New Horizons LORRI Pluto Encounter Partially Processed Data Overview

During the migration to the Planetary Data System's (PDS) PDS4 data standards, this current description was adapted from the PDS3 dataset catalog file, including updates found in the KEM1 Encounter phase version, providing light edits to the text, format, flow, and to make the description to better conform to this PDS4 data collection.

Abstract

This data set contains Partially Processed data taken by the New Horizons LOng Range Reconnaissance Imager (LORRI) instrument during the PLUTO ENCOUNTER mission phase.

This data set contains LORRI observations taken during the the Approach (Jan-Jul, 2015), Encounter, Departure, and Transition mission sub-phases, including flyby observations taken on 14 July, 2015, and departure and calibration data through late October, 2016. Departure observations include a ring search of the Pluto system and 1994 JR1 observations. This data set completes the Pluto mission phase deliveries for LORRI.

Changes since prior versions include the addition of data downlinked between the end of January, 2016 and the end of October, 2016, completing the delivery of all data covering the Pluto Encounter and subsequent Calibration Campaign. It includes multi-map observations from the Approach phase, observations of the moons, hi-res, full-frame observations from Pluto Encounter and Departure, sliver maps, and ring search observations. There may be some overlap between prior datasets and this dataset, due to only partial, windowed, or lossy data in prior datasets. Observations at closest approach to Pluto are marked with _CA in the Request ID. This dataset also includes functional tests from the Calibration Campaign, including a regular observation of NGC3532. Finally it includes the first set of distant KBO observations.

There were minor changes to the level 2 LORRI calibration process, as well as to the LORRI calibration constants for the final Pluto P3 PDS delivery. The process change involves gap removal during calibration. Files with gaps come in many flavors, depending on where the gap lies within the image. This update recognizes some additional possibilities, mainly that the gap might be close to the bottom or top of the image (and therefore the previous algorithm would fail because it filled the gap with median pixel info from both above and below the gap). The new algorithm will take the info from one side of the gap exclusively, when appropriate.

These data were migrated from the previously released PDS3 data set NH-P-LORRI-3-PLUTO-V3.0.

Data Set Overview

This data set contains Partially Processed data taken by the LOng Range Reconnaissance Imager (LORRI) instrument during the PLUTO ENCOUNTER mission phase. The closest approach to Pluto occurred on July 14, 2015, at approximately 11:50 UTC.

LORRI is a narrow angle (Field Of View, FOV = 0.29 degree square), high resolution (5 microradian/pixel), telescope. A two-dimensional (2-D) CCD (Charged Coupled Device) detector, with 1024x1024 pixels (optically active region) operates in standard frame-transfer mode. LORRI can also perform on-chip 4x4 binning to produce images of 256x256 pixels. LORRI has no color filters and so provides panchromatic imaging over a wide bandpass extending approximately from 350 nm to 850 nm. The common data product is a 2-D image of brightnesses that can be calibrated to physical units once color spectrum information is known. Refer to the Science Operations Center (SOC) Instrument Interface Control Document (ICD) within the PDS for more details (PDS4 LID `urn:nasa:pds:nh_documents:mission:soc_inst_icd`).

During the Pluto Charon Encounter mission phase starting in January, 2015, there were several sub-phases: three Approach sub-phases, (AP1, AP2 and AP3); a CORE sequence for the Pluto flyby on 14 July, 2015 (Day Of Year 195), sometimes also referred to as NEP (Near-Encounter Phase); three Departure sub-phases (DP1, DP2, DP3); a Transition sub-phase closing out the Pluto Encounter mission phase ending in late October, 2016. For this final LORRI delivery for the Pluto mission phase, this data set includes the Approach data plus all CORE, Departure and Transition sequences' data downlinked through the end of October, 2016, including observations of Trans-Neptunian Object (TNO) 15810 Arawn (1994 JR1) and a low-resolution ring search taken in November, 2015. Transition activities in 2016 include observations of several KBOs and a calibration campaign.

This dataset includes (1) Non-Critical and Critical Optical Navigation (OpNav) observations; (2) Hazard observations; (3) Observations of Pluto, Charon, Nix, Hydra, Kerberos, and Styx during Approach; (4) Pluto Encounter observations, from the day before and the day of encounter; (5) Departure observations of Pluto; (6) Departure and Transition observations of TNOs and calibration stars.

Optical Navigation images, identified by NAV in the observation name, were taken regularly up until 2 days before closest approach. This dataset also includes three OpNav images from 2 days after closest approach.

Hazard observations were taken in order to perform a detailed search for any objects that could only be seen as the spacecraft neared the Pluto system. Sets of images were taken about every two weeks starting two months before closest approach. Each set had 8 images, with a mosaic of 4 images at two different roll angles.

Approach observation objectives were to search for changes with pan imaging over multiple rotations, perform satellite photometry to further resolve the orbits of Kerberos, Styx, and possible other bodies, and image Nix and Hydra.

Encounter observation objectives were to obtain maximum resolution imaging of the entire surface of Pluto and Charon at regular longitudinal intervals for cartographic knowledge; to observe Pluto and Charon at a small (12-30 degrees) solar phase angle to support phase integrals; and to obtain regional stereo images of Pluto for stereographic mapping at the

highest possible resolution, which is essential for understanding the relief of features on Pluto, and understanding the magnitude of geologic processes and the origin of geologic features.

Transition observation objectives were to obtain imaging of several KBOs including a light curve sequence of 15810 Arawn, and to execute a post-Pluto calibration campaign to feed back into the calibration of encounter data.

Every observation provided in this data set was taken as a part of a particular sequence. For this data set, these sequences can be found in the LORRI document collection under PDS4 LID `urn:nasa:pds:nh_documents:lorri:seq_lorri_pluto`. Please note that some sequences provided may have zero corresponding observations.

Version History

Each subsection below details the major changes between the prior versions of this data set, listing the newest versions before older versions.

PDS4 v1.0 (migration from PDS3 V3.0)

This data collection was migrated from Planetary Data System's (PDS) PDS3 archive standards to the PDS4 archive standards, which involved changing the PDS formatted product labels. The products themselves have remained unchanged. The major changes from the PDS3 V3.0 data set are:

- the calibration files, documents, and data products were reorganized into separate collections of calibration files, documents, and data products, instead of being in a single package as it was in prior PDS3 data set versions.
- the geometry keyword values found within the PDS4 labels were calculated using the most recent SPICE kernels available at label creation. Note that the FITS headers have not been updated and their geometry keyword values therefore remain unchanged.
- the PDS4 data labels were produced using the PDS3 data labels and/or FITS headers, and so any fixes and/or updates to the PDS3 label pipeline as found in future mission phases may not have been implemented here.

Please note that in PDS3 this data was called calibrated, but the data is not fully calibrated. For PDS4, this data is considered partially processed. Please take note of that where it may say that it is calibrated data.

PDS3 V3.0 (NH-P-LORRI-3-PLUTO-V3.0)

This is VERSION 3.0 of this data set. This P3 Pluto Encounter dataset release includes all data from the previous two Pluto deliveries and adds data that was downlinked from 1/31/2016 through 10/31/2016. This dataset completes delivery of all data covering the Pluto Encounter and subsequent Calibration Campaign.

This dataset contains data from the Pluto Encounter timeframe as well as two ring search observations and imaging of the KBO plutino JR1 in November of 2015.

There were minor changes to the level 2 LORRI calibration process, as well as to the LORRI calibration constants for the final Pluto P3 PDS delivery.

The process change involves gap removal during calibration. Files with gaps come in many flavors, depending on where the gap lies within the image. This update recognizes some additional possibilities, mainly that the gap might be close to the bottom or top of the image (and therefore the previous algorithm would fail because it filled the gap with median pixel info from both above and below the gap). The new algorithm will take the info from one side of the gap exclusively, when appropriate.

As of V3.0, targets for some stars and radio sources have been updated so that the TARGET_NAME keyword in the label is accurate and more descriptive than only STAR or CALIBRATION. However the user should confirm that targets from the data FITS files, if applicable for a given instrument, match the label name, as there are a few instances where the FITS keywords for TARGET, SPCCBTNM, and PNTMTHD are not accurate. The simplest way to check is to instead look at the RA and Dec in the keywords SPCBRRA and SPCBRDEC in the FITS file. This issue mostly only occurs with star targets.

PDS Citation Information: Weaver, H., NEW HORIZONS CALIBRATED LORRI PLUTO ENCOUNTER V3.0, NH-P-LORRI-3-PLUTO-V3.0, NASA Planetary Data System, 2018. https://doi.org/10.26007/6775-8M09

PDS3 V2.0 (NH-P-LORRI-3-PLUTO-V2.0)

This is VERSION 2.0 of this data set. This P2 Pluto Encounter dataset release provides updates to the Pluto dataset between P1 (data on the ground by 7/31/2015) and P2 (data on the ground by 1/31/2016). This dataset contains data that may have been downlinked with lossy compression initially and now has been re-downlinked losslessly. Lossy data from P1 has been regenerated to increase the number of flagged bad pixels in the quality map. All liens from the initial Pluto delivery have also now been resolved. This dataset contains data from the Pluto Encounter timeframe as well as two ring search observations and imaging of the KBO plutino JR1 in November of 2015.

PDS Citation Information: Cheng, A., NEW HORIZONS CALIBRATED LORRI PLUTO ENCOUNTER V2.0, NH-P-LORRI-3-PLUTO-V2.0, NASA Planetary Data System, 2016.

PDS3 V1.0 (NH-P-LORRI-3-PLUTO-V1.0)

This is VERSION 1.0 of this data set. For this first LORRI delivery for the Pluto mission phase, this data set includes only the Approach data plus the subset of the CORE sequence data that was downlinked through the end of July, 2015.

Liens were never resolved for this data set version but will be in the next version.

Citation Information: Cheng, A., NEW HORIZONS CALIBRATED LORRI PLUTO ENCOUNTER V1.0, NH-P-LORRI-3-PLUTO-V1.0, NASA Planetary Data System, 2016.

General statement about data set versions after V1.0

The pipeline (see Processing below) was re-run on these data for each version since the first (V1.0). A pipeline rerun usually changes the FITS headers but not the FITS data of raw data sets. In some cases, partially processed or calibrated FITS data may change because the calculated geometry of an observation has changed. See data set version-specific sections above for significant exceptions to this general statement, i.e., changes to pipeline processing, calibration processing, and data delivered.

An all-instrument Calibration Campaign occurred in July 2016. For most instruments, calibrations were updated as of April 2017 which changed the data in the calibrated data sets. Calibration changes are described in the data set version-specific sections.

Note that even if this is not a partially processed or calibrated data set, calibration changes are listed as the data will have been re-run and there will be updates to the calibration files, to the documentation and to the steps required to calibrate the data.

Processing

The data in this data set were created by a software data processing pipeline on the Science Operations Center (SOC) at the Southwest Research Institute (SwRI), Department of Space Operations. This SOC pipeline assembled data as FITS files from raw telemetry packets sent down by the spacecraft and populated the data labels with housekeeping and engineering values, and computed geometry parameters using SPICE kernels. The pipeline did not resample the data.

Calibration

Detailed information about calibration of LORRI data is available in the SOC Instrument Interface Control Document (ICD) within the PDS (PDS4 LID `urn:nasa:pds:nh_documents:mission:soc_inst_icd`). The LORRI calibration will only be briefly summarized here; refer to the ICD for details about what is summarized here.

N.B. The units of the RDR image data are calibrated Data Number (DN); responsivity factors are provided in the PDS label (within the *nh:Radiometric_Conversion_Constants* class) and FITS headers to convert the calibrated DNs to physical units; the factor to use is dependent on the target scene spectrum. Refer to the ICD and other LORRI documentation, Cheng et al. (2008), Morgan et al. (2005) for more detail. Note also that some versions of Cheng et al. (2008), including the published version, have an error in the units of its Figure 9 ordinate.

The calibration of LORRI images involves all of the following steps in order:

1) Bias subtraction
2) Signal linearization
3) Charge transfer inefficiency (CTI) correction
4) Dark subtraction
5) Smear removal
6) Flat-fielding

7) Absolute calibration (DN with scene-dependent radiance divisors)

Ground testing has demonstrated that the linearization, CTI and dark subtraction steps are not necessary i.e. the output from the Bias subtraction step may be passed directly to Smear removal step.

In addition, the calibration procedure calculates the error and a data quality flag for each pixel and includes those results in the calibrated data product as additional PDS OBJECTs (FITS extensions) appended to the main OBJECT with the data image. The quality flag PDS OBJECT is an image of values of the same size as the main IMAGE product, with each quality flag pixel mapped to the corresponding pixel in the main product. A quality flag value of zero indicates a valid pixel; a non-zero value indicates an invalid pixel. Each quality extension pixel value is an accumulated sum of individual quality flag values. The list below contains the quality flag value associated with each condition:

Quality Flag Value	Quality Flag Description
0	Good pixel
1	Defect in reference deltabias image (0 or NaN)
2	Defect in reference flatfield image (0 or NaN)
4	Permanent CCD defect (e.g. dead pixel) *
8	Hot Pixel identified in hotpixel map *
16	Saturated pixel in level1 data (A/D value of 4095)
32	Missing level1 data (assume fill value of 0)
64	unused at present

Note that for windowed products, all pixels in an image are not returned in the downlink telemetry. In the raw data, the pipeline sets such pixels to zero DN (Data Number); the calibration processes those zero-DN pixels as if they were real raw values, but also flags them as missing data in the quality flag PDS OBJECT (FITS extension). Displaying such images using an automatic stretch (contrast enhancement) may result in a confusing result with the majority of the displayed image appearing as an inverse of the calibration (calibration of zero values); therefore the quality flag PDS OBJECT should always be checked when looking at these data.

Ongoing in-flight calibration observations will be analyzed to assess the long term stability of the calibration, including whether the currently unused steps may need to be implemented in the future.

* As of late 2016, there are no known dead or hot pixels on the LORRI detector, so all hot and dead pixel map calibration files contain all zeroes. From the current flat-field calibration file it can be seen that there are many pixels with relative sensitivities up to six times the mean (unity), those called warm pixels. Those pixels are calibrated in the flat-field step.

Data

The observations in this data set are stored in data files using standard Flexible Image Transport System (FITS) format. Each FITS file has a corresponding detached PDS label file, named

according to a common convention. The FITS files may have image and/or table extensions. See the PDS label plus the document collection for a description of these extensions and their contents.

This Data section comprises the following sub-topics:

- Filename/Product IDs
- Instrument description
- Other sources of information useful in interpreting these Data
- Visit Description, Visit Number, and Target in the Data Labels

Filename/Product IDs

The filenames and Local product Identifiers (LID) of observations adhere to a common convention, e.g.:

```
lor_0123456789_0x630_eng.fit
^^^ ^^^^^^^^^^ ^^^^^ ^^^\__/
|         |        |     |  ^^
|         |        |     |   |
|         |        |     |   +--File type (includes dot)
|         |        |     |      - .FIT for FITS file
|         |        |     |      - .LBLX for PDS label
|         |        |     |      - not part of LID
|         |        |     |
|         |        |     +--ENG for CODMAC Level 2 data
|         |        |        SCI for CODMAC Level 3 data
|         |        |
|         |        +--Application ID (ApID) of the telemetry data
|         |           packet from which the data come
|         |           N.B. ApIDs are case-insensitive
|         |
|         +--MET (Mission Event Time) i.e. Spacecraft Clock
|
+--Instrument designator
```

Instrument Designator(s):

Instrument Designator	Description
LOR	LORRI

See the SOC Instrument Interface Control Document (ICD) within the PDS for more details (PDS4 LID `urn:nasa:pds:nh_documents:mission:soc_inst_icd`).

Mission Event Time (MET)

Note that, depending on the observation, the Mission Event Time (MET) in the data filename and in the LID may be similar to the MET of the actual observation acquisition, but should not be used as an analog for the acquisition time. The MET is the time that the data are transferred from the instrument to spacecraft memory and is therefore not a reliable indicator of the actual

observation time. The PDS labels are better sources to use for the actual timing of any observation. The specific keywords for which to look are:

- start_date_time
- stop_date_time
- start_clock_count
- stop_clock_count

Application ID (ApID)

Here is a summary of the types of files generated by each ApID (N.B. ApIDs are case-insensitive) along with the instrument designator that go with each ApID:

ApIDs	Data product description/Prefix(es)
0x630	LORRI High-res Lossless (CDH 1)/LOR
0x636	LORRI High-res Lossless (CDH 2)/LOR
0x632	LORRI High-res Lossy (CDH 1)/LOR
0x638	LORRI High-res Lossy (CDH 2)/LOR
0x631	LORRI High-res Packetized (CDH 1)/LOR
0x637	LORRI High-res Packetized (CDH 2)/LOR
0x633	LORRI 4x4 Binned Lossless (CDH 1)/LOR
0x639	LORRI 4x4 Binned Lossless (CDH 2)/LOR
0x635	LORRI 4x4 Binned Lossy (CDH 1)/LOR
0x63B	LORRI 4x4 Binned Lossy (CDH 2)/LOR
0x634	LORRI 4x4 Binned Packetized (CDH 1)/LOR
0x63A	LORRI 4x4 Binned Packetized (CDH 2)/LOR
0x63C	LORRI Co-added 4x4 Binned Lossless (CDH 1)
0x63D	LORRI Co-added 4x4 Binned Lossless (CDH 2)

There are other ApIDs that contain housekeeping values and other values. See the SOC Instrument ICD for more details: `urn:nasa:pds:nh_documents:mission:soc_inst_icd`

Please note that not all ApIDs may be found in this data set.

Instrument description

Refer to the following files for a description of this instrument.:

- New Horizon LORRI instrument overview: `urn:nasa:pds:nh_documents:lorri:lorri_inst_overview`
- LORRI Space Science Review (SSR) paper: `urn:nasa:pds:nh_documents:lorri:lorri_ssr`
- SOC Instrument ICD: `urn:nasa:pds:nh_documents:mission:soc_inst_icd`
- LORRI SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:lorri:nh_lorri_ti`

Other sources of information useful in interpreting these Data

Refer to the following files for more information about these data:

- NH Mission Trajectory Table: `urn:nasa:pds:nh_documents:mission:nh_mission_trajectory`
- Field of View Illustration: `urn:nasa:pds:nh_documents:mission:nh_fov`

- LORRI SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:lorri:nh_lorri_ti`

Visit Description, Visit Number, and Target in the Data Labels

The observation sequences were defined in Science Activity Planning (SAP) documents and grouped by Visit Description and Visit Number. The SAPs are spreadsheets with one Visit Description & Number per row. A nominal target is also included on each row and included in the data labels but does not always match with the target name field's value in the data labels. In some cases, the target was designated as right_ascension_angle, declination_angle pointing values in the form "right_ascension_angle, declination_angle =123.45,-12.34" indicating Right Ascension and Declination, in degrees, of the target from the spacecraft in the Earth Equatorial J2000 inertial reference frame. This indicates that either the target was a star, or the target's ephemeris was not loaded into the spacecraft's attitude and control system which in turn meant the spacecraft could not be pointed at the target by a body identifier and an inertial pointing value had to be specified as Right Ascension and Declination values. PDS-SBN practices do not allow putting a value like right_ascension_angle, declination_angle =... in the PDS target name keyword's value. In those cases, the PDS target purpose value is set calibration. Target name may be None for a few observations in this data set; typically, that means the observation is a functional test so None is an appropriate entry for those targets, but the PDS user should also check the nh:observation_description and nh:sequence_id keywords in the PDS label, plus the provided sequence list (`urn:nasa:pds:nh_documents:lorri:seq_lorri_pluto`) to assess the possibility that there was an intended target. These two keywords are especially useful for star targets as often stars are used as part of instrument calibrations and are included as part of the sequencing description which is captured in these keywords.

Ancillary Data

The geometry items included in the data labels were computed using the SPICE kernels archived in the New Horizons SPICE data set, NH-J/P/SS-SPICE-6-V1.0.

Every observation provided in this data set was taken as a part of a particular sequence. A list of these sequences has been provided within the NH LORRI document collection (see PDS4 LID `urn:nasa:pds:nh_documents:lorri`) within the PDS, one file for each mission phase. The sequence identifier and description are included in the PDS label for every observation.

N.B. While every observation has an associated sequence, every sequence may not have associated observations. Some sequences may have failed to execute due to spacecraft events (e.g., safing). No attempt has been made during the preparation of this data set to identify such empty sequences.

Time

There are several time systems, or units, in use in this dataset: New Horizons spacecraft MET (Mission Event Time or Mission Elapsed Time), UTC (Coordinated Universal Time), and TDB (Barycentric Dynamical Time).

This section will give a summary description of the relationship between these time systems. For a complete explanation of these time systems the reader is referred to the documentation

distributed with the Navigation and Ancillary Information Facility (NAIF) SPICE toolkit from the PDS NAIF node, (see http://naif.jpl.nasa.gov/).

The most common time unit associated with the data is the spacecraft MET. MET is a 32-bit counter on the New Horizons spacecraft that runs at a rate of about one increment per second starting from at value of zero at "19.January, 2006 18:08:02 UTC" or "JD2453755.256337 TDB."

The leapsecond adjustment (DELTA_ET = ET - UTC) was 65.184s at NH launch, and the first four additional leapseconds occurred at the ends of 12/2009, 06/2012, 06/2015, and 12/2016. Refer to the NH SPICE data set, NH-J/P/SS-SPICE-6-V1.0, and the SPICE toolkit documentation, for more details about leapseconds.

The data labels for any given product in this dataset usually contain at least one pair of common UTC and MET representations of the time at the middle of the observation. Other portions of the products, for example tables of data taken over periods of up to a day or more, will only have the MET time associated with a given row of the table.

For the data user's use in interpreting these times, a reasonable approximation (+/- 1s) of the conversion between Julian Day (TDB) and MET is as follows:

```
JD TDB = 2453755.256337 + ( MET / 86399.9998693 )
```

For more accurate calculations the reader is referred to the NAIF/SPICE documentation as mentioned above.

Reference Frame

Geometric Parameter Reference Frame

Earth Mean Equator and Vernal Equinox of J2000 (EMEJ2000) is the inertial reference frame used to specify observational geometry items provided in the data labels. Geometric parameters are based on best available SPICE data at time of data creation.

Epoch of Geometric Parameters

All geometric parameters provided in the data labels were computed at the epoch midway between the start_date_time and stop_date_time label fields.

Software

The observations in this data set are in standard FITS format with PDS labels and can be viewed by a number of PDS-provided and commercial programs. For this reason, no special software is provided with this data set.

Confidence Level Overview

During the processing of the data in preparation for delivery with this volume, the packet data associated with each observation were used only if they passed a rigorous verification process including standard checksums.

In addition, raw (CODMAC Level 2) observation data for which adequate contemporary housekeeping and other ancillary data are not available may not be reduced to partially processed or calibrated (CODMAC Level 3) data. This issue is raised here to explain why some data products in the raw data set may not have corresponding data products in the partially processed or calibrated data set.

Known Issues

Below is a list of all deficiencies and irregularities that are known to exist at the time of publication.

Exposure time discrepancy of 0.6 ms

Careful analysis of LORRI raw data images reveals that the exposure time values in the FITS headers should be increased by 0.0006 seconds (0.6 ms). The preferred solution is to decrease the image start time by 0.0006 seconds, which causes a 0.0003 second shift in the image mid-time. No PDU or EDU data values are affected in either raw or calibrated data files. Since image mid-time is the base for most SPICE calculations, this change indirectly affects (in a very minor way) many values in the FITS headers and the data label files, including (but not limited to) the following:

- FITS Headers keywords: STARTMET, DURMET, EXPTIME, SPC*, RATE*, CD[12]_[12], CRVAL[12], PA_[XY]INST, PA_SUN*, SOL_ELON, and EAR_ELON
- Data Label Files: nh:start_clock_count, img:exposure_duration, geom:Vector_Cartesian_Position_Spacecraft_To_Target, geom:Vector_Cartesian_Position_Sun_To_Target, geom:Vector_Cartesian_Position_Earth_To_Target, geom:Vector_Cartesian_Position_Sun_To_Spacecraft, geom:Vector_Cartesian_Position_Earth_To_Spacecraft, geom:spacecraft_geocentric_distance, geom:spacecraft_heliocentric_distance, geom:spacecraft_target_center_distance, geom:target_geocentric_distance, geom:target_heliocentric_distance, geom:qcos, geom:qsin1, geom:qsin2, and geom:qsin3

Removed Surface_Geometry class

The PDS4 geom:Surface_Geometry class, with attributes for subsolar and subspacecraft latitude and longitude, was removed from products with the following targets: 2060 CHIRON, 28978 IXION, 307261 (2002 MS4), 50000 QUAOAR, 523335 (2010 JJ124), KERBEROS, and STYX. The SPICE kernels provided with the PDS3 delivery did not contain body-fixed reference frames for those targets, so these values could not be reliably recomputed. This may be fixed in a future delivery.

Data coverage and quality

Every observation provided in this data set was taken as a part of a particular sequence. For this data set, these sequences can be found in the LORRI document collection under PDS4 LID

`urn:nasa:pds:nh_documents:lorri:seq_lorri_pluto`. Please note that some sequences provided may have zero corresponding observations.

Refer to the Confidence Level Overview section above for a summary of steps taken to assure data quality.

The LORRI instrument replaces the first 34 12-bit pixels of each LORRI image (408 bits; 51 bytes) with encoded binary header information, so those first 34 pixel values in the first row are not representative of the brightness of the imaged scene at those locations; these pixels are in the bottom-left corner of images displayed left-to-right and bottom-to-top. Furthermore, if the image was LOSSY-compressed before downlink (ApIDs 0x632, 0x635, 0x638, 0x63B), the header information corrupts the first 40 pixels of the first 8 rows of the image because of the Discrete Cosine Transform compression algorithm. The SOC pipeline extracts these data into the FIRST34 extension of LORRI FITS files, which is also corrupt in LOSSY-compressed files. The SOC calibration pipeline also flags these pixels as bad in the QUALITY_MAP extension of partially processed or calibrated FITS files; no such flags are available in the raw FITS files; the SOC pipeline did not flag the additional corrupt pixels beyond the first 34 in LOSSY-compressed data until the Pluto P2 delivery late in 2016.

Caveat about target name in PDS labels and observational

The downlink team on New Horizons has created an automated system to take various uplink products, decode things like Chebyshev polynomials in command sequences representing celestial body ephemerides for use on the spacecraft to control pointing, and infer from those data what the most likely intended target was at any time during the mission. This works well during flyby encounters and less so during cruise phases and hibernation.

The user of these PDS data needs to be cautious when using the target name and other target-related parameters stored in this data set. This is less an issue for the plasma and particle instruments, more so for pointed instruments. To this end, the heliocentric ephemeris of the spacecraft, the spacecraft-relative ephemeris of the inferred target, and the inertial attitude of the instrument reference frame are provided with all data, in the J2000 inertial reference frame, so the user can check where that target is in the Field Of View (FOV) of the instrument.

Finally, note that, within the FITS headers of the data products, the sequence tables, and other NH Project-internal documents used in this data set, informal names are often used for targets instead of the canonical names used within the PDS labels. For example, during the Pluto mission phase, instead of the target name '15810 ARAWN (1994 JR1)' there might be found any of the following: 1994JR1; 1994 JR1; JR1. However, within the context of this data set, these project abbreviations are not ambiguous (e.g. there is only one NH target with 'JR1' in its name), so there has been, and will be, no attempt to expand such abbreviations where they occur outside formal PDS keyword values.

Contact Information

For any questions regarding the data format of the archive, contact the New Horizons LORRI Principal Investigator: Harold A Weaver, Southwest Research Institute

Harold A Weaver
Johns Hopkins University
Applied Physics Laboratory
Space Exploration Sector
11100 Johns Hopkins Road
Laurel, MD 20723-6099
USA

Further Reading

Cheng, A.F., H.A. Weaver, S.J. Conard, M.F. Morgan, O. Barnouin-Jha, J.D. Boldt, K.A. Cooper, E.H. Darlington, M.P. Grey, J.R. Hayes, K.E. Kosakowski, T. Magee, E. Rossano, D. Sampath, C. Schlemm, and H.W. Taylor, Long-Range Reconnaissance Imager on New Horizons, Space Sci. Rev., Volume 140, Numbers 1-4, pp. 189-215, 2008. https://doi.org/10.1007/s11214-007-9271-6 (preprint provided in PDS with LID `urn:nasa:pds:nh_documents:lorri:lorri_ssr`)

Morgan, F., S.J. Conard, H.A. Weaver, O. Barnouin-Jha, A.F. Cheng, H.W. Taylor, K.A. Cooper, R.H. Barkhouser, R. Boucarut, E.H. Darlington, M.P. Grey, I. Kuznetsov, T.J. Madison, M.A. Quijada, D.J. Sahnow, and J.M. Stock, Calibration of the New Horizons Long-Range Reconnaissance Imager, Proc. SPIE 5906, Astrobiology and Planetary Missions, 59061E, 2005. https://doi.org/10.1117/12.616880 (preprint provided in PDS with LID `urn:nasa:pds:nh_documents:lorri:morgan_spie`)

Steffl, A.J., J. Peterson, B. Carcich, L. Nguyen, and S.A. Stern, NEW HORIZONS SPICE KERNELS, V1.0, NH-J/P/SS-SPICE-6-V1.0, NASA Planetary Data System, 2007. https://doi.org/10.17189/1520109