Lunar CRater Observation and Sensing Satellite (LCROSS) Project

Planetary Data System (PDS) Data Product Software Interface Specification

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CONFIGURATION MANAGEMENT

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1. Purpose and Scope of Document

The purpose of this data product SIS is to provide users of the LCROSS PDS Archive with a detailed description of the products and a description of how they were generated, including data sources and destinations. The LCROSS instrument suite was designed to provide an integrated set of imaging and spectral observations that complement each other, and the products share many metadata fields and processing steps. Therefore, the LCROSS science team has produced a single, integrated SIS to describe all of the products together.

The data products described in this document include calibrated and uncalibrated images in binary format with associated, detached labels, calibrated and uncalibrated spectra in ascii tables, also with detached labels, and photometer time histories, again in calibrated and uncalibrated variants in ascii tables with detached labels.

The document is intended to provide enough information to enable users to read and understand these data products. The users for whom this document is intended are the scientists who will analyze the data, including those associated with the project and those in the general planetary science community.

2. Applicable Documents

This Data Product SIS is responsive to the following LCROSS and PDS documents:

Ref	Document Number	Extension Document Title
1	04.05.PDSArchivePlan.01	LCROSS Project Archive Generation, Validation and Transfer Plan, April 23, 2007
2	04.05.PDSICD.01	LCROSS Science Team and PDS Node Interface Control Document, version 1.1, October 18, 2007.
3	4.05PDSArchiveSIS.01	LCROSS Planetary Data System Archive Volume Software Interface Specification
4	JPL D-31224	Planetary Data System Archive Preparation Guide (APG), Version 1.1, August 29, 2006
5	JPL D-7669	Planetary Data System Data Standards Reference, Version 3.7, Part 2, March, 20, 2006
6	JPL D-7116 Rev. E	Planetary Science Data Dictionary Document, August 28, 2002
7	04.01.SciMP.01 PDS DOCUMENT directory	LCROSS Science Plan
8	PDS DOCUMENT directory	LCROSS Instrument Calibration Summary

3. Relationships with Other Interfaces

The software interface between LCROSS and the PDS is described in this document and the LCROSS Planetary Data System Archive Volume Software Interface Specification. Changes in either document could affect the other. In addition, changes to the processing tools used to generate the LCROSSS data products could affect the data product, this SIS and the archive plan.

4. Data Product Characteristics and Environment

4.1 Overview of Instruments

Table 1 summarizes the LCROSS instruments. Subsequent sections give more detail.

Mnemonic	Name	Frequency Range	Sampling Frequency	Resolution	Field of View
VIS	Visible light (TV) camera		variable	720 x 486	30.1 x 22.8 deg
NIR1	Near infrared camera 1	1.4-1.7 microns	variable	320 x 240; 720 x 486 downlinked	28.7 x 21.7 deg
NIR2	Near infrared camera 2	1.0-1.7 microns	variable	320 x 240; 720 x 486 downlinked	28.7 x 21.7 deg
MIR1	Mid-infrared camera 1	5-9.4 microns	variable	164 x 128	15 x 11 deg
MIR2	Mid-infrared camera 2	7.5-13.5 microns	variable	164 x 128	15 x 11 deg
NSP1	Near infrared spectrometer 1	1.141-2.446 microns	1.7 Hz	100 pixels	1 deg diameter circular cross section
NSP2	Near infrared spectrometer 2	1.141-2.446 microns	1.7 Hz	100 pixels	130 deg diameter circular cross section
VSP	Visible and Ultraviolet light spectrometer	262-650 nm	variable	1024 pixels	1 deg diameter circular cross section
TLP	Total luminance photometer	400-1000 nm	1000 Hz	1	10.8 x 11.5 deg

Table 1 Instrument Overview

4.1.1 Visible Camera

The LCROSS Visible Camera (VIS) is a ruggedized analog video camera from the RocketCam™ camera family developed by Ecliptic Enterprises. Inc. The VIS camera unit consists of a camera module and a lens. The camera's focal plane sensor (1/2 inch color CCD) has an NTSC 768 H) x 494 (V) pixel format and produces a 30 Hz full-frame (video) rate. Each full frame consists of two interlaced frames, each produced at a 60 Hz interlaced field rate. The image aspect ratio [H:V] is 1.33. The pixel aspect ratio [H/V] is 86% (i.e., they are not square).

The VIS camera f/8, 12 mm focal length lens provides a 30.1 deg [H] x 22.8deg [V] (37.6 deg [D]) full-angle field of view.

Raw 8-bit composite video (CVBS) NTSC images are digitized, reducing them to 720 x 486, then compressed by a wavelet-based, lossy compression algorithm implemented by the Analog Devices ADV612 video codec chip. This process removes the interlacing and produces full-frame, digitized images at 30Hz. This data stream is then decimated to achieve a frame rate that fits within the downlink bandwidth, typically 1 Hz. These steps are performed onboard the LCROSS spacecraft by the payload Data Handling Unit's (DHU) video compression board. The images are decompressed on the ground by GSEOS (Ground Support Equipment Operating System) using a proprietary Analog Devices decompression library and saved to disk as 8-bit, 720 x 486 RGB images in PNG format.

Although the VIS settings are configurable in the camera design, there is a single fixed-mode of the VIS camera used on the LCROSS mission. This is described by the manufacturer as auto-exposure with automatic gain control (AGC) and white balance enabled. This mode cannot be altered during the mission.

4.1.2 Near Infrared Cameras

The LCROSS payload has two near-infrared cameras. The LCROSS Near-Infrared Cameras (NIR1 and NIR2) are ruggedized SU320-KTX cameras manufactured by Goodrich Sensors Unlimited. The NIR1 camera unit consists of a camera module, a lens, and a longpass filter from Spectragon. The NIR2 camera unit consists of a camera module and a lens. For each camera, the sensor unit is a Sensors Unlimited's SU320AM-1.7T1 indium gallium arsenide (InGaAs) focal plane array (FPA) having 320 (H) x 240 (V) pixels on a 40 micron pitch. In the LCROSS payload design, the digital output signal from these two cameras are upscaled into an NTSC standard analog video format (EIA-170), resulting in 8-bit NTSC 768 (H) x 494 (V) pixel format at a 30 Hz frame rate, and then digitized at 720 x 486 and decimated like VIS. This signal path was chosen to meet a tight development schedule. Like the VIS images, the image aspect ratio [H:V] is 1.33 and the pixel aspect ratio [H/V] is 86% (i.e., they are not square).

The NIR1 and NIR2 cameras each possesses a f/1.4, 25 mm focal length C-mount glass lens that provides a 28.7deg [H] x 21.7deg [V] (36.0 deg [D]) full-angle field of view. The NIR1 camera unit's filter is a longpass 3.69% slope, 1.4115 micron cut-on wavelength. NIR2 is unfiltered and spectral response is limited by the responsivity of the InGaAs detector (1.0-1.7 microns).

Like VIS, raw 8-bit composite video (CVBS) NTSC images are digitized, reducing them to 720 x 486, then compressed by a wavelet-based, lossy compression algorithm implemented by the Analog Devices ADV612 video codec chip [7]. This process removes the interlacing and produces full-frame, digitized images at 30Hz. This data stream is then decimated to achieve a frame rate that fits within the downlink bandwidth, typically 1 Hz. These steps are performed onboard the LCROSS spacecraft by the payload Data Handling Unit's (DHU) video compression board. The images are decompressed on the ground by GSEOS (Ground Support Equipment Operating System) using a proprietary Analog Devices decompression library and saved to disk as 8-bit, 720 x 486 RGB images in PNG format.

Before the data is transferred to the DHU as analog video, the cameras themselves generate 12-bit digital data, apply pixel-by-pixel offset and gain correction to the data, perform contrast stretching enhancement of the data, insert test information, and pass the data through a video look-up table memory. All these options are selectable via command parameters communicated to the cameras via scripts to the DHU. In the main LCROSS science modes for these cameras, pixel-by-pixel offset, gain, and bad-pixel correction features are enabled (which perform a first-order flat field correction), a digital gain of 1x is fixed, a global offset value of 100 is fixed, and the automatic gain control (which primarily adjusts exposure time to scene) is disabled. Exposure time is set by a configurable parameter (OPR) which refers to a set of on-board lookup table (LUT) parameters to optimize performance (gain and integration time) for sensitivity. Contrast stretching enhancement is typically disabled for the LCROSS science data except under certain instances (starfield) to improve dynamic detection limits at the expense of losing radiometric calibration. During some payload command sequences, these parameters are varied to facilitate payload initialization and health status monitoring. For instance, some images are generated with a high global offset value which forces image saturation. These variations appear only at the beginning of command sequences.

The main science (configurable) modes for the NIRs are:

1. AGC:ON (lunar swingby), to allow the NIRs to adjust their integration and gain setting as per the look-up table (OPR 0-15, effective integration times from 0.11 to 16.24 ms, respectively, with optimized gain adjustment).

2. AGC:OFF, OPR 6 (Normal Camera Operation) chosen to best sample the impact ejecta radiance. This mode has an effective integration time of 0.83 ms with an intrinsic (cannot be altered) optimized pixel gain for that integration time.

3. AGC:OFF, OPR 15 (Highest Sensitivity Camera Operation) chosen to provide the longest exposure times for faintest targets (e.g., impact flash and crater). This mode has an effective integration time of 16.24 ms with an intrinsic (cannot be altered) optimized pixel gain for that integration time.

4.1.3 Mid Infrared Cameras

The LCROSS payload has two mid-infrared cameras. One LCROSS Mid-Infrared Camera (MIR1) is a ruggedized MIRIC© TB2-30 camera unit from Thermoteknix, Ltd. UK. MIR1 also consists of a lens and 5-9.4 micron bandpass filter internal to the ruggedized-camera unit body. The second LCROSS Mid-Infrared Camera (MIR2) is an unfiltered ThermoVision® Micron/A10 with lens from FLIR Systems. Both camera bodies each have a 164 (H) x 128 (V) uncooled microbolometer sensor array with a 51 micron pixel pitch.

The MIR1 and MIR2 cameras each possess a f/1.6, 30 mm focal length lens that provides a 15deg [H] x 11deg [V] (18.6 deg [D]) full-angle field of view. The MIR1 camera unit's filter is a 5-9.4 micron bandpass. MIR2 is unfiltered and spectral response is limited by the responsivity of the Vox bolometer array (7.5-13.5 microns).

Although the Vox bolometer arrays at 164 (H) x 128 (V) pixel format, the payload Data Handling Unit's (DHU) processes and compresses the output as 14-bit video with 160 (H) x 120 (V) displayed detector samples at a 30 Hz frame rate. The images are decompressed by the Ecliptic Enterprise provided Electrical Ground Support Equipment GSEOS and saved to disk as 14-bit 160 (H) x 120 (V) images.

Each MIR camera possesses two operational modes, high-sensitivity (low scene temperature) and low-sensitivity (high scene temperature) gain states. The former (High-Gain) is designed for scene temperatures less than +150 C and is the primary mode for both cameras during the LCROSS mission. The Lo-Gain mode, designed for imaging up to +500C is never used, except during the instrument health status checks.

Both cameras have onboard an active process called "flat-field correction" (FFC), during which a small calibration flag rotates in front of the detector array, presenting a uniform temperature (i.e. a "flat field") to every detector element. While imaging the flat-field, the camera updates correction coefficients, resulting in a more uniform array output. The video image is frozen during the entire process, which takes approximately half a second, and it resumes automatically thereafter. Repeating the FFC operation often prevents the imagery from appearing "grainy". Both cameras have been programmed (configurable setting) to perform a FFC at whenever the temperature changes by a 1.6C degrees or at the end 120 s (2 minutes time (whichever comes first). This setting was recommended by the manufacturer.

4.1.4 Near Infrared Spectrometers

The LCROSS payload has two Near-Infrared Spectrometers. Both units' main spectrometer optics and electronics modules are designed and manufactured by Polychromix, Ltd. The differences between NSP1 and NSP2 lie only in their unique fore-optics design and configuration on the LCROSS spacecraft. LCROSS Near-Infrared Spectrometer 1 (NSP1) is placed in the +X direction which is positioned toward the lunar surface (nadir-looking) during the final descent. The other LCROSS Near-Infrared Spectrometer 2 (NSP2) faces the –Z direction on the spacecraft which is orientated toward the Sun during final descent to measure the solar spectrum as the spacecraft descends into the dynamic ejecta curtain and thus provides an "occultation" measurement. Each NSP instrument consists of a fore-optics unit feeding a single 0.22 NA 600 micron core-diameter low-OH fiber into its respective spectrometer unit. The fiber core acts as the effective entrance slit feeding light into a dispersive system that involves an innovative electronically-tunable MEMs device to spatially mask the spectra information onto a single-element TEC-cooled InGaAs detector. This design provides a compact, low mass and very low power, moderately low resolution near-infrared spectrometer. The spectral information is transferred to the LCROSS Data Handling Unit (DHU) which packages it for transfer to the ground. The spectrometer has three modes (Hadamard Spectrum, Impact Flash and Diagnostic Mode), each which require unique post-processing steps to retrieve spectral information. In all three cases, this computation is performed on the ground through an ARC-provided pipeline after the data has been decompressed by the Ecliptic Enterprise provided Electrical Ground Support Equipment GSEOS and saved to disk.

The NSP1 fore-optic unit is a 2 mirror, 1 lens design by Aurora Design & Technologies, to provide a highly efficient 3-inch diameter collecting area into a single 0.22 NA 600 micron core-diameter fiber. The fiber is a 75 cm length AnhydroguideG, low-OH optimized for the VIS/IR Spectral Range with a FC termination at the optic end and a SMA termination inside the NSP1 spectrometer module. This fore-optics provides an effective 1 degree full field-of-view for NSP1.

The NSP2 fore-optic unit is a stacked-sandwich diffuser design by Aurora Design & Technologies to provide an approximate 130 degree full field-of-view. The fiber is a 145 cm length AnhydroguideG, low-OH optimized for the VIS/IR Spectral Range with a FC termination at the optic ends and a SMA termination inside the NSP2 spectrometer module.

Each spectrometer is capable of three modes: Hadamard Spectrum (HS), Impact Flash (IF) and Diagnostic Mode (DM).

1. Hadamard Spectrum mode provides a single 100 pixel spectra at 1.7Hz rate. This 100 pixel spectra covers 1.141-2.446 micron spectral region with 0.0136 um/pixel. This is the nominal operating setting for NSP2, and for most of NSP1 in the LCROSS mission.

2. Impact Flash Mode provides a 5 “mask” spectra at 72 Hz rate, providing a faster rate method to measure the 1.423, 1.586, 1.852, 2.009, and 2.303 micron regions. It is used only on NSP during alignment checks against a limb (lunar swingby and earthmoon) and for the <2 second near-infrared flash event after the Centaur impact. Locations of masks in the spectral region are flashed programmed into the NSP unit themselves and cannot be altered unless the NSP unit itself is reprogrammed.

Diagnostic Mode is not used, except for some ancillary health checking during some of the low-level LCROSS flight sequences. This is a 3 “mask” spectra providing a measurement of the “dark” position, a second “fixed mirror” position, and a constant value.

4.1.5 Visible Spectrometer

The LCROSS visible spectrometer (VSP) is a modified commercial model from Ocean Optics, Inc., with its core operation based on their commercial-off-the-shelf (COTS) QE65000 spectrometer. The LCROSS VSP instrument consists of a custom-built Cassegrain-type telescope fore-optic with lens feeding a single 0.12 NA 600 micron core-diameter UV/VIS optical fiber into the spectrometer unit. The spectrometer unit itself is a traditional slit-fed f/4 cross Czerny-Turner spectrometer with an oversized camera mirror, dispersing light onto a single 1044x64 pixel Hammamatsu CCD detector. The spectral range for the flight unit has been measured to cover the 262-650 nm range at a dispersion of 0.40-0.36 nm/pixel. The VSP co-adds the spectra on-board, delivering a 1x1044 pixel spectra to the LCROSS Data Handling Unit (DHU) for packaging and time-stamping. The CCD detector is cooled by an internal Thermal Electric Cooler (TEC), whose operational set-point is programmable but typically set to -10 deg C.

The VSP fore-optic unit is a 2 mirror, 1 lens design by Aurora Design & Technologies, to provide a highly efficient 3-inch diameter collecting area into a single 0.12 NA 600 micron core-diameter fiber. The fiber is a 75 cm length SuperguideG, UV/VIS Spectral Range from FiberGuide with FC terminations at both ends. This fore-optics provides an effective 1 degree full field-of-view for the VSP.

Although the data produced by the VSP to the DHU is a 1x1044 format spectra, only the first 1024 pixels contain spectral information. Pixels 1025 through 1044 are measurements of “dark areas” outside the image plane which may be used for dark current subtraction or instrument health status. The interval rate between spectra is a unique combination of the VSP spectral mode (single or bracket), the configurable integration times, and the DHU packaging time, and is typically 0.2-0.5 Hz in the various flight sequences.

The VSP spectrometer electronics design supports a number of configurable options. The LCROSS payload design has adopted to only use two distinct modes to achieve spectra: single and bracket spectra. The single mode is a single exposure time spectra taken and then repeated in a continuous fashion. The bracket spectra mode is a single "triplet" of spectra taken and then repeated. The triplet is defined as a base exposure time, followed by that exposure divided by an integer (i.e., shorter exposure), followed by the base exposure time multiplied by the same integer (i.e., longer exposure).

For each mode, the exposure time for a particular spectral acquisition is configurable between 8ms and 65535 ms (1.09 minutes). Both modes and exposure time values are configurable via commands sent to the DHU.

The main science (configurable) modes for the LCROSS VSP are:

1. Bracket Mode: 100ms, 200ms, 400ms triplet spectra (bright target) at 0.5 Hz rate; used for lunar swingby
2. Single Mode: 4s integration spectra (faint target) discretely commanded; used for acquiring spectra of the impact flash or starfield.
3. Bracket Mode: 100ms, 500ms, 2500ms triplet spectra (nominal science exposures) at 0.2 Hz rate; used for the final ejecta curtain measurements and health monitoring.

4.1.6 Total Luminance Photometer

The Total Luminance Photometer (TLP) provides a visible light intensity value (in total power) of the crater flash event over the visible range. The TLP instrument consists of two units, the Sensor Electronics Module (SEM) and the Digital Electronics Module (DEM). The SEM contains the optics, the sensor assembly and signal filtering. The DEM converts the analog sensor signal to a digital output. In addition to sampling the sensor's signal, there are two AD590 temperature sensors in the SEM package whose voltage levels are sampled and measured by the DEM. The SEM design is a NASA Ames technology development. The DEM is a set of commercial units (CPU, analog I/O and power supply) modified for this application.

The TLP's single-element visible light detector is designed to operate at a 1000 Hz constant rate. The lens elements deliver an approximate unobstructed 10 degree field-of-view, focusing this light onto an uncooled Advanced Photonix, Inc. (API) avalanche photodiode (APD). The APD, with support from the APD module, amplifies the received optical signal and outputs a signal voltage proportional to pulse shape of the impact flash. This signal voltage passes through a high-pass filter (HPF), which removes the background light level. The signal is further amplified, then passed through a low-pass filter (LPF) to remove high frequency noise. The filtered analog signal leaves the SEM and enters the DEM where the flash data is digitized and placed into a data frame containing other information. Finally, the data frame is converted to RS-422 serial data stream which is sent to the DHU.

The TLP is sensitive over the 400-1000 nm spectral region is expected to detect a total power event in this waveband less than 10nW.

The TLP is operated only briefly during the LCROSS mission, from 20 minutes before the centaur impact flash until approximately 3 minutes afterwards.

4.2 Overview of Data Products

4.2.1 Visible Camera

The visible camera provides uncalibrated imagery as context for images and spectra captured by the other instruments. Each VIS data product is a three-channel, binary-formatted, 720 (h) x 486 (v) image with a detached PDS label, formatted as ASCII. The label describes the payload boresight vector from spacecraft to boresight intersection with the target at the time the image was captured.

4.2.2 Near Infrared Cameras

Raw data products from the two near infrared cameras are three-channel, binary-formatted images with associated, detached PDS labels, formatted as ASCII. The near infrared cameras have a single channel, but, because they are multiplexed with the three channel visible camera on the spacecraft, images from the NIR cameras are downlinked as color images.

Calibrated data products from the NIR cameras are single channel, binary formatted images, also with associated, detached PDS labels that are formatted in ASCII. A single channel of the three-channel downlinked images is selected for calibration. In this data release, the red channel is always used. Each calibrated image file is a 32-bit PC_REAL greyscale image, with a 720 x 486 pixel format. The image aspect ratio [H:V] is 1.33. The effective field-of-view [FOV] is 28.3 [H] x 21.4 [V] degrees. The time each image was captured is encoded in the image's filename.

After initialization, the near-infrared cameras were operated by setting two independent parameters. First is LCROSS:NIRf,_OPR an integer [0, 15] inclusive describing one of 16 operational configurations stored in the camera's non-volatile memory. The factory default settings for these configurations were used. The OPR setting determines the camera's integration time (in the labels as LCROSS:NIR_INTEGRATION_TIME in microseconds) and gain setting (LCROSS:NIR_GAIN in electrons per DN). Second, the LCROSS:ENHANCEMENT_MODE [OFF,ON] describes whether image stretching is performed within the camera. This was enabled only during the STARFIELD data collection period. These cameras have additional configuration settings that were redundant or kept constant and so are not noted in the labels.

4.2.3 Mid Infrared Cameras

Raw and calibrated data products from the two mid infrared cameras are single channel, binary-formatted images with detached labels in ASCII. Each calibrated image file is a 160 x 120, 32-bit PC_REAL greyscale image. The effective field-of-view [FOV] is 16.0 [H] x 11.0 [V] degrees. The time each image was captured is encoded in the image's filename. Gain is either High Gain for best sensitivity with low scene temperatures (T < +150 C) or Low Gain for best sensitivity with high scene temperatures (+150 C < T < +500 C). The majority of the mid-infrared images are taken at High Gain.

4.2.4 Near Infrared Spectrometers

The near infrared spectrometers implement three modes: (1) hadamard spectrum, (2) flash and (3) diagnostic. Data from the first two appear in the LCROSS PDS archive. In Hadamard mode, these spectrometers produce 100 pixel spectra every 0.7 seconds. In Flash mode, they produce a 6 pixel spectra every 14 milliseconds.

Raw and calibrated Hadamard data products from the two near infrared spectrometers are ascii-formatted tables with associated, detached PDS labels, also formatted as ascii. The near infrared spectrometers produce spectra containing 100 measurements representing light sampled from 1.16 to 2.48 micrometers in steps of 11 nanometers. Each table contains 100 rows and one column. Tables corresponding to raw data products contain integers representing counts while tables corresponding to calibrated products contain floating point numbers corresponding to radiance.

Raw and calibrated Flash data products from the near infrared spectrometers are ascii-formatted tables with associated, detached PDS labels, also formatted as ascii. Each table row contains a timestamp plus one flash spectra (6 columns). The tables contain a variable number of rows. Raw flash spectra tables contain integer counts while calibrated tables contain floating point numbers corresponding to radiance.

4.2.5 Visible Spectrometer

Raw and calibrated data products from the visible spectrometer are ascii-formatted tables with associated PDS labels, also formatted as ascii. The visible spectrometer produces spectra containing 1024 measurements representing light sampled from 263 to 650 nanometers. With each spectra are included 20 dark or reference pixels for a total of 1044 measurements. The .tab files contain one column and 1044 rows. These values are described in the detached labels as two tables although the tables are together in one file. The first table contains a 1024 pixel spectra, and another contains a 20 row table of reference values. The 1024 pixel spectra appears in the file first. Tables corresponding to raw data products contain integers representing counts while tables corresponding to calibrated products contain floating point numbers corresponding to radiance.

The visible spectrometer has two modes: (1) single spectrum and (2) bracket mode. In bracket mode, the spectrometer captures three spectra in quick succession, the first at the commanded integration time, the second at a shorter integration time, and the third at a longer integration time. Given wide uncertainty in predictions about the brightness of the LCROSS impact event, bracket mode is intended to guard against errors in picking the exposure time setting for this spectrometer.

In the data archive, spectra taken with bracket mode enabled have been separated and are submitted in separate labeled files. This means that EXPOSURE_DURATION attribute can vary widely across spectra captured at nearly the same time.

4.2.6 Total Luminance Photometer

The raw and calibrated data products from the total luminance photometer are ascii-formatted tables with associated, detached labels, also formatted as ascii. Each table row contains two columns. One is a timestamp and the other, a value corresponding to the instrument measurement. In the raw data product, this value is an integer count corresponding to a voltage measurement within the instrument. In the calibrated data product, this value is a floating point value corresponding to voltage corrected to correspond to a detector temperature of 0°C. Conversion from counts to volts is described in the LCROSS Instrument Calibration Summary [8]. Timestamps are UTC. The TLP produces measurements at 1000 Hz, so timestamps increase by one millisecond per row unless there are telemetry dropouts. If telemetry dropouts occur, that data will be missing in the file. That is, timestamps could skip by more than 1 msec.

4.3 Data Processing

4.3.1 Data Processing Level

This SIS uses the Committee On Data Management And Computation (CODMAC) data level numbering system to describe the processing level of LCROSS data products. Raw data products are considered CODMAC "Level 2" ["Edited Data"] while Calibrated (Cal) data products are considered CODMAC “Level 3”. Refer to Table 2 for a summary of the CODMAC and NASA data processing levels.

All LCROSS data products referred to as ‘Raw’ are at CODMAC data level 2. All data products referred to as ‘Calibrated’ are at CODMAC data level 3.

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 1A	Calibrated - Level 3	NASA Level 0 (CODMAC Level 2) 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 1B	Resampled - Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
		Resanpled and mapped
Level 2	Derived - Level 5	Geophysical parameters, generally derived from NASA Level 1 data (CODMAC Levels 3 and 4) , 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.

Table 2: Data Processing Levels

4.3.2 Data Product Generation

The LCROSS data products are produced by LCROSS science team members from the NASA Ames Research Center using telemetry processing software provided by the DHU contractor and custom software developed by the LCROSS team.

4.3.3 Data Flow

Figure 1 shows data flow onboard the spacecraft. The mid infrared cameras (MIR1, MIR2), the near infrared (NSP1, NSP2) and visible (VSP) spectrometers and the photometer (TLP) all transfer uncompressed data from their respective sensors to the payload data handling unit (DHU) via serial digital connections. The visible and near infrared cameras (VIS, NIR1, NIR2) transfer images via NTSC, analog connections. One of these three is selected via a digital switch (mux), digitized and then compressed highly using a lossy, wavelet-based compression algorithm. This is the only lossy compression used in the signal chain between any lcross instrument and the PDS archive.

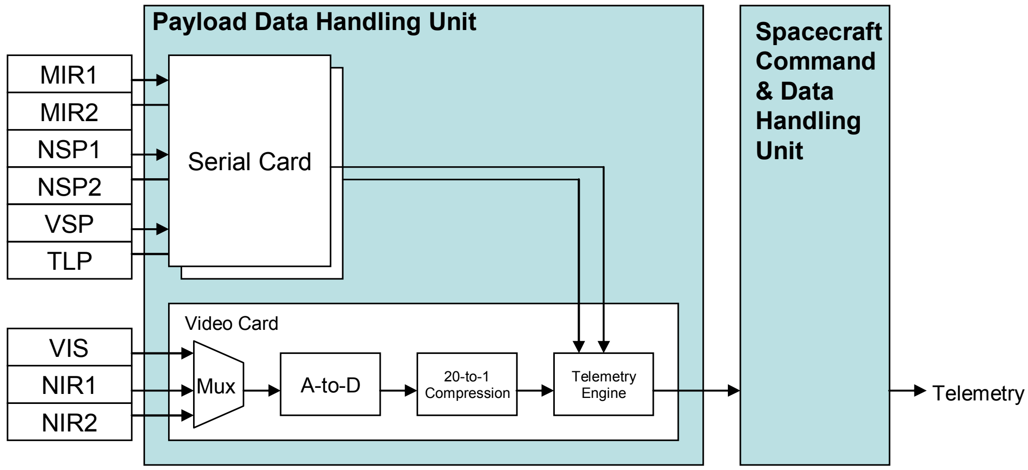

Figure 1 Data flow onboard

Figure 2 shows data flow on the ground. LCROSS payload telemetry is processed by GSEOS (Ground Support Equipment Operating System). To generate LCROSS image products, GSEOS extracts them from telemetry and converts them to PNG format with the MET-based packet timestamp encoded in the filename. In addition to the more common three channel, 8-bits-per-channel format used for the visible and near infrared camera images, the PNG format also supports the 16-bit, single channel image format which is used for the mid infrared camera images. Spectra are extracted from telemetry and written to disk as ascii CSV files. Data from the Total Luminance Photometer is generated at 1000hz and is written into a single, streaming file in CSV format. When the Near Infrared Spectrometers are in Flash mode, their output is treated similarly. The resulting image and spectra files are collected into a dataset used within the payload team called a "Sequence Run". A separate Sequence Run is created every time the payload Data Handling Unit (DHU) is powered on. Finally, custom software called Archive Builder reorganizes the sequence run datasets to create the PDS archive.

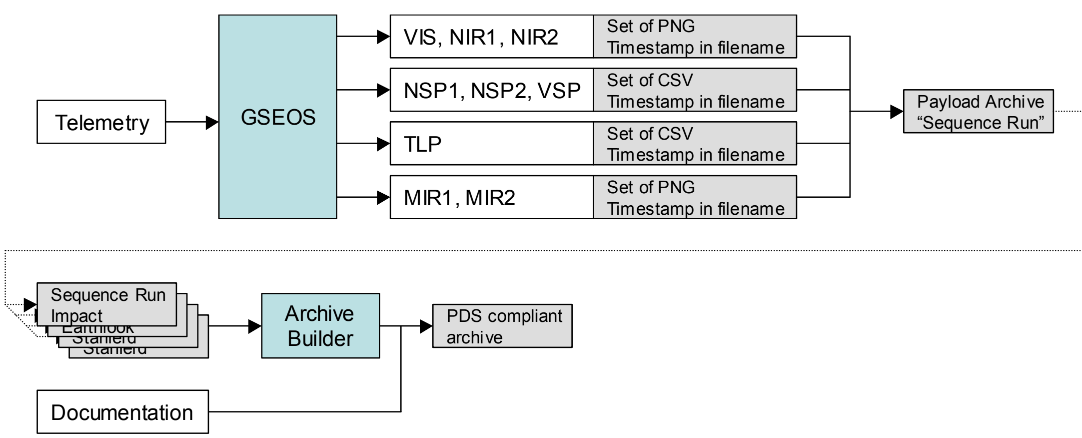

Figure 2 Data flow on the ground

Archive Builder comprises the data processing pipeline that goes from raw images and spectra to calibrated ones.

Table 3 shows the expected size of each individual data product, and Table 4 shows the total data volume generated for the PDS archive for each of the planned periods of data collection during the LCROSS mission.

Instrument	Individual Data Product Size		Comment
	Raw (kb)	Calibrated (kb)	
VIS	1000	n/a	3 color image
NIR1	342	1367	single channel image
NIR2	342	1367	single channel image
MIR1	39	77	single channel image
MIR2	39	77	single channel image
NSP1 Hadamard	4	4	100 pixel, hadamard mode spectra
NSP1 Flash	~700	~700	Single file containing all flash spectra
NSP2	4	4	100 pixel, hadamard mode spectra
NSP1 Flash	500	500	Single file containing all flash spectra
VSP	11	12	1024 pixel spectra
TLP	8400	9600	Single file containing all TLP readings from a 23 min recording

Table 3 Expected size of the major data products

Payload Activation	Expected Data Volume (Mb)
quicklook	186
starfield	2417
swingby	8851
Earthlook<n>	1155
Moonlook<n>	2372
Separation	580
Impact	10129

Table 4 Expected data volume by mission phase

4.3.4 Producing Calibrated Data Products

The following sections briefly describe the processing steps planned for LCROSS instrument data. The PDS archive will not contain all of the products mentioned or implied below; which will be included are marked clearly. Our goal is to provide all of the raw data available, sufficient documentation to redo any processing, and a minimal set of the most useful derived products.

4.3.4.1 Visible Camera

Each VIS image is a 8-bit [0-255 DN] three color (R,G,B) image with size 720 (H) x 486 (V). As since this unit is configured for automatic exposure, gain and white balance, the actual DN values of each pixel are not calibratable. The platescale (to be confirmed on orbit using spacecraft altitude from lunar surface and known lunar features) is expected to confirm an iFOV of 0.050 degree x 0.050 degree (per pixel).

VIS data products are provided in raw form only.

4.3.4.2 Near Infrared Cameras

Each NIR image is an 8-bit [0-255 DN] grey-scale image of size 720 (H) x 486 (V). The platescale (to be confirmed on orbit using spacecraft altitude from lunar surface and known lunar features) is expected to confirm an iFOV of 0.045 degree x 0.045 degree (per pixel). In normal science operations both cameras are used with the same gain and exposure settings to allow for a “difference” image. However, a pair of NIR images may be separated by up to 2 seconds (e.g. 1000k curtain mode) and thus have different spatial footprints. The raw DN image values will be converted to a radiance level [units: W/(m^2 sr)] by applying a multiplicative conversion from a look-up table based on laboratory calibration data sets. As since each NIR camera has an automatic pixel-to-pixel correction per exposure enabled, a separate flat field step is not part of this pipeline. Additionally the noise introduced by converting from digital to analog and back to digital dominates the stable pixel to pixel variation so that reference flats taken in this mode are not very useful.

For each NIR image, the following Pipeline is envisioned:

Step 0: NIR: Xpix,Ypix, RGB Values in DN. Each DN Range is 8-bit [0:255].

Step 1: NIR Image Convert RGB values to grayscale via selection of the red channel.

Step 2: Flag pixels with DN > 250 DN (i.e., saturation-check) and NTSC-edge effects (i.e., known bad pixels for NIRs) to create badpixel map.

Step 3: Subtract NIR dark (grayscale) image for same camera setting (i.e., gain, OPR)

Step 4: Divide dark-subtracted NIR images by exposure time in seconds

Step 5: Multiply Step 4 by the calibration coefficient to transform [DN/s] to [W/m^2 sr]. The area and steradian values are those for a 40umx40um pixel fed by a f/1.4 lens. The resulting image is X,Y,[W/m^2 sr]. An error estimate on the radiance conversion will also be supplied. [This is a calibrated data product.]

Step 6 (optional): Apply bad-pixel map from Step 2 to Step 5 images. This may result in replacement of pixels with their nearest neighbor, or, in the case of a full row or column of edge pixels, a cropped image. As we are using a NIR camera mode which automatically provides bad-pixel correction within each exposure, this calibration step deals mainly with saturation and image processing errors occurring in the analog-to-digital conversion or other processing within the DHU.

The dual-NIR Image Radiometric Pipeline is envisioned to be:

Step 1: Take Level 2 data products from each NIR, shift the NIR2 image into the coordinate system of NIR1. Each file is in X,Y,[W/m^2 sr]

Step 2: Subtract NIR1 (filtered) from NIR2 (unfiltered) to reveal contributed flux [W/m^2 sr] from the 1.0-1.4um region. [This is a calibrated data product.]

4.3.4.3 Mid Infrared Cameras

Each MIR image is a 14-bit [0-16383 DN] image with size 160 (H) x 120 (V). The platescale is expected to confirm an iFOV of 0.073 degree x 0.073 degree (per pixel). This will be confirmed on orbit using spacecraft altitude from lunar surface and known lunar features. In normal science operations both cameras are used with the same gain and exposure settings to allow for a “difference” image. However, pairs of MIR images may be separated by up to 2 seconds (e.g. 1000k curtain mode) and thus have different spatial footprints at a given time. The raw DN image values will be converted to an effective temperature [units: degrees C)] by applying a multiplicative conversion from a look-up table based on laboratory calibration data sets. Each camera automatically provides an internal flat-field correction calibrated against a target of known temperature every 2 minutes, so this processing is part of the Level 0 products. There is no subsequent flat field correction step.

For each MIR image, the following Pipeline is envisioned:

Step 0: MIR: Xpix,Ypix, Raw Values in DN. Each DN Range is 14-bit [0:16383]. [This is the raw data product.]

Step 1: Flag pixels with DN > 11,000 DN (i.e., saturation-check) to create badpixel map. This is not expected in orbit since values ~11,000 DN represent +500C.

Step 2: Apply the calibration function to output from Step 0 to transform [DN] to [deg C]. The resulting image is X,Y,[deg C]. An error estimate on the temperature conversion will also be supplied. Work on the calibration function is not complete as of this writing, but it will be generated by fitting a polynomial to lab calibration data. Although this conversion may slightly be instrument temperature dependent, lab calibration was only performed at +19 to +21C (room temperature). This best-effort calibration will be described in a calibration report contained in the documentation section of the PDS archive. [This is the calibrated data product.]

Step 3 (optional): Apply bad-pixel map from Step 1 to Step 2 images.

There are currently no plans to provide a data product representing the difference between MIR2 and MIR1 analogous to the one for the near infrared cameras because radiometric calibration to units of radiance was not performed on the MIR imagers. However, by assuming the target of the image pair can be reasonably modeled as a black body, then the two mid-infrared camera images could be differenced after being co-registered. This approach to subtract MIR1 (filtered) from MIR2 (unfiltered) could reveal flux contribution from the 9.4-13.0 micron region.

4.3.4.4 Near Infrared Spectrometers

LCROSS’ near infrared spectrometers have two operational modes: Hadamard and Flash. Hadamard mode produces full-resolution spectra (100 pixels) at 1.7 hz. Flash mode produces 6 pixel spectra at [fill in] hz and is used, as the name implies, to capture the impact flash.

Hadamard Mode: Raw NSP spectra data in Hadamard Mode is the form of 256 16-bit masks. This spectral data is processed through a pipeline to produce a 1x100 pixel array of 24-bit values. Saturation can be checked at this stage by a well-known pattern of values in the first masks and will be noted to the spectra headers.

Each reduced NSP spectra in Hadamard Mode is 100 pixels in length, each pixel's raw value is signed 24-bit [-1.6e7 to +1.6e7] DN. Wavelength calibration will be checked in-orbit using solar lines and reflectance from the lunar surface during fly-by. In Hadamard Mode, a representative dark spectra is taken with every single exposure (i.e., the mask position when all mirrors are flipped out of the beam), therefore removing the need for a separate dark spectra subtraction in the pipeline.

For each NSP spectra in Hadamard Mode, the following pipeline is envisioned:

> Step 0: Raw Mask Values.
>
> Step 1 (Level 1): Apply Hadamard transformation to get Raw DNs by pixel [-1.6e7 to +1.6e7]. [This is a raw product.]
>
> Step 2: Apply wavelength calibration from look up table to create a Pixel Number, Wavelength [microns], Raw Value [DN]. Wavelength calibration has been performed in the lab and will be rechecked in orbit.
>
> Step 3: Apply radiometric calibration function, converting DN to [W/m^2 um sr] from laboratory calibration results from a calibrated GSFC integrating sphere and spectralon plate. Also to be provided are the intrinsic errors in this calibration. Spectra are now in Pixel Number, Wavelength [microns], Spectral Radiance [W/m^2 um sr]. [This is the calibrated product.]

Flash Mode: In flash mode, the near infrared spectrometers take low-resolution spectra at a rate of 72 Hz. Each low resolution spectra consists of five 32-bit masks, each of which covers a wider range of wavelength than a single pixel in Hadamard Mode. This is encoded in the downlink as the difference between the mask DNs and a 6^{th}, dark mask value.

For each NSP spectra in Flash Mode, the following pipeline is envisioned:

> Step 0: Timestamp + 6 raw Mask Values
>
> Step 1: Subtract Dark Mask from the Five Science Mask positions to give a dark subtract value for the Five Science Masks. [This is the raw data product.]
>
> Step 2: Apply radiometric calibration function converting DN to [W/m^2 um sr]. The calibration function is documented in the calibration report and generated from laboratory calibration results from a calibrated GSFC integrating sphere and spectralon plate. Error bars are also provided. Spectra is now in Timestamp + 5 radiance values [W/m^2 sr]. Each radiance value has been integrated over its mask wavelength range as documented in the calibration report. [This is the calibrated data product.]

4.3.4.5 Visible Spectrometers

The raw spectral data delivered by the VSP is 16-bit unsigned 1044 data pixels [0-65535 DN] for which the first 1024 pixels are spectral data points, and pixels 1024-1043 represent dark areas off the CCD. Wavelength calibration will be checked on-orbit by measuring the solar spectra and/or features from reflected light off the lunar surface during lunar swingby. Although the VSP posses two main operation modes, single spectra and bracket spectra, each data element is essentially the same, a set of 1044 numbers representing a spectra for a given integration time.

For each VSP spectra, the following pipeline is envisioned:

> Step 0: VSP data is in Pixel Number, Raw Data Values [0-65535 DN] [This is the raw data product.]
>
> Step 1: Flag pixels with DN > 65500 DN (i.e., saturation-check)

Step 2: Apply wavelength calibration from look up table to create a Wavelength [microns], Raw Value [DN]. Wavelength calibration has been performed in the lab and will be rechecked in orbit. The pixels which represent dark areas are given a NaN wavelength VSP data is in Pixel Number, Wavelength [nm], Raw Data Values [DN].

Step 3 (Level 1): Subtract wavelength calibrated dark spectra (from either laboratory database or from an equivalent dark view on orbit) for the same integration time. Note that if the dark is taken from the ground database, it may have a different wavelength calibration and this needs to be identified clearly. Dark values from the ancillary pixels 1025-1044 (given the NaN wavelength in Step 2) should serve as a check on the values used. When the TEC is enabled on the VSP for the range of exposures used on the LCROSS program (except 4 s), the dark current is relatively flat across the VSP spectral range.

Step 4: Divide dark-subtracted VSP by exposure time in seconds to create a time-normalized DN/s spectra.

Step 5 (Level 2). Apply radiometric calibration function converting DN/s to [W/m^2 um sr] from laboratory calibration results from a calibrated GSFC integrating sphere and spectralon plate. Also to be provided are the intrinsic errors in this calibration. Spectra is now in Pixel Number, Spectral Radiance [W/m^2 um sr]. [This is the calibrated data product.]

4.3.4.6 Total Luminance Photometer

Step 0: TLP raw data a single file containing 24 minutes of time x Raw Data Values [0-65535 DN] records. [This is the raw data product.]

Step 1: Apply the calibration function documented in the TLP Calibration Report [9] to get Time x Voltage [Volts]. [This is the calibrated data product.]

4.3.5 Labeling and Identification

A file naming scheme has been adapted for the LCROSS image and spectrum data products from the convention used by the GSEOS telemetry processing software. The filename for LCROSS data products is formed by:

<instrument>_<raw/cal>_<timestamp>.<ext>

where

`instrument` is one of VIS,NIR1,NIR2,MIR1,MIR2,NSP1,NSP2,VSP,TLP

`raw` or `cal` indicates the processing level of the product (raw = CODMAC level 2, cal = calibrated = CODMAC level 3)

`timestamp` = `yyyyMMddhhmmss.mmm`

where the timestamp represents UTC in years, months, days, hours, minutes, second and milliseconds.

`ext` is IMG (image) or TAB (table)

4.4 Standards Used in Generating Data Products

4.4.1 PDS Standards

The LCROSS data products comply with Planetary Data System standards for file formats and labels as specified in the PDS Standards Reference [5] and the Planetary Science Data Dictionary Document [6].

4.4.2 Time Standards

LCROSS data products are time stamped using the spacecraft mission elapsed time clock which counts milliseconds since epoch. A SPICE-format spacecraft clock kernel (SCLK) is provided to describe the mapping between MET in milliseconds and UTC.

PDS labels for LCROSS data products use keywords containing time values, such as start time and stop time. Each time value standard is defined according to the keyword definition. See Appendix 7.4.

4.4.3 Coordinate Systems

All LCROSS instruments except for NSP2 are oriented along the spacecraft's +X axis. Small errors of orientation due to mounting are described in a NAIF-format frame kernel, which also contains the frame of the spacecraft's star tracker. NAIF-format trajectory and attitude kernels are also provided, which allow observation geometry to be computed.

4.4.4 Data Storage Conventions

LCROSS tabular data products and detached PDS label files are stored as ASCII text. Each line or record in the files is terminated with a two-character sequence of carriage return (<CR>, ASCII 13) and line feed (<LF>, ASCII 10) to comply with PDS standards [5]. This line terminator sequence will allow the data files and labels to be easily read on most computers, which recognize either the carriage return, the line feed, or the <CR>/<LF> sequence as an ASCII record terminator.

LCROSS image data are stored as binary arrays of most-significant-byte-first unsigned integer pixels for the raw data, and as least-significant-byte-first IEEE real pixels (PDS data type "PC_REAL") for the calibrated data.

Both tables and images are described by detached PDS labels.

4.5 Data Validation

Validation consists of two parts, science validation and PDS standards validation. The LCROSS team performs validation for science content of the data. The PDS Nodes that receive the data products perform validation for compliance with PDS standards, including checking for correct PDS syntax, for accepted standard values of keywords, and for internal consistency of label items.

The design of LCROSS products as specified in this document and in sample products will be submitted to the PDS for peer review before operations begin. PDS requires data products to pass a peer review before being archived. PDS will conduct the peer review.

5. Detailed Data Product Specifications

5.1 Data Product Structure and Organization

Each LCROSS data product is structured as two files, a label and a data file. The structure of each data file is described in the corresponding label.

5.2 Data Format Descriptions

The product data formats are described completely and formally in the product labels.

5.3 Label and Header Descriptions

Each LCROSS data product has a detached PDS label which is stored as ASCII text. These labels are written in Object Description Language [5], and object-oriented language with keywords describing the structure of the associated data product and other keywords describing metadata useful for additional post-processing or for finding products with desired characteristics. LCROSS images are represented by binary PDS Image objects, and spectra are represented by ascii PDS table objects. Each label contains a pointer statement (^object = location) referring to the location of the data product itself. In all cases, the LCROSS data products are in the same directory as the associated label. For further Object Description Language details, see [5].

6. Applicable Software

6.1 Utility Programs

No utility programs are provided with the LCROSS data archive.

6.2 Applicable PDS Software Tools

PDS-labeled tables can be viewed with the program NASAView, developed by the PDS. NASAView is available in versions that run on SUN/SOLARIS, Windows, and LINUX operating systems. NASAView can be obtained from the PDS web site http://pds.jpl.nasa.gov/tools/software_download.cfm.

6.3 Software Distribution and Update Procedures

See the NASAView website for distribution and update information.

7. Appendices

7.1 Glossary

Term	Definition
platescale	TBD

7.2 Acronyms

AGC	Automatic Gain Control
APD	Avalanche Photodiode
ARC	Ames Research Center
CCD	Charge Couple Device
CM	Configuration Management
CODMAC	Committee on Data Management and Computation
COTS	Commercial Off The Shelf
CSV	Comma Separated Value
DEM	Digital Electronics Module
DHU	Data Handling Unit
DN	Digital Number
FFC	Flat Field Correction
FPA	Focal Plane Array
GSEOS	Ground Support Equipment Operating System
GSFC	Goddard Space Flight Center
HPF	High Pass Filter
iFOV	Per pixel Field of View
InGaAs	Indium Gallium Arsenide
JPL	Jet Propulsion Laboratory
LCROSS	Lunar Crater Observation and Sensing Satellite
LPF	Low Pass Filter
LUT	Lookup table
MEMs	MicroElectroMechanical Systems
MET	Mission Elapsed Time
MIR1	Mid Infrared Camera 1
MIR2	Mid Infrared Camera 2
NAIF	Navigation and Ancillary Information Facility
NaN	Not a Number
NASA	National Aeronautics and Space Administration
NIR1	Near Infrared Camera 1
NIR2	Near Infrared Camera 2
NSP1	Near Infrared Spectrometer 1
NSP2	Near Infrared Spectrometer 2
NTSC	National Television System Committee (analog video standard)
OPR	OPeRating mode of NIR cameras
PDS	Planetary Data System
PNG	Portable Network Graphics (image format)
RGB	Red-green-blue
SCLK	Spacecraft Clock Kernel
SEM	Sensor Electronics Module
SIS	Software Interface Specification
SMA	Safety & Mission Assurance
TEC	Thermal Electric Cooler
TLP	Total Luminance Photometer
UTC	Universal Coordinated Time
VIS	Visible Camera
VSP	Visible Spectrometer

7.3 Example PDS Labels

This section contains samples for a representative sampling of LCROSS image and spectrum data products.

7.3.1 Visible Camera Raw

```
PDS_VERSION_ID          = PDS3

/*          FILE FORMAT AND LENGTH */

RECORD_TYPE                     = FIXED_LENGTH
RECORD_BYTES                    = 2160
FILE_RECORDS                    = 486

/*          POINTERS TO START RECORDS OF OBJECTS IN FILE */

^IMAGE                          = "LCROSS_VIS_RAW_20091009113127258.IMG"

/*          IMAGE DESCRIPTION */

DATA_SET_ID                     = "LCROSS-E/L-VIS-2-RAW-V1.0"
PRODUCT_ID                      = "LCROSS_VIS_RAW_20091009113127258"
PRODUCT_TYPE                    = RAW_IMAGE
PRODUCER_INSTITUTION_NAME       = "AMES RESEARCH CENTER"
MISSION_NAME                    = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
MISSION_PHASE_NAME              = "IMPACT"
INSTRUMENT_HOST_NAME            = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
INSTRUMENT_HOST_ID              = "LCROSS"
INSTRUMENT_NAME                 = "VISIBLE CAMERA"
INSTRUMENT_ID                   = "VIS"
TARGET_NAME                     = MOON
START_TIME                      = 2009-10-09T11:31:27.225
STOP_TIME                       = 2009-10-09T11:31:27.258
SPACECRAFT_CLOCK_START_COUNT    = "000003460409302"
SPACECRAFT_CLOCK_STOP_COUNT     = "000003460409335"
PRODUCT_CREATION_TIME           = 2009-10-09T11:31:27.258
SC_TARGET_POSITION_VECTO        = { 92.86416092282, -216.08985988898, 527.35534980086 }
SC_SUN_POSITION_VECTOR          = { -143560297.514943, -38510059.613195, -16711209.21401 }
INTERCEPT_POINT_LATITUDE        = -84.64
INTERCEPT_POINT_LONGITUDE       = 311.262
INSTRUMENT_TEMPERATURE          = 19.45
INSTRUMENT_TEMPERATURE_COUNT    = 3110

/*          DESCRIPTION OF OBJECTS CONTAINED IN FILE */

OBJECT                          = IMAGE
  BANDS                         = 3
  BAND_STORAGE_TYPE             = SAMPLE_INTERLEAVED
  BAND_NAME                     = "N/A"
  BAND_SEQUENCE                 = "(RED, GREEN, BLUE)"
  LINES                         = 486
  LINE_SAMPLES                  = 720
  SAMPLE_TYPE                   = MSB_UNSIGNED_INTEGER
  SAMPLE_BITS                   = 8
  SAMPLE_BIT_MASK               = 2#11111111#
  OFFSET                        = 0
  SCALING_FACTOR                = 1
  VALID_MINIMUM                 = 0
  VALID_MAXIMUM                 = 255
END_OBJECT                      = IMAGE
END
```

7.3.2 Near Infrared Camera Calibrated

```
PDS_VERSION_ID          = PDS3
PDS_VERSION_ID          = PDS3

/*          FILE FORMAT AND LENGTH */

RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 2880
FILE_RECORDS                   = 486

/*          POINTERS TO START RECORDS OF OBJECTS IN FILE */

^IMAGE                         = "LCROSS_NIR2_CAL_20091009113128456.IMG"

/*          IMAGE DESCRIPTION */

DATA_SET_ID                    = "LCROSS-E/L-NIR2-3-CAL-V1.0"
PRODUCT_ID                     = "LCROSS_NIR2_CAL_20091009113128456"
PRODUCER_INSTITUTION_NAME      = "AMES RESEARCH CENTER"
PRODUCT_TYPE                   = CALIBRATED_IMAGE
MISSION_NAME                   = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
MISSION_PHASE_NAME             = "IMPACT"
INSTRUMENT_HOST_NAME           = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
INSTRUMENT_HOST_ID             = "LCROSS"
INSTRUMENT_NAME                = "NEAR INFRARED CAMERA 2"
INSTRUMENT_ID                  = "NIR2"
TARGET_NAME                    = MOON
START_TIME                     = 2009-10-09T11:31:28.456
STOP_TIME                      = 2009-10-09T11:31:28.456
SPACECRAFT_CLOCK_START_COUNT   = "000003460410533"
SPACECRAFT_CLOCK_STOP_COUNT    = "000003460410533"
PRODUCT_CREATION_TIME          = 2009-10-09T11:31:28.456
SC_TARGET_POSITION_VECTOR      = { 92.42284444544, -215.16224048904, 524.9271412944 }
SC_SUN_POSITION_VECTOR         = { -143560288.020447, -38510085.2533, -16711222.119592 }
INTERCEPT_POINT_LATITUDE       = -84.639
INTERCEPT_POINT_LONGITUDE      = 311.274
INSTRUMENT_TEMPERATURE         = 19.45
INSTRUMENT_TEMPERATURE_COUNT   = 3110
LCROSS:NIR_ENHANCEMENT_MODE    = OFF
LCROSS:NIR_OPR                 = 5
LCROSS:NIR_INTEGRATION_TIME    = 610
LCROSS:NIR_GAIN                = 2200

/*          DESCRIPTION OF OBJECTS CONTAINED IN FILE */

OBJECT                         = IMAGE
  BANDS                        = 1
  BAND_NAME                    = "N/A"
  LINES                        = 486
  LINE_SAMPLES                 = 720
  SAMPLE_TYPE                  = PC_REAL
  SAMPLE_BITS                  = 32
  SAMPLE_BIT_MASK              = 2#11111111111111111111111111111111#
  OFFSET                       = 0
  SCALING_FACTOR               = 1
  VALID_MINIMUM                = 0.000
  VALID_MAXIMUM                = 0.200
  UNIT                         = "WATT*M**-2*SR**-1"
END_OBJECT                     = IMAGE
END
```

7.3.3 Mid Infrared Camera Raw

```
PDS_VERSION_ID          = PDS3

/*          FILE FORMAT AND LENGTH */

RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 320
FILE_RECORDS                   = 120

/*          POINTERS TO START RECORDS OF OBJECTS IN FILE */

^IMAGE                         = "LCROSS_MIR1_RAW_20091009113021512.IMG"

/*          IMAGE DESCRIPTION */

DATA_SET_ID                    = "LCROSS-E/L-MIR1-2-RAW-V1.0"
PRODUCT_ID                     = "LCROSS_MIR1_RAW_20091009113021512"
PRODUCT_TYPE                   = RAW_IMAGE
PRODUCER_INSTITUTION_NAME      = "AMES RESEARCH CENTER"
MISSION_NAME                   = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
MISSION_PHASE_NAME             = "IMPACT"
INSTRUMENT_HOST_NAME           = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
INSTRUMENT_HOST_ID             = "LCROSS"
INSTRUMENT_NAME                = "MID INFRARED CAMERA 1"
INSTRUMENT_ID                  = "MIR1"
TARGET_NAME                    = MOON
START_TIME                     = 2009-10-09T11:30:21.479
STOP_TIME                      = 2009-10-09T11:30:21.512
SPACECRAFT_CLOCK_START_COUNT   = "000003460344556"
SPACECRAFT_CLOCK_STOP_COUNT    = "000003460344589"
PRODUCT_CREATION_TIME          = 2009-10-09T11:30:21.512
SC_TARGET_POSITION_VECTOR      = { 116.97958275456, -269.24699237472, 657.80715174912 }
SC_SUN_POSITION_VECTOR          = { -143560924.200995, -38508367.280247, -16710357.569437
}
INTERCEPT_POINT_LATITUDE       = -84.649
INTERCEPT_POINT_LONGITUDE      = 311.419
INSTRUMENT_TEMPERATURE         = 19.42
INSTRUMENT_TEMPERATURE_COUNT   = 3111
INST_GAIN_STATE                = HIGH
MISSING_PACKET_FLAG            = NO

/*          DESCRIPTION OF OBJECTS CONTAINED IN FILE */

OBJECT                         = IMAGE
  BANDS                        = 1
  BAND_NAME                    = "N/A"
  LINES                        = 120
  LINE_SAMPLES                 = 160
  SAMPLE_TYPE                  = MSB_UNSIGNED_INTEGER
  SAMPLE_BITS                  = 16
  SAMPLE_BIT_MASK              = 2#1111111111111111#
  OFFSET                       = 0
  SCALING_FACTOR               = 1
  VALID_MINIMUM                = 0
  VALID_MAXIMUM                = 16383
END_OBJECT                     = IMAGE
END
```

7.3.4 Near Infrared Spectrometer Calibrated

```
PDS_VERSION_ID                = PDS3

/*          FILE FORMAT AND LENGTH */

RECORD_TYPE                   = FIXED_LENGTH
RECORD_BYTES                  = 10
FILE_RECORDS                  = 100

/*          POINTERS TO START RECORDS OF OBJECTS IN FILE */

^SPECTRUM                     = "LCROSS_NSP1_CAL_20091009113021491.TAB"

/*          DESCRIPTION */

DATA_SET_ID                   = "LCROSS-E/L-NSP1-3-CAL-V1.0"
PRODUCT_ID                    = "LCROSS_NSP1_CAL_20091009113021491"
PRODUCT_TYPE                  = CALIBRATED_SPECTRUM
PRODUCER_INSTITUTION_NAME     = "AMES RESEARCH CENTER"
MISSION_NAME                  = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
MISSION_PHASE_NAME            = "IMPACT"
INSTRUMENT_HOST_NAME          = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
INSTRUMENT_HOST_ID            = "LCROSS"
INSTRUMENT_NAME               = "NEAR INFRARED SPECTROMETER 1"
INSTRUMENT_ID                 = "NSP1"
TARGET_NAME                   = MOON
START_TIME                    = 2009-10-09T11:30:20.991
STOP_TIME                     = 2009-10-09T11:30:21.491
SPACECRAFT_CLOCK_START_COUNT  = "000003460344068"
SPACECRAFT_CLOCK_STOP_COUNT   = "000003460344568"
PRODUCT_CREATION_TIME         = 2009-10-09T11:30:21.491
SC_TARGET_POSITION_VECTOR     = { 116.99041926864, -269.26724978868, 657.84661062228 }
SC_SUN_POSITION_VECTOR         = { -143560924.200995, -38508367.280247, -16710357.569437
}
INTERCEPT_POINT_LATITUDE      = -84.649
INTERCEPT_POINT_LONGITUDE     = 311.419
INSTRUMENT_TEMPERATURE        = 16.52
INSTRUMENT_TEMPERATURE_COUNT  = 3201
LCROSS:SATURATION_FLAG        = N
LCROSS:BORESIGHT_TO_SUN       = 99.308

/*          DESCRIPTION OF OBJECTS CONTAINED IN FILE */

OBJECT                        = SPECTRUM
  INTERCHANGE_FORMAT          = ASCII
  ROWS                        = 100
  ROW_BYTES                   = 13
  COLUMNS                     = 1
  SAMPLING_PARAMETER_NAME     = "WAVELENGTH"
  MINIMUM_SAMPLING_PARAMETER  = 1.16932
  MAXIMUM_SAMPLING_PARAMETER  = 2.47862
  SAMPLING_PARAMETER_UNIT     = "MICROMETER"
  DESCRIPTION                 = "Near infrared spectrum organized as 1
                                 column with 100 rows.  The CALIB directory
                                 contains the pixel to wavelength mapping."

    OBJECT                    = COLUMN
      NAME                    = FLUX
      DATA_TYPE               = ASCII_REAL
      START_BYTE              = 1
      BYTES                   = 11
      UNIT                    = "WATT*MICRON**-1*M**-2*SR**-1"
    END_OBJECT                = COLUMN
END_OBJECT                    = SPECTRUM
END
```

7.3.5 Visible Spectrometer Raw

```
PDS_VERSION_ID                 = PDS3

/*          FILE FORMAT AND LENGTH */

RECORD_TYPE                    = FIXED_LENGTH
RECORD_BYTES                   = 7
FILE_RECORDS                   = 1044

/*          POINTERS TO START RECORDS OF OBJECTS IN FILE */

^SPECTRUM                      = ("LCROSS_VSP_RAW_20091009113018817.TAB",1)
^TABLE                         = ("LCROSS_VSP_RAW_20091009113018817.TAB",1025)

/*           DESCRIPTION */

DATA_SET_ID                    = "LCROSS-E/L-VSP-2-RAW-V1.0"
PRODUCT_ID                     = "LCROSS_VSP_RAW_20091009113018817"
PRODUCT_TYPE                   = RAW_SPECTRUM
PRODUCER_INSTITUTION_NAME      = "AMES RESEARCH CENTER"
MISSION_NAME                   = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
MISSION_PHASE_NAME             = "IMPACT"
INSTRUMENT_HOST_NAME           = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"
INSTRUMENT_HOST_ID             = "LCROSS"
INSTRUMENT_NAME                = "VISIBLE SPECTROMETER"
INSTRUMENT_ID                  = "VSP"
TARGET_NAME                    = MOON
START_TIME                     = 2009-10-09T11:30:18.317
STOP_TIME                      = 2009-10-09T11:30:18.817
SPACECRAFT_CLOCK_START_COUNT   = "000003460340317"
SPACECRAFT_CLOCK_STOP_COUNT    = "000003460340817"
PRODUCT_CREATION_TIME          = 2009-10-09T11:30:18.817
SC_TARGET_POSITION_VECTOR      = { 118.44073980942, -271.93659351141, 662.83106986707 }
SC_SUN_POSITION_VECTOR         = { -143560952.689118, -38508290.351354, -16710318.86613 }
INTERCEPT_POINT_LATITUDE       = -84.652
INTERCEPT_POINT_LONGITUDE      = 311.66
INSTRUMENT_TEMPERATURE         = 15.97
INSTRUMENT_TEMPERATURE_COUNT   = 3218
LCROSS:SATURATION_FLAG         = N
EXPOSURE_DURATION              = 0.500
LCROSS:TEC_SETPOINT            = -10.00
LCROSS:TEC_TEMPERATURE         = -10.90
LCROSS:PACKET_TIMESTAMP        = "3460345242"
LCROSS:VSP_BRACKET_NUMBER      = 1

/*          DESCRIPTION OF OBJECTS CONTAINED IN FILE */

OBJECT                         = SPECTRUM
  INTERCHANGE_FORMAT           = ASCII
  ROWS                         = 1024
  ROW_BYTES                    = 7
  COLUMNS                      = 1
  SAMPLING_PARAMETER_NAME      = "WAVELENGTH"
  MINIMUM_SAMPLING_PARAMETER   = 262.984
  MAXIMUM_SAMPLING_PARAMETER   = 650.300
  SAMPLING_PARAMETER_UNIT      = "NANOMETER"
  DESCRIPTION                  = "VSP spectrum organized as 1 column with
                                  1024 rows plus non-spectral pixels.  The
                                  CALIB directory contains the pixel to wavelength
                                  mapping"

    OBJECT                       = COLUMN
      NAME                       = COUNTS
      DATA_TYPE                  = ASCII_INTEGER
      START_BYTE                 = 1
      BYTES                      = 5
    END_OBJECT                   = COLUMN
```

```
END_OBJECT                      = SPECTRUM

OBJECT                          = TABLE
  INTERCHANGE_FORMAT            = ASCII
  ROWS                          = 20
  ROW_BYTES                     = 7
  COLUMNS                       = 1
  DESCRIPTION                   = "Non-spectral pixels"

  OBJECT                        = COLUMN
    NAME                        = NON_SPECTRAL_PIXELS
    DATA_TYPE                   = ASCII_INTEGER
    START_BYTE                  = 1
    BYTES                       = 5
  END_OBJECT                    = COLUMN
END_OBJECT                      = TABLE
END
```

7.3.6 Total Luminance Photometer Calibrated

```
PDS_VERSION_ID              = PDS3
RECORD_TYPE                 = FIXED_LENGTH
RECORD_BYTES                = 36
FILE_RECORDS                = 237692
^TABLE                      = "LCROSS_TLP_CAL_20091009104100_IMPACT.TAB"
PRODUCER_INSTITUTION_NAME = "AMES RESEARCH CENTER"
MISSION_NAME                = "LUNAR CRATER OBSERVATION AND SENSING SATELLITE"

OBJECT                      = TABLE
  INTERCHANGE_FORMAT        = ASCII
  ROWS                      = 237692
  COLUMNS                   = 6
  ROW_BYTES                 = 36
  DESCRIPTION               = "Total Luminance Photometer data is organized as a
                                table with a varying number of rows.  The columns represent
                                time and volts."
  OBJECT                    = COLUMN
    NAME                    = TIME
    DATA_TYPE               = CHARACTER
    START_BYTE              = 2
    BYTES                   = 23
  END_OBJECT                = COLUMN
  OBJECT                    = COLUMN
    NAME                    = VOLTAGE
    DATA_TYPE               = ASCII_REAL
    START_BYTE              = 27
    BYTES                   = 10
    UNIT                    = V
  END_OBJECT                = COLUMN
END_OBJECT                  = TABLE
END
```

7.4 Keywords appearing in the labels

Keyword	Definition
BANDS	The BANDS element indicates the number of bands in an image or other object.
BAND_NAME	BAND_NAME is the name given to a single band in a multi-band image or image qube. If the band is a spectral band, BAND_NAME refers to the associated spectral range; for example, RED, GREEN, BLUE, 415nm, 750nm, 900nm. Examples of names of non-spectral bands are 'Phase angle', 'Thermal inertia', 'Bolometric albedo', 'Latitude', 'Elevation in meters relative to MOLA'.
BAND_SEQUENCE	The band_sequence element identifies the order in which spectral bands are stored in an image or other object. Note: In the PDS, this data element is used to identify the primary colors composing a true color image. The standard values that appear in sets of three support color image display. They are not appropriate for describing multi-spectral bands. For these, it is advisable to use the sampling_parameter keywords defined elsewhere in the PSDD.

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.
BYTES	The bytes element indicates the number of bytes allocated for a particular data representation. When BYTES describes an object with variable length (e.g., FIELD), BYTES gives the maximum number of bytes allowed.
COLUMNS	The columns element represents the number of columns in each row of a data object.
DATA_SET_ID	The data_set_id element is a unique alphanumeric identifier for a data set or a data product. The data_set_id value for a given data set or product is constructed according to flight project naming conventions. In most cases the data_set_id is an abbreviation of the data_set_name. Example value: MR9/VO1/VO2-M-ISS/VIS-5-CLOUD-V1.0.
DATA_TYPE	The data_type element supplies the internal representation and/or mathematical properties of a value being stored. When DATA_TYPE is used within a FIELD object definition, its value applies only when the field is populated.
DESCRIPTION	The description element provides a free-form, unlimited-length character string that represents or gives an account of something.
EXPOSURE_DURATION	The exposure_duration element provides the value of the time interval between the opening and closing of an instrument aperture (such as a camera shutter). Note: For MPF, the IMP camera does not have a shutter in the traditional sense, so this value is the integration time for manual and automatic exposures.
FILE_RECORDS	The file_records element indicates the number of physical file records, including both label records and data records.
IMAGE	An image object is a regular array of sample values. Image objects are normally processed with special display tools to produce a visual representation of the sample values. This is done by assigning brightness levels or display colors to the various sample values. Images are composed of LINES and SAMPLES. They may contain multiple bands, in one of several storage orders.

INSTRUMENT_HOST_ID	The instrument_host_id element provides a unique identifier for the host where an instrument is located. This host can be either a spacecraft or an earth base (e.g., and observatory or laboratory on the earth). Thus, the instrument_host_id element can contain values which are either spacecraft_id values or earth_base_id values.
INSTRUMENT_HOST_NAME	The instrument_host_name element provides the full name of the host on which an instrument is based. This host can be either a spacecraft or an earth base. Thus, the instrument_host_name element can contain values which are either spacecraft_name values or earth_base_name values.
INSTRUMENT_ID	The instrument_id element provides an abbreviated name or acronym which identifies an instrument. Note: The instrument_id is not a unique identifier for a given instrument.
INSTRUMENT_NAME	The instrument_name element provides the full name of an instrument.
INSTRUMENT_TEMPERATURE	The INSTRUMENT_TEMPERATURE element provides the temperature, in degrees Celsius, of an instrument or some part of an instrument. This keyword may be used in conjunction with INSTRUMENT_TEMPERATURE_POINT to more fully describe either single or multiple temperatures at various locations within a single instrument. If there is more than one measurement taken for a given instrument, a multi- value ordered set of values (i.e., sequence) may be constructed to associate each temperature measurement in the INSTRUMENT_TEMPERATURE list with a corresponding item in the INSTRUMENT_TEMPERATURE_POINT sequence of values.
INSTRUMENT_TEMPERATURE_COUNT	The instrument_temperature_count element provides the instrument temperature in raw counts or DN values.
INST_GAIN_STATE	The INST_GAIN_STATE element indicates the gain state of the Mini-TES analog signal amplifier. Valid values are LOW and HIGH.
INTERCEPT_POINT_LATITUDE	The intercept_point_latitude element provides the latitude of a point on the body surface. This intercept point can describe the point at which lighting geometry is calculated or the point at which the target body resolution is calculated.

INTERCEPT_POINT_LONGITUDE	The intercept_point_longitude element provides the longitude of a point on the body surface. This intercept point can describe the point at which lighting geometry is calculated or the point at which the target body resolution is calculated.
INTERCHANGE_FORMAT	The interchange_format element represents the manner in which data items are stored. Example values: BINARY, ASCII.
LCROSS:BORESIGHT_TO_SUN	Angle between the instrument boresight vector and the spacecraft to sun vector in degrees
LCROSS:MIR_CAL_VALID	The response of the mid-IR cameras exhibited a startup transient. The calibration is valid only after this transient had settled. This keyword indicates whether the image was taken before or after this point. Its values are Y and N.
LCROSS:NIR_ENHANCEMENT_MODE	Indicates whether in-camera image stretching was enabled or disabled. Values are ON and OFF.
LCROSS:NIR_GAIN	Focal plane sensitivity in electrons per count. Value is approximate and inferred from the OPR value and the factory OPR definitions.
LCROSS:NIR_INTEGRATION_TIME	The integration time in msec.
LCROSS:NIR_OPR	Operational setting number, from 0 to 15. The OPR setting determines the integration time and gain.
LCROSS:PACKET_TIMESTAMP	A 32 bit unsigned integer representing time from the GPS epoch of Jan 1st, 1980 in milliseconds. Note a 32 bit millisecond counter wraps in ~50 days, so mapping its value to UTC requires additional information such as the date the packets were generated. This timestamp is assigned by one of three clocks depending on which Data Handling Unit circuit board was connected to the instrument that generated the data in the packet. This mapping is described in the LCROSS Instrument Calibration Summary.
LCROSS:SATURATION_FLAG	Indicates whether a spectra is saturated based on a mechanical test.
LCROSS:TEC_SETPOINT	Applies to VSP packets only. Indicates the setpoint of the Thermo-Electric Cooler in degrees C.
LCROSS:TEC_TEMPERATURE	Applies to VSP packets only. Indicates the measured temperature of the Thermo-Electric Cooler in degrees C.
LCROSS:VSP_BRACKET_NUMBER	Applies to VSP packets only. When in ‘bracket’ mode, the VSP captures three spectra in quick succession, varying the integration time between

	each to 'bracket' a given, nominal integration time. This approach was used to manage uncertainty about what the proper integration time should be. The bracket number indicates whether the spectra is first, second or third within one of those triples and is useful for tracking back to identify where in the downlinked packet the spectra was stored.
LABEL_RECORDS	The label_records element indicates the number of physical file records that contain only label information. The number of data records in a file is determined by subtracting the value of label_records from the value of file_records.
LINES	The lines element indicates the total number of data instances along the vertical axis of an image. Note: In PDS label convention, the number of lines is stored in a 32-bit integer field. The minimum value of 0 indicates no data received.
LINE_SAMPLES	The line_samples element indicates the total number of data instances along the horizontal axis of an image.
MAXIMUM_SAMPLING_PARAMETER	The maximum_sampling_parameter element identifies the maximum value at which a given data item was sampled. For example, a spectrum that was measured in the 0.4 to 3.5 micrometer spectral region would have a maximum_sampling_parameter value of 3.5. The sampling parameter constrained by this value is identified by the sampling_parameter_name element.
MINIMUM_SAMPLING_PARAMETER	The minimum_sampling_parameter element identifies the minimum value at which a given data item was sampled. For example, a spectrum that was measured in the 0.4 to 3.5 micrometer spectral region would have a minimum_sampling_parameter value of 0.4. The sampling parameter constrained by this value is identified by the sampling_parameter_name element.
MISSING_CONSTANT	The missing_constant element supplies the value used to indicate that no data were available.
MISSING_PACKET_FLAG	Applies to MIR images only. Indicates whether the image is missing data. Each image was assembled from 20 telemetry packets. A missing packet appears as a horizontal bar 8 pixels high of zero data. This flag indicates whether an image contains one or more such bars.
MISSION_NAME	The mission_name element identifies a major planetary mission or project. A given planetary mission may be associated with one or more

	spacecraft.
MISSION_PHASE_NAME	The mission_phase_name element provides the commonly-used identifier of a mission phase.
NAME	The name data element indicates a literal value representing the common term used to identify an element or object. See also: 'id'.
NOT_APPLICABLE_CONSTANT	The not_applicable_constant element supplies the numeric value used to represent the figurative constant 'N/A'. 'N/A' (Not Applicable) is defined as indicating when values within the domain of a particular data element do not apply in a specific instance.
NOTE	The note element is a text field which provides miscellaneous notes or comments (for example, concerning a given data set or a given data processing program).
OBSERVATION_ID	The observation_id element uniquely identifies a scientific observation within a data set.
OFFSET	The offset element indicates a shift or displacement of a data value. See also: scaling_factor. Note: Expressed as an equation: true value = offset value + (scaling factor x stored value).
PDS_VERSION_ID	The PDS_version_id data element represents the version number of the PDS standards documents that is valid when a data product label is created. Values for the PDS_version_id are formed by appending the integer for the latest version number to the letters 'PDS'. Examples: PDS3, PDS4.
PRODUCER_INSTITUTION_NAME	The producer_institution_name element identifies a university, research center, NASA center or other institution associated with the production of a data set. This would generally be an institution associated with the element producer_full_name.
PRODUCT_CREATION_TIME	The product_creation_time element defines the UTC system format time when a product was created. Formation rule: YYYY-MM-DDThh:mm:ss[.fff]
PRODUCT_ID	The product_id data element represents a permanent, unique identifier assigned to a data product by its producer. See also: source_product_id.
PRODUCT_TYPE	The PRODUCT_TYPE data element identifies the type or category of a product within a data set. Examples: EDR, DOCUMENT, CALIBRATION_IMAGE, SPICE_SP_KERNEL, TRAJECTORY.

RECORD_BYTES	The record_bytes element indicates the number of bytes in a physical file record, including record terminators and separators. When RECORD_BYTES describes a file with RECORD_TYPE = STREAM (e.g. a SPREADSHEET), its value is set to the length of the longest record in the file.
RECORD_TYPE	The record_type element indicates the record format of a file. Note: In the PDS, when record_type is used in a detached label file it always describes its corresponding detached data file, not the label file itself. The use of record_type along with other file-related data elements is fully described in the PDS Standards Reference.
ROWS	The rows element represents the number of rows in a data object.
ROW_BYTES	The row_bytes element represents the maximum number of bytes in each data object row.
SAMPLE_BITS	The sample_bits element indicates the stored number of bits, or units of binary information, contained in a line_sample value.
SAMPLE_BIT_MASK	The sample_bit_mask element identifies the active bits in a sample. Note: In the PDS, the domain of sample_bit_mask is dependent upon the currently-described value in the sample_bits element and only applies to integer values. For an 8-bit sample where all bits are active the sample_bit_mask would be 2#11111111#.
SAMPLE_TYPE	The sample_type element indicates the data storage representation of sample value.
SAMPLING_PARAMETER_INTERVAL	The sampling_parameter_interval element identifies the spacing of points at which data are sampled and at which a value for an instrument or dataset parameter is available. This sampling interval can be either the original (raw) sampling or the result of some resampling process. For example, in 48-second magnetometer data the sampling interval is 48. The sampling parameter (time, in the example) is identified by the sampling_parameter_name element.
SAMPLING_PARAMETER_NAME	The sampling_parameter_name element provides the name of the parameter which determines the sampling interval of a particular instrument or dataset parameter. For example, magnetic field intensity is sampled in time increments, and a spectrum is sampled in wavelength or frequency.

SAMPLING_PARAMETER_UNIT	The sampling_parameter_unit element specifies the unit of measure of associated data sampling parameters.
SCALING_FACTOR	The scaling factor element provides the constant value by which the stored value is multiplied. See also: offset.
SC_SUN_POSITION_VECTOR	The sc_sun_position_vector element indicates the x-, y-, and z- components of the position vector from observer to sun, center expressed in J2000 coordinates, and corrected for light time and stellar aberration, evaluated at epoch at which image was taken.
SC_TARGET_POSITION_VECTOR	The sc_target_position_vector element indicates the x-, y-, z- components of the position vector from observer to target center expressed in J2000 coordinates, and corrected for light time and stellar aberration, evaluated at epoch at which image was taken. For the LCROSS data, the target is the intersection of the payload or instrument boresight and the surface of the target body (Moon or Earth). For the PREIMPACT and IMPACT data collection periods, the length of this vector can be taken as a good approximation of altitude.
SPACECRAFT_CLOCK_START_COUNT	The spacecraft_clock_start_count element provides the value of the pacecraft clock at the beginning of a time period of interest.
SPACECRAFT_CLOCK_STOP_COUNT	The spacecraft_clock_stop_count element provides the value of the spacecraft clock at the end of a time period of interest.
SPACECRAFT_NAME	The spacecraft_name element provides the full, unabbreviated name of a spacecraft. See also: spacecraft_id, instrument_host_id.
START_BYTE	The start_byte element in a data object identifies the location of the first byte of the object, counting from 1. For nested objects, the start_byte value is relative to the start of the enclosing object.
START_TIME	The start_time element provides the date and time of the beginning of an event or observation (whether it be a spacecraft, ground-based, or system event) in UTC. Formation rule: YYYY-MM-DDThh:mm:ss[.fff].
STOP_TIME	The stop_time element provides the date and time of the end of an observation or event (whether it be a spacecraft, ground-based, or system event) in UTC. Formation rule: YYYY-MM-DDThh:mm:ss[.fff].

TARGET_NAME	The target_name element identifies a target. The target may be a planet, satellite,ring,region, feature, asteroid or comet. See target_type.
UNIT	The unit element provides the full name or standard abbreviation of a unit of measurement in which a value is expressed. Example values: square meter, meter per second. Note: A table of standard units representing those published by the Systeme Internationale appears in the 'Units of Measurement' section of the PSDD. (Please refer to the table of contents for its location.) The values in this table's 'Unit Name' column constitute the standard values for the data element UNIT.
VALID_MAXIMUM	The valid_maximum data element represents the maximum value that is valid for a data object. Valid_minimum and valid_maximum define the valid range of values for a data object, such as -90 to 90 for a column object containing latitude values.