Data Introduction: New Horizons Spacecraft, LORRI Instrument

This is an abbreviated guide to the main elelements of this [instrument] data set to provide an overview and a quick path to viewing the data. Many details and subtleties regarding these data have been excluded here tfor the sake of brevity and clarity; those who plan to perform scientific analysis on these data must read the documentation referenced by or provided in this data set.

Instrument and Operations:

The LOng Range Reconnaissance Imager (LORRI) is a narrow angle (FOV=0.29deg), high resolution (IFOV=5microradian), Ritchey-Chrétien telescope with a 20.8 cm diameter primary mirror, a focal length of 263 cm, and a three lens field-flattening assembly. A 1024 x 1024 pixel (optically active region) CCD detector located at the telescope focal plane operates in standard frame-transfer mode. LORRI does not have any color filters; it provides panchromatic imaging over a wide bandpass extending approximately from 350 nm to 850 nm. The LORRI telescope is designed to maintain focus over the entire operating temperature range (-125 C to +40 C) without a focus adjustment mechanism. For further details see [CONARDETAL2005] (instrument design and fabrication), [MORGANETAL2005] (instrument calibration), and [CHENGETAL2008] (LORRI-specific mission overview); see also the Science Operations Center to Instrument Interface Control Document (ICD; files SOC_INST_ICD*.* under the DOCUMENT/ directory).

The LORRI adds significant capabilities to New Horizons, including the highest available spatial resolution (50 m/pixel at the Pluto closest approach distance of 10,000 km) and redundancy for the primary optical imager, MVIC on Ralph.

The exposure time for LORRI is adjustable in 1ms increments from 0 to 29,967ms. A frame transfer (readout) smear removal algorithm developed permits practical exposure times as short as 1ms. The LORRI exposure time can be commanded to a specific value, or LORRI can be operated in “auto-exposure” mode, in which the LORRI flight software sets the exposure time automatically based on the signal level in a previous image. The spacecraft attitude drift is nominally !25-30 microradian/s; LORRI was designed for an exposure time range of 50 to 200ms, with 100ms as the nominal design value; or the nominal exposure time, the typical spacecraft drift is less than 1 pixel.

LORRI can be operated in “rebin” mode in which case the signal in a 4 x 4 pixel region is summed on-chip to produce an active region that is 256 x 256 pixels covering the same full FOV as the unbinned mode. The main purpose of rebin mode is to provide high sensitivity acquisition of faint objects requiring an exposure time of ~10 sec. Rebin-mode data may also be referred to as binned, 4x4 and/or 256x256. This is as opposed to the terms unbinned, 1x1, and/or 1024x1024, referring to data that are not summed on-chip.

LORRI has two onboard lamps that are used for in-flight testing of basic functionality; LORRI may be commanded to return one of four fixed test patterns instead of brightness data from the CCD.

In addition to image data from the optically-active region of the CCD, four (unbinned) or one (binned) pixels per row of dark reference data are downlinked with each image. The median of these pixels is used as the basis of the bias subtraction.

Each raw pixel datum, excluding test pattern modes, is the result of a 12-bit Analog-to-Digital Conversion (ADC), so the raw pixel values (Data Numbers; DNs) theoretically range is 0 to 4095DN (ADC saturation); in practice the ADC electrical bias sets the lower limit for real brightness data at 546-547DN for typical operating temperatures.

The first 34 pixels (408 bits; 51 8-bit bytes) of raw pixel data are overwritten on-board by a synoptic image header (time tag, voltage and temperature analog measurements, exposure and mode settings, etc.). The image (brightness) data from those pixels are not recoverable.

LORRI data may be windowed as part of the on-board compression and downlink sequence commanding. That is, up to eight sub-rectangles of the entire 1024x1024 or 256x256 image may be present in telemetry radiated to Earth, for the purpose of saving downlink bandwidth.

Directory- and file-names: data/YYYYMMDD_METMET/lor_metmetmetm_0xaaa_ttt_v.sfx

The data are all stored as file pairs of one detached PDS label and one FITS file per exposure. The directory and file names are delimited by underscores and slashes as demonstrated above: ***YYYYMMDD*** is year, month and day-of-month; ***METMET*** is the first six digits of the ten-digit MET clock (Mission Event Time; ~spacecraft seconds since launch); ***lor*** is the prefix for LORRI data; ***metmetmetm*** is the full ten-digit MET of the image; ***0xaaa*** is the Application (Process) Identifier (ApID) for the telemetry data packet type; ***ttt*** is either ***eng*** or ***sci*** for EDR or RDR data; ***v*** is a version number; ***sfx*** is ***fit*** or ***lbl*** for the FITS or PDS label file.

Searching for data

There is a brief summary of the types of observations in the data set catalog (***catalog/dataset.cat)***. There is also a table of the sequences in the data set documentation (***document/seq_lorri_...)***. Each row in that table provides 1) a sequence ID that matches NEW_HORIZONS:SEQUENCE_ID keywords in data product PDS labels, 2) a time, in UTC & SCLK, just before all observations of that sequence, 3) a brief prose description of the observations. Refer to the sequence table label (***document/seq_lorri_*.lbl)*** for more detail.

Data file contents

Each EDR (raw) image comprises four data objects in the FITS file, described by its detached PDS label. The first data object (PDU; Primary Data Unit) is the image, with the 12-bit data stored in 16-bit integers. An unbinned image is 1028 pixels wide by 1024 pixel high, with the optically-active and -inactive pixels in continuous rows; the binned data size is 257 x 256. The remaining three objects (Extension Data Units; EDUs) are a histogram (EDU 1), the synoptic image header (EDU 2), and housekeeping information from telemetry (EDU 3).

Each RDR (calibrated) image comprises three data objects in the FITS file, described by its PDS label. The first data object (PDU) is the calibrated image in floating point format and DN units. Keywords in the PDS label and FITS header define conversions from DN to radiance (intensity; for diffuse targets) and to irradiance (flux; for point targets) units. The image size is 1024x1024 (unbinned) or 256x256 (binned); the dark reference pixels have been removed. The remaining two objects are error and quality map images of the same size as the PDU image, where each pixel in a map corresponds to the same pixel in the PDU image. The second object (EDU 1) is an error map in floating point format and DN units. The third object (EDU 2) is a quality map in 16-bit integer format, with each bit indicating a quality state (missing data; saturated data; calibration file defects; etc.); a quality pixel value of zero indicates usable data; any non-zero data means the pixel value, both raw and calibrated, is suspect and/or should be ignored. For example, the missing data bit (bit 5; integer 32) will be set for all 34 pixels overwritten by the synoptic image header.

N.B. ***Refer to the ICD for more detail e.g. unit conversion, data quality bit definitions, etc.***

N.B. ***Missing pixel data are typically zeroes in the raw PDU image, and can be due to intentional windowing, telemetry dropouts, etc. In any event, the calibration pipeline will process ALL raw pixel data in the PDU regardless of quality, which may result in unrealistic calibrated values in the PDU. Such values may for example cause confusing contrast stretches when displaying the image. IT IS THE USER'S RESPONSIBILITY to check the quality map FIRST when using or viewing image or map data to understand such apparent anomalies.***

N.B. ***The first 34 raw pixels in the first row (overwritten with the synoptic image header) are replaced with the corresponding raw pixel values from the second row before calibration.***

Image calibration comprises four processing steps: Bias subtraction; Readout smear removal; Flat-fielding; Absolute calibration and conversion to physical units. Refer to the ICD for more detail.

Reading the data

Various tools are available to read these data. In the IDL environment, the READPDS.PRO package from PDS-SBN can read the data using the PDS label to access the accompanying FITS file. To use the FITS file directly, the NASA FITS Office has utilities and libraries in multiple languages and environments (from C to R and beyond). Refer to the documentation provided and referenced at those web sites for support.

N.B. ***Some utilities and libraries refer to the PDU as if it were EDU 0.***