data quality information for the observation.

DATA_QUALITY_DESC

A description of how the DATA_QUALITY_ID value is set.

LRO:TEMPERATURE_SCS

Set to the temperature of the LROC SCS in degrees Celsius, as converted from the raw engineering counts.

LRO:TEMPERATURE_FPA

Set to the temperature of the LROC FPA in degrees Celsius, as converted from the raw engineering counts.

LRO:TEMPERATURE_FPGA

Set to the temperature of the LROC FPGA in degrees Celsius, as converted from the raw engineering counts.

LRO:TEMPERATURE_TELESCOPE

Set to the temperature of the LROC telescope corresponding to NAC-L or NAC-R, as converted from the raw engineering counts.

LRO:TEMPERATURE_SCS_RAW

Set to the raw engineering counts for the LROC SCS.

LRO:TEMPERATURE_FPA_RAW

Set to the raw engineering counts for the LROC (F)ocal (P)lane (A)rray.

LRO:TEMPERATURE_FPGA_RAW

Set to the raw engineering counts for the LROC (F)ield (P)rogrammable (G)ate (A)rray.

LRO:TEMPERATURE_TELESCOPE_RAW

Set to the raw engineering counts for the LROC Telescope corresponding to NAC-L or NAC-R.

LRO:BEGIN_TEMPERATURE_SCS

Set to the temperature of the LROC SCS in degrees Celsius, as converted from the raw engineering counts, at the beginning of a series of WAC frames.

LRO:MIDDLE_TEMPERATURE_SCS

Set to the temperature of the LROC SCS in degrees Celsius, as converted from the raw engineering counts, at the middle of a series of WAC frames.

LRO:END_TEMPERATURE_SCS

Set to the temperature of the LROC SCS in degrees Celsius, as converted from the raw engineering counts, at the end of a series of WAC frames.

LRO:BEGIN_TEMPERATURE_FPA

Set to the temperature of the LROC FPA in degrees Celsius, as converted from the raw engineering counts, at the beginning of a series of WAC frames.

LRO:MIDDLE_TEMPERATURE_FPA

Set to the temperature of the LROC FPA in degrees Celsius, as converted from the raw engineering counts, at the middle of a series of WAC frames.

LRO:END_TEMPERATURE_FPA

Set to the temperature of the LROC FPA in degrees Celsius, as converted from the raw engineering counts, at the end of a series of WAC frames.

LRO:BEGIN_TEMPERATURE_SCS_RAW

Set to the raw engineering counts for the LROC SCS at the beginning of a series of WAC frames.

LRO:MIDDLE_TEMPERATURE_SCS_RAW

Set to the raw engineering counts for the LROC SCS at the middle of a series of WAC frames.

LRO:END_TEMPERATURE_SCS_RAW

Set to the raw engineering counts for the LROC SCS at the end of a series of WAC frames.

LRO:BEGIN_TEMPERATURE_FPA_RAW
Set to the raw engineering counts for the LROC (F)ocal (P)lane (A)rray at the beginning of a series of WAC frames.

LRO:MIDDLE_TEMPERATURE_FPA_RAW
Set to the raw engineering counts for the LROC (F)ocal (P)lane (A)rray at the middle of a series of WAC frames.

LRO:END_TEMPERATURE_FPA_RAW
Set to the raw engineering counts for the LROC (F)ocal (P)lane (A)rray at the end of a series of WAC frames.

CROSSTRACK_SUMMING
Indicates if NAC observation was taken with crosstrack summing (2) or no crosstrack summing (1). Keyword only applies to NAC products.

BANDWIDTH
Set to the bandwidth value, in nanometers, for both NAC and WAC observations. For NACs the value is 300nm, for WAC it can be a combination of the following: 32, 15, 36, 20, 20, 23, 39, dependent on which UV and/or Vis bands were acquired.

CENTER_FILTER_WAVELENGTH
Set to the center filter wavelength, in nanometers, for both NAC and WAC observations. For NACs the value is 600nm. For WAC it can be a combination of the following: 321, 360, 415, 566, 604, 643, 689, dependent on which UV and/or Vis bands were acquired.

LINE_EXPOSURE_DURATION
For NAC products, LINE_EXPOSURE_DURATION can have values between 337.6 and 35,281.6 microseconds, in 128/15 microsecond increments
(LINE_EXPOSURE_DURATION = [LINE_EXPOSURE_CODE * 128/15] + 337.6).

LRO:LINE_EXPOSURE_CODE
Index range from 0 to 4095 each corresponding to one LINE_EXPOSURE_DURATION increment.

LRO:DAC_RESET_LEVEL
Records the commanded DAC reset level for either the NAC LEFT or NAC RIGHT.

LRO:CHANNEL_A_OFFSET
Records the commanded NAC channel A offset for either the NAC LEFT or NAC RIGHT.

LRO:CHANNEL_B_OFFSET
Records the commanded NAC channel B offset for either the NAC LEFT or NAC RIGHT.

LRO:COMPAND CODE
Indicates which stored companding table was used (0-7) (see Appendix B).

LRO:LINE CODE
Records the commanded value for the number of NAC lines to acquire, in 1024 increments (LINES = LINES_CODE * 1024)

LRO:BTERM
NAC companding bterms (see Appendix B)

LRO:MTERM
NAC companding mterm (see Appendix B)

LRO:XTERM
>   NAC companding xterms (see Appendix B)
LRO:COMPRESSION_FLAG:
>   Indicates if lossless compression was commanded (0=no, 1=yes)
LRO:MODE
>   Set to the mode value as commanded for both NAC and WAC observations.
EXPOSURE_DURATION
>   For WAC products, LINE_EXPOSURE_DURATION can have values between 0 and
>   6.5535 seconds, in 100 microsecond incremenets.
LRO:EXPOSURE_CODE
>   Records the commanded exposure code for a WAC observation.
INTERFRAME_DELAY
>   Set to the value of the interframe delay between WAC framelets. Keyword can have
>   values between 25/64 and 280/64 seconds, in 1/64 seconds increments.
INSTRUMENT_MODE_ID
>   Records the commanded WAC mode: BW, COLOR, VIS or UV.
FILTER_NUMBER
>   Records the WAC filter numbers taken during an observation, which corresponds to the
>   INSTRUMENT_MODE_ID: (4) or (5) or (1,2,3,4,5,6,7) or (1,2,3,4,5) or (6,7). Filter (4)
>   is optimal BW band, with filter (5) as an alternate.
LRO:LOOKUP_TABLE_TYPE
>   Always set to STORED.
LRO:LOOKUP_CONVERSION_TABLE
The table defines the onboard translation from 11-bit to 8-bit pixels. There are 2048 pairs of
values in the table. The first pair in the table corresponds to the range of 11-bit pixels that map to
0 DN value of the output 8-bit pixel. Subsequent pairs correspond to incremental output DN
values. Table is included in CDR products for completeness, de-companding has already
occurred during the generation of the CDR. Example:

>   LRO:LOOKUP_CONVERSION_TABLE= ((0,1), (2,3), (4,5),...)

Input pixel values 0-1 were mapped to output DN value 0, 2-3 mapped to DN value 1, 4-5
mapped to DN 2, etc.)
LRO:NFRAMES
>   Records the commanded number of frames for a WAC observation.
LRO:BAND_CODE
>   Records the commanded band code for a WAC observation.
LRO:INTERFRAME_GAP_CODE
>   Records the commanded interframe gap code for a WAC observation.
LINES
>   Set to the number of lines captured by the observation.
LINE_SAMPLES
>   Set to the number of samples in a line.
SAMPLE_BITS
>   Set to 8-bit for NAC or WAC EDR products. Set to 16-bit for NAC CDR products with
>   I/F units. Set to 32-bit for NAC CDR products with RADIANCE units and all WAC
>   CDR products.

SAMPLE_TYPE
Set to LSB_INTEGER for EDR products and NAC CDR products with I/F units. Set to PC_REAL for NAC CDR products with RADIANCE units and any WAC CDR product.

UNIT
Unit of measurement represented by pixel values (digital number or DN). NAC and WAC EDR files have a value of "RAW INSTRUMENT COUNT" for this keyword. NAC CDR files can have a value of Scaled I/F (a 2 byte integer) or radiance (W / (m**2 micrometer sr) (a 4 byte real). WAC CDR files can have a value of I/F or radiance (a 4 byte real).

MD5_CHECKSUM
The calculated MD5 checksum for the data stream, as a 32 character string value.

Appendix A – 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.

Archive Volume, Archive Volume Set – A volume is a unit of media on which data products are stored; for example, one CD-ROM or DVD-ROM. An *archive volume* is a volume containing all or part of an archive; that is, data products plus documentation and ancillary files. When an archive spans multiple volumes, they are called an *archive volume set*. Usually the documentation and some ancillary files are repeated on each volume of the set, so that a single volume can be used alone. The LROC EDR Archive will be stored, distributed, and archived solely on computer disk for the foreseeable future (there will be no formal hard-copy archive such as CD-ROM or DVD-ROM).

Catalog Information – Descriptive information about a data set (e.g. mission description, spacecraft description, instrument description), expressed in Object Description Language (ODL) that is suitable for loading into a PDS catalog.

Companding – A method for mitigating the detrimental effects of a channel with limited dynamic range. The use of companding allows signals with a large dynamic range to be transmitted over facilities that have a smaller dynamic range capability.

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. An example of a data product is a planetary image, a spectrum table, or a time series table.

Data Set – An accumulation of data products. A data set together with supporting documentation and ancillary files is an archive.

I/F – Defined as the spectral radiance divided by the solar spectral irradiance of the Sun at target distance divided by pi. Thus, it is the ratio of the radiance observed from a surface to that of a perfect white Lambertian surface illuminated by the same light source but at normal incidence.

MD5 – The Message Digest algorithm 5 is widely used cryptographic hash function with a 128-bit hash value, commonly used to check the integrity of files. An MD5 hash is typically expressed as a 32-character string of hexadecimal numbers.

Standard Data Product – A data product generated in a predefined way using well-understood procedures, processed in "pipeline" fashion. Data products that are generated in a nonstandard way are sometimes called *special data products*.

A

Appendix B – NAC and WAC Companding Schemes

NAC images are companded using a piecewise linear transfer function with up to five segments. The LROC instrument can store up to eight NAC transfer functions, currently six functions are defined. The six transfer functions implemented in NAC hardware can be expressed in pseudo code.

Pseudo code
The companding logic operates as follows:

```
if pixin < xterm0 then pix <= pixin(7 downto 0)
elsif pixin < xterm1 then pix <= pixin/2+bterm_0
elsif pixin < xterm2 then pix <= pixin/4+bterm_1
elsif pixin < xterm3 then pix <= pixin/8+bterm_2
elsif pixin < xterm4 then pix <= pixin/16+bterm_3
else pix <= pixin/32+bterm_4
end if
```

The code parameters are:
- "bterm" (i.e. the y-intercept of the linear function):
  bterm = [[0, 8, 25, 59, 128], [0, 0, 0, 0, 0], [0, 0, 0, 0, 0], [0, 16, 69, 103, 128], [0, 0, 0, 65, 128], [0, 0, 14, 65, 128]]
- "xterm" (i.e. the inflection point on the x-axis (12-bit axis)):
  xterm = [[0, 32, 136, 543, 2207], [511, 0, 0, 0, 0], [0, 0, 0, 0, 4095], [0, 64, 424, 536, 800], [0, 0, 0, 1040, 2000], [0, 0, 112, 816, 2000]]
- "pixin" is input 12-bit DN
- The first line of the code makes sure that only the 8 least significant bits are processed ("7 downto 0" refers to the bit number of a 12-bit byte), i.e. a 12-bit value of 256 DN rolls over to a value of 0 DN.

The companding scheme can also be described as linear functions with corresponding segments defined by 12-bit DN ranges.

Code 0: NAC nominal table (square-root-like)

	linear function	12-bit DN range (y)	8-bit DN range (x)
segment 1	$y = \frac{1}{2} \cdot x + 0$	0 – 31	0 – 15
segment 2	$y = \frac{1}{4} \cdot x + 8$	32 – 135	16 – 41
segment 3	$y = 1/8 \cdot x + 25$	136 – 542	42 – 92
segment 4	$y = 1/16 \cdot x + 59$	543 – 2206	92 – 196
segment 5	$y = 1/32 \cdot x + 128$	2207 – 4095	196 – 255

Code 1: NAC lin1 (0 DN to 255 DN mapped one-to-one)

	linear function	12-bit DN range (y)	8-bit DN range (x)
segment 1	$y = x$	0 – 255	0 – 255
segment 2	$y = x – 256$	256 – 510	0 – 254
segment 3	$y = 1/32 \cdot x$	511 – 4095	15 – 127

B

Code 2: NAC lin16 (12 bit to 8 bit linear)

	linear function	12-bit DN range (y)	8-bit DN range (x)
segment 1	$y = 1/16 \cdot x$	0 – 4094	0 – 255
segment 2	$y = 1/32 \cdot x$	4095 – 4095	127 – 127

Code 3: NAC low signal table (optimized for DN < 500)

	linear function	12-bit DN range (y)	8-bit DN range (x)
segment 1	$y = \frac{1}{2} \cdot x + 0$	0 – 63	0 – 31
segment 2	$y = \frac{1}{4} \cdot x + 16$	64 – 423	32 – 121
segment 3	$y = 1/8 \cdot x + 69$	424 – 535	122 – 135
segment 4	$y = 1/16 \cdot x + 103$	536 – 799	136 – 152
segment 5	$y = 1/32 \cdot x + 128$	800 – 4095	153 – 255

Code 4: NAC high signal table (optimized for 500 < DN < 2000)

	linear function	12-bit DN range (y)	8-bit DN range (x)
segment 1	$y = 1/8 \cdot x + 0$	0 – 1039	0 – 129
segment 2	$y = 1/16 \cdot x + 65$	1040 – 1999	130 – 189
segment 3	$y = 1/32 \cdot x + 128$	2000 – 4095	190 – 255

Code 5: NAC cap Nq/Ne table (minimize quantization noise for low DN)

	linear function	12-bit DN range (y)	8-bit DN range (x)
segment 1	$y = \frac{1}{4} \cdot x + 0$	0 – 111	0 – 27
segment 2	$y = 1/8 \cdot x + 14$	112 – 815	28 – 115
segment 3	$y = 1/16 \cdot x + 65$	816 – 1999	116 – 189
segment 4	$y = 1/32 \cdot x + 128$	2000 – 4095	190 – 255

Simply inverting the companding equations allows the 8-bit value to be decompanded back to the original 12-bit DN. However there is an ambiguity when inverting, the 8-bit value could have been any of a number of 12-bit values within the particular bin. The inverted equation returns the lowest 12-bit DN within the bin. An alternate method is to use a lookup table and for a particular implementation the analyst can choose the lowest, middle, or highest value within a bin (or any value that meets the particular requirements).

Example 12-bit bins for companding Scheme 0 (square root).
The first 12-bit bin (0, 1) maps to the 8-bit value 0, the second 12-bit bin (2, 3) maps to the 8-bit value 1, the third 12-bit (4, 5) bin maps to the 8-bit value 2 so on and so forth until the 256th 12-bit bin (4064, 4095) which maps to 255.

(0, 1), (2, 3), (4, 5), (6, 7), (8, 9), (10, 11), (12, 13), (14, 15), (16, 17), (18, 19), (20, 21), (22, 23), (24, 25), (26, 27), (28, 29), (30, 31), (32, 35), (36, 39), (40, 43), (44, 47), (48, 51), (52, 55), (56, 59), (60, 63), (64, 67), (68, 71), (72, 75), (76, 79), (80, 83), (84, 87), (88, 91), (92, 95), (96, 99), (100, 103), (104, 107), (108, 111), (112, 115), (116, 119), (120, 123), (124, 127), (128, 131), (132, 135), (136, 143), (144, 151), (152, 159), (160, 167), (168, 175), (176, 183), (184, 191), (192, 199), (200, 207), (208, 215), (216, 223), (224, 231), (232, 239), (240, 247), (248, 255), (256, 263), (264, 271), (272, 279), (280, 287), (288, 295), (296, 303), (304, 311), (312, 319), (320, 327), (328, 335), (336, 343), (344, 351), (352, 359), (360, 367), (368, 375), (376, 383), (384, 391), (392, 399), (400, 407), (408, 415), (416,

423), (424, 431), (432, 439), (440, 447), (448, 455), (456, 463), (464, 471), (472, 479), (480, 487), (488, 495), (496, 503), (504, 511), (512, 519), (520, 527), (528, 535), (536, 543), (544, 559), (560, 575), (576, 591), (592, 607), (608, 623), (624, 639), (640, 655), (656, 671), (672, 687), (688, 703), (704, 719), (720, 735), (736, 751), (752, 767), (768, 783), (784, 799), (800, 815), (816, 831), (832, 847), (848, 863), (864, 879), (880, 895), (896, 911), (912, 927), (928, 943), (944, 959), (960, 975), (976, 991), (992, 1007), (1008, 1023), (1024, 1039), (1040, 1055), (1056, 1071), (1072, 1087), (1088, 1103), (1104, 1119), (1120, 1135), (1136, 1151), (1152, 1167), (1168, 1183), (1184, 1199), (1200, 1215), (1216, 1231), (1232, 1247), (1248, 1263), (1264, 1279), (1280, 1295), (1296, 1311), (1312, 1327), (1328, 1343), (1344, 1359), (1360, 1375), (1376, 1391), (1392, 1407), (1408, 1423), (1424, 1439), (1440, 1455), (1456, 1471), (1472, 1487), (1488, 1503), (1504, 1519), (1520, 1535), (1536, 1551), (1552, 1567), (1568, 1583), (1584, 1599), (1600, 1615), (1616, 1631), (1632, 1647), (1648, 1663), (1664, 1679), (1680, 1695), (1696, 1711), (1712, 1727), (1728, 1743), (1744, 1759), (1760, 1775), (1776, 1791), (1792, 1807), (1808, 1823), (1824, 1839), (1840, 1855), (1856, 1871), (1872, 1887), (1888, 1903), (1904, 1919), (1920, 1935), (1936, 1951), (1952, 1967), (1968, 1983), (1984, 1999), (2000, 2015), (2016, 2031), (2032, 2047), (2048, 2063), (2064, 2079), (2080, 2095), (2096, 2111), (2112, 2127), (2128, 2143), (2144, 2159), (2160, 2175), (2176, 2191), (2192, 2207), (2208, 2239), (2240, 2271), (2272, 2303), (2304, 2335), (2336, 2367), (2368, 2399), (2400, 2431), (2432, 2463), (2464, 2495), (2496, 2527), (2528, 2559), (2560, 2591), (2592, 2623), (2624, 2655), (2656, 2687), (2688, 2719), (2720, 2751), (2752, 2783), (2784, 2815), (2816, 2847), (2848, 2879), (2880, 2911), (2912, 2943), (2944, 2975), (2976, 3007), (3008, 3039), (3040, 3071), (3072, 3103), (3104, 3135), (3136, 3167), (3168, 3199), (3200, 3231), (3232, 3263), (3264, 3295), (3296, 3327), (3328, 3359), (3360, 3391), (3392, 3423), (3424, 3455), (3456, 3487), (3488, 3519), (3520, 3551), (3552, 3583), (3584, 3615), (3616, 3647), (3648, 3679), (3680, 3711), (3712, 3743), (3744, 3775), (3776, 3807), (3808, 3839), (3840, 3871), (3872, 3903), (3904, 3935), (3936, 3967), (3968, 3999), (4000, 4031), (4032, 4063), (4064, 4095)

WAC data are companded with a square root scheme similar to NAC scheme 0. WAC companding is implemented through a lookup table reproduced here.

WAC square-root companding table: 11-bit to 8-bit

0	0	25	22	50	34	75	43	100	51	125	58
1	0	26	22	51	34	76	43	101	51	126	58
2	1	27	23	52	35	77	44	102	51	127	58
3	2	28	23	53	35	78	44	103	52	128	58
4	4	29	24	54	35	79	44	104	52	129	59
5	5	30	24	55	36	80	45	105	52	130	59
6	7	31	25	56	36	81	45	106	53	131	59
7	8	32	25	57	37	82	45	107	53	132	59
8	9	33	26	58	37	83	46	108	53	133	60
9	10	34	27	59	37	84	46	109	53	134	60
10	11	35	27	60	38	85	46	110	54	135	60
11	12	36	27	61	38	86	47	111	54	136	60
12	13	37	28	62	38	87	47	112	54	137	61
13	13	38	28	63	39	88	47	113	54	138	61
14	14	39	29	64	39	89	48	114	55	139	61
15	15	40	29	65	40	90	48	115	55	140	61
16	16	41	30	66	40	91	48	116	55	141	62
17	16	42	30	67	40	92	48	117	56	142	62
18	17	43	31	68	41	93	49	118	56	143	62
19	18	44	31	69	41	94	49	119	56	144	62
20	19	45	32	70	41	95	49	120	56	145	63
21	19	46	32	71	42	96	50	121	57	146	63
22	20	47	32	72	42	97	50	122	57	147	63
23	20	48	33	73	42	98	50	123	57	148	63
24	21	49	33	74	43	99	51	124	57	149	64

150	64	204	76	258	86	312	95	366	104	420	112
151	64	205	76	259	86	313	95	367	104	421	112
152	64	206	76	260	86	314	96	368	104	422	112
153	65	207	76	261	87	315	96	369	104	423	112
154	65	208	76	262	87	316	96	370	104	424	112
155	65	209	77	263	87	317	96	371	105	425	112
156	65	210	77	264	87	318	96	372	105	426	113
157	66	211	77	265	87	319	96	373	105	427	113
158	66	212	77	266	87	320	97	374	105	428	113
159	66	213	77	267	88	321	97	375	105	429	113
160	66	214	78	268	88	322	97	376	105	430	113
161	66	215	78	269	88	323	97	377	106	431	113
162	67	216	78	270	88	324	97	378	106	432	113
163	67	217	78	271	88	325	97	379	106	433	114
164	67	218	78	272	89	326	98	380	106	434	114
165	67	219	79	273	89	327	98	381	106	435	114
166	68	220	79	274	89	328	98	382	106	436	114
167	68	221	79	275	89	329	98	383	106	437	114
168	68	222	79	276	89	330	98	384	107	438	114
169	68	223	79	277	89	331	98	385	107	439	114
170	68	224	80	278	90	332	99	386	107	440	115
171	69	225	80	279	90	333	99	387	107	441	115
172	69	226	80	280	90	334	99	388	107	442	115
173	69	227	80	281	90	335	99	389	107	443	115
174	69	228	80	282	90	336	99	390	107	444	115
175	70	229	81	283	90	337	99	391	108	445	115
176	70	230	81	284	91	338	100	392	108	446	115
177	70	231	81	285	91	339	100	393	108	447	116
178	70	232	81	286	91	340	100	394	108	448	116
179	70	233	81	287	91	341	100	395	108	449	116
180	71	234	82	288	91	342	100	396	108	450	116
181	71	235	82	289	91	343	100	397	108	451	116
182	71	236	82	290	92	344	100	398	109	452	116
183	71	237	82	291	92	345	101	399	109	453	116
184	72	238	82	292	92	346	101	400	109	454	116
185	72	239	83	293	92	347	101	401	109	455	117
186	72	240	83	294	92	348	101	402	109	456	117
187	72	241	83	295	92	349	101	403	109	457	117
188	72	242	83	296	93	350	101	404	109	458	117
189	73	243	83	297	93	351	102	405	110	459	117
190	73	244	83	298	93	352	102	406	110	460	117
191	73	245	84	299	93	353	102	407	110	461	117
192	73	246	84	300	93	354	102	408	110	462	118
193	73	247	84	301	93	355	102	409	110	463	118
194	74	248	84	302	94	356	102	410	110	464	118
195	74	249	84	303	94	357	102	411	110	465	118
196	74	250	85	304	94	358	103	412	111	466	118
197	74	251	85	305	94	359	103	413	111	467	118
198	74	252	85	306	94	360	103	414	111	468	118
199	75	253	85	307	94	361	103	415	111	469	119
200	75	254	85	308	95	362	103	416	111	470	119
201	75	255	85	309	95	363	103	417	111	471	119
202	75	256	86	310	95	364	104	418	111	472	119
203	75	257	86	311	95	365	104	419	112	473	119

B

474	119	528	126	582	133	636	139	690	145	744	151
475	119	529	126	583	133	637	139	691	145	745	151
476	119	530	126	584	133	638	139	692	145	746	151
477	120	531	127	585	133	639	140	693	146	747	151
478	120	532	127	586	133	640	140	694	146	748	152
479	120	533	127	587	133	641	140	695	146	749	152
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481	120	535	127	589	134	643	140	697	146	751	152
482	120	536	127	590	134	644	140	698	146	752	152
483	120	537	127	591	134	645	140	699	146	753	152
484	121	538	127	592	134	646	140	700	146	754	152
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487	121	541	128	595	134	649	141	703	147	757	153
488	121	542	128	596	135	650	141	704	147	758	153
489	121	543	128	597	135	651	141	705	147	759	153
490	121	544	128	598	135	652	141	706	147	760	153
491	121	545	128	599	135	653	141	707	147	761	153
492	122	546	128	600	135	654	141	708	147	762	153
493	122	547	129	601	135	655	141	709	147	763	153
494	122	548	129	602	135	656	141	710	147	764	153
495	122	549	129	603	135	657	142	711	148	765	153
496	122	550	129	604	135	658	142	712	148	766	153
497	122	551	129	605	136	659	142	713	148	767	154
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500	123	554	129	608	136	662	142	716	148	770	154
501	123	555	130	609	136	663	142	717	148	771	154
502	123	556	130	610	136	664	142	718	148	772	154
503	123	557	130	611	136	665	142	719	148	773	154
504	123	558	130	612	136	666	143	720	149	774	154
505	123	559	130	613	137	667	143	721	149	775	154
506	123	560	130	614	137	668	143	722	149	776	154
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508	124	562	130	616	137	670	143	724	149	778	155
509	124	563	131	617	137	671	143	725	149	779	155
510	124	564	131	618	137	672	143	726	149	780	155
511	124	565	131	619	137	673	143	727	149	781	155
512	124	566	131	620	137	674	143	728	149	782	155
513	124	567	131	621	137	675	144	729	150	783	155
514	124	568	131	622	138	676	144	730	150	784	155
515	125	569	131	623	138	677	144	731	150	785	155
516	125	570	131	624	138	678	144	732	150	786	156
517	125	571	132	625	138	679	144	733	150	787	156
518	125	572	132	626	138	680	144	734	150	788	156
519	125	573	132	627	138	681	144	735	150	789	156
520	125	574	132	628	138	682	144	736	150	790	156
521	125	575	132	629	138	683	144	737	150	791	156
522	125	576	132	630	138	684	145	738	150	792	156
523	126	577	132	631	139	685	145	739	151	793	156
524	126	578	132	632	139	686	145	740	151	794	156
525	126	579	132	633	139	687	145	741	151	795	156
526	126	580	133	634	139	688	145	742	151	796	157
527	126	581	133	635	139	689	145	743	151	797	157

C

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801	157	855	163	909	168	963	173	1017	178	1071	183
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803	157	857	163	911	168	965	173	1019	178	1073	183
804	157	858	163	912	168	966	173	1020	178	1074	183
805	157	859	163	913	168	967	173	1021	178	1075	183
806	158	860	163	914	168	968	173	1022	178	1076	183
807	158	861	163	915	168	969	173	1023	178	1077	183
808	158	862	163	916	168	970	174	1024	179	1078	183
809	158	863	163	917	169	971	174	1025	179	1079	183
810	158	864	163	918	169	972	174	1026	179	1080	184
811	158	865	164	919	169	973	174	1027	179	1081	184
812	158	866	164	920	169	974	174	1028	179	1082	184
813	158	867	164	921	169	975	174	1029	179	1083	184
814	158	868	164	922	169	976	174	1030	179	1084	184
815	159	869	164	923	169	977	174	1031	179	1085	184
816	159	870	164	924	169	978	174	1032	179	1086	184
817	159	871	164	925	169	979	174	1033	179	1087	184
818	159	872	164	926	169	980	175	1034	179	1088	184
819	159	873	164	927	170	981	175	1035	180	1089	184
820	159	874	164	928	170	982	175	1036	180	1090	184
821	159	875	165	929	170	983	175	1037	180	1091	185
822	159	876	165	930	170	984	175	1038	180	1092	185
823	159	877	165	931	170	985	175	1039	180	1093	185
824	159	878	165	932	170	986	175	1040	180	1094	185
825	160	879	165	933	170	987	175	1041	180	1095	185
826	160	880	165	934	170	988	175	1042	180	1096	185
827	160	881	165	935	170	989	175	1043	180	1097	185
828	160	882	165	936	170	990	175	1044	180	1098	185
829	160	883	165	937	170	991	176	1045	180	1099	185
830	160	884	165	938	171	992	176	1046	181	1100	185
831	160	885	165	939	171	993	176	1047	181	1101	185
832	160	886	166	940	171	994	176	1048	181	1102	185
833	160	887	166	941	171	995	176	1049	181	1103	186
834	160	888	166	942	171	996	176	1050	181	1104	186
835	161	889	166	943	171	997	176	1051	181	1105	186
836	161	890	166	944	171	998	176	1052	181	1106	186
837	161	891	166	945	171	999	176	1053	181	1107	186
838	161	892	166	946	171	1000	176	1054	181	1108	186
839	161	893	166	947	171	1001	176	1055	181	1109	186
840	161	894	166	948	172	1002	177	1056	181	1110	186
841	161	895	166	949	172	1003	177	1057	182	1111	186
842	161	896	167	950	172	1004	177	1058	182	1112	186
843	161	897	167	951	172	1005	177	1059	182	1113	186
844	161	898	167	952	172	1006	177	1060	182	1114	187
845	162	899	167	953	172	1007	177	1061	182	1115	187
846	162	900	167	954	172	1008	177	1062	182	1116	187
847	162	901	167	955	172	1009	177	1063	182	1117	187
848	162	902	167	956	172	1010	177	1064	182	1118	187
849	162	903	167	957	172	1011	177	1065	182	1119	187
850	162	904	167	958	172	1012	177	1066	182	1120	187
851	162	905	167	959	173	1013	178	1067	182	1121	187

D

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1123	187	1177	192	1231	196	1285	201	1339	205	1393	209
1124	187	1178	192	1232	197	1286	201	1340	205	1394	210
1125	187	1179	192	1233	197	1287	201	1341	205	1395	210
1126	188	1180	192	1234	197	1288	201	1342	205	1396	210
1127	188	1181	192	1235	197	1289	201	1343	206	1397	210
1128	188	1182	192	1236	197	1290	201	1344	206	1398	210
1129	188	1183	192	1237	197	1291	201	1345	206	1399	210
1130	188	1184	193	1238	197	1292	201	1346	206	1400	210
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1138	189	1192	193	1246	198	1300	202	1354	206	1408	211
1139	189	1193	193	1247	198	1301	202	1355	206	1409	211
1140	189	1194	193	1248	198	1302	202	1356	207	1410	211
1141	189	1195	193	1249	198	1303	202	1357	207	1411	211
1142	189	1196	194	1250	198	1304	202	1358	207	1412	211
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1144	189	1198	194	1252	198	1306	203	1360	207	1414	211
1145	189	1199	194	1253	198	1307	203	1361	207	1415	211
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1151	190	1205	194	1259	199	1313	203	1367	207	1421	212
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1153	190	1207	194	1261	199	1315	203	1369	208	1423	212
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1157	190	1211	195	1265	199	1319	204	1373	208	1427	212
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1159	190	1213	195	1267	199	1321	204	1375	208	1429	212
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1166	191	1220	196	1274	200	1328	204	1382	209	1436	213
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1171	191	1225	196	1279	200	1333	205	1387	209	1441	213
1172	192	1226	196	1280	200	1334	205	1388	209	1442	213
1173	192	1227	196	1281	201	1335	205	1389	209	1443	213
1174	192	1228	196	1282	201	1336	205	1390	209	1444	213
1175	192	1229	196	1283	201	1337	205	1391	209	1445	213

E

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1447 214	1501 218	1555 222	1609 226	1663 229	1717 233
1448 214	1502 218	1556 222	1610 226	1664 230	1718 233
1449 214	1503 218	1557 222	1611 226	1665 230	1719 233
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1468 215	1522 219	1576 223	1630 227	1684 231	1738 235
1469 215	1523 219	1577 223	1631 227	1685 231	1739 235
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1477 216	1531 220	1585 224	1639 228	1693 232	1747 235
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1484 216	1538 220	1592 224	1646 228	1700 232	1754 236
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1486 217	1540 221	1594 225	1648 228	1702 232	1756 236
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1491 217	1545 221	1599 225	1653 229	1707 233	1761 236
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1495 217	1549 221	1603 225	1657 229	1711 233	1765 237
1496 217	1550 221	1604 225	1658 229	1712 233	1766 237
1497 217	1551 221	1605 225	1659 229	1713 233	1767 237
1498 217	1552 221	1606 225	1660 229	1714 233	1768 237
1499 218	1553 222	1607 225	1661 229	1715 233	1769 237

F

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1771 237	1825 241	1879 244	1933 248	1987 252	2041 255
1772 237	1826 241	1880 244	1934 248	1988 252	2042 255
1773 237	1827 241	1881 245	1935 248	1989 252	2043 255
1774 237	1828 241	1882 245	1936 248	1990 252	2044 255
1775 237	1829 241	1883 245	1937 248	1991 252	2045 255
1776 237	1830 241	1884 245	1938 248	1992 252	2046 255
1777 237	1831 241	1885 245	1939 248	1993 252	2047 255
1778 238	1832 241	1886 245	1940 248	1994 252	
1779 238	1833 241	1887 245	1941 249	1995 252	
1780 238	1834 241	1888 245	1942 249	1996 252	
1781 238	1835 241	1889 245	1943 249	1997 252	
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1785 238	1839 242	1893 245	1947 249	2001 252	
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1788 238	1842 242	1896 246	1950 249	2004 253	
1789 238	1843 242	1897 246	1951 249	2005 253	
1790 238	1844 242	1898 246	1952 249	2006 253	
1791 238	1845 242	1899 246	1953 249	2007 253	
1792 239	1846 242	1900 246	1954 249	2008 253	
1793 239	1847 242	1901 246	1955 249	2009 253	
1794 239	1848 242	1902 246	1956 250	2010 253	
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1799 239	1853 243	1907 246	1961 250	2015 253	
1800 239	1854 243	1908 246	1962 250	2016 253	
1801 239	1855 243	1909 246	1963 250	2017 253	
1802 239	1856 243	1910 246	1964 250	2018 254	
1803 239	1857 243	1911 247	1965 250	2019 254	
1804 239	1858 243	1912 247	1966 250	2020 254	
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1822 241	1876 244	1930 248	1984 251	2038 255	
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