

New Horizons LORRI Instrument

Overview

This document is an overview of the New Horizons' LOng-Range Reconnaissance Imager (LORRI) Instrument. This LORRI description was originally adapted from Conrad et al. (2005), Cheng et al. (2008), and the New Horizons website. During migration to PDS4, this current copy was adapted from the PDS3 LORRI instrument catalog file, providing light edits to the text, format, and flow.

Instrument Overview

The LOng-Range Reconnaissance Imager (LORRI) is an instrument that was designed, fabricated, and qualified for the New Horizons mission to the outermost planet Pluto, its giant satellite Charon, and the Kuiper Belt, which is the vast belt of icy bodies extending roughly from Neptune's orbit out to 50 astronomical units (AU). New Horizons launched in January 2006 as the inaugural mission in NASA's New Frontiers program.

Specifications

NAME:	LORRI (Long-Range Reconnaissance Imager)
DESCRIPTION:	High-resolution telescope
PRINCIPAL INVESTIGATOR:	Hal Weaver, Applied Physics Laboratory (APL)
WAVELENGTH RANGE:	350 - 850 nm
FIELD OF VIEW:	5.06 x 5.06 mRad (0.29 x 0.29 degrees)
ANGULAR RESOLUTION:	0.00494 mRad, unbinned
WAVELENGTH RESOLUTION:	N/A
PRIMARY DATA FORMAT(S):	1) 1024x1024 2-D pixel array (unbinned) 2) 256x256 2-D pixel array (4x4 binned)

PRIMARY MEASURED QUANTITIES:

- 1) Raw data:per-pixel brightnesses as Data Numbers (DNs)
- 2) Calibrated data:per-pixel brightnesses as calibrated DN.

N.B. Calibrated image data pixels are in units of calibrated DN, with scene-dependent conversion divisors to radiance provided in the FITS headers and PDS labels. Refer to the Science Operations Center (SOC) Interface Control Document (ICD) for more detail.

Description

LORRI is a narrow angle (field of view=0.29 deg), high resolution (instantaneous field of view = 4.94 μ rad), Ritchey-Chretien 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), back-thinned, backside-illuminated charge-coupled device (CCD) detector (model CCD

47-20 from E2V Technologies) is located at the telescope focal plane and is operated in standard frame-transfer mode. LORRI does not have any color filters; it provides panchromatic imaging over a wide bandpass that extends approximately from 350 nm to 850 nm. A unique aspect of LORRI is the extreme thermal environment, as the instrument is situated inside a near room temperature spacecraft, while pointing primarily at cold space. This environment forced the use of a silicon carbide optical system, which is designed to maintain focus over the operating temperature range without a focus adjustment mechanism. Another challenging aspect of the design is that the spacecraft is thruster-stabilized (no reaction wheels), which places stringent limits on the available exposure time and the optical throughput needed to accomplish the high-resolution observations required. LORRI was designed and fabricated by a combined effort of The Johns Hopkins University Applied Physics Laboratory (APL) and SSG Precision Optonics Incorporated (SSG).

LORRI has four subassemblies in close proximity connected by electrical harnesses. These are the optical telescope assembly (OTA), the aperture cover door, the associated support electronics (ASE), and the focal plane unit (FPU). Except for the door, all are mounted inside the spacecraft on its central deck; the door is mounted to an external spacecraft panel. LORRI is electronically shuttered, with no moving parts aside from the cover door. The ASE implements all electrical interfaces between LORRI and the spacecraft except for the door control, several spacecraft thermistors, and two decontamination heaters. Conrad et al. (2005) gives a detailed description of LORRI design, manufacture and test.

The in-flight performance and calibration of LORRI from launch through 2019 has been documented in Weaver et al. (2020).

Scientific Objectives

- Hemispheric panchromatic maps of Pluto and Charon at best resolution exceeding 0.5 km/pixel.
- Search for atmospheric haze at a vertical resolution <5 km
- Long time base of observations, extending over 10 to 12 Pluto rotations
- Panchromatic maps of the far-side hemisphere
- High resolution panchromatic maps of the terminator region
- Panchromatic, wide phase angle coverage of Pluto, Charon, Nix, and Hydra
- Panchromatic stereo images of Pluto, Charon, Nix, and Hydra
- Orbital parameters, bulk parameters of Pluto, Charon, Nix, and Hydra
- Search for satellites and rings

Calibration

See Cheng et al. (2008).

Detectors

Frame transfer CCD. See Cheng et al. (2008) for details.

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 are called warm pixels. Warm pixels are calibrated in the flat-field step.

Electronics

LORRI electronics consist of the ASE and FPU. The ASE contains three printed circuit cards. These are the low voltage power supply (LVPS), the event processor unit (EPU), and the imager input/output (IM I/O). The ASE is the primary interface between the spacecraft and the FPU, which mounts and controls the CCD. Additional information can be found in Conrad et al. (2005).

Filters

None.

Optics

The LORRI OTA is a Ritchey-Chretien design, with high system throughput required because of the short allowed exposure time and low light level at Pluto. The complete LORRI OTA design was evaluated with a computer-aided design model including stray light analysis. Specular reflections and bidirectional reflectance distribution functions of the Aeroglaze Z-306 black paint, primary and secondary mirrors, field group optics and focal plane were included in the model. The primary and secondary baffle tubes were sized to minimize obscuration and suppress direct paths to the FPA's active area. The telescope magnification and obscuration were balanced, affecting the optical sensitivity and MTF, respectively. Out-of-field stray light was evaluated by generating point source transmittance curves with angular scans across the boresight in two orthogonal directions (-70 degrees to +70 degrees for each scan) to search for any obscured paths with unacceptable amplitude.

See Cheng et al. (2008) for more details.

Operational Modes

LORRI high-rate image data telemetry APID definitions

APID	Command and Data Handling (C&DH) side	binning mode	compression type
0x630	1	1x1	lossless
0x631	1	1x1	packetized
0x632	1	1x1	lossy
0x633	1	4x4	lossless
0x634	1	4x4	packetized
0x635	1	4x4	lossy
0x636	2	1x1	lossless
0x637	2	1x1	packetized
0x638	2	1x1	lossy
0x639	2	4x4	lossless
0x63A	2	4x4	packetized
0x63B	2	4x4	lossy

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 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.

Measured Parameters

Radiance.

In calibrated images, radiance is stored as a combination of two items: calibrated DN in each pixel; scene spectrum-dependent divisors in each FITS header and PDS label to convert per-pixel DNs to radiances. Refer to section 9.3.1.4 of the SOC Instrument Interface Control Document (ICD) for more detail, including a discussion of units. In the FITS headers of calibrated images, divisor and unit information reside in a section labeled 'LORRI Level 2 Absolute Calibration Parameters'.

References

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)

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Further Reading

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. Sahnou, 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>

SOC Instrument Interface Control Document (ICD):

urn:nasa:pds:nh_documents:mission:soc_inst_icd, NASA Planetary Data System.

Weaver, H.A., A.F. Cheng, F. Morgan, H.W. Taylor, S.J. Conard, J.I. Nunez, D.J. Rodgers, T.R. Lauer, W.M. Owen, J.R. Spencer, O. Barnouin, A.S. Rivkin, C.B. Olkin, S.A. Stern, L.A. Young, M.B. Tapley, and M. Vincent, In-flight Performance and Calibration of the Long Range Reconnaissance Imager (LORRI) for the New Horizons Mission, *Publications of the Astronomical Society of the Pacific*, Volume 132, Issue 1009, id.035003, 2020. <https://doi.org/10.1088/1538-3873/ab67ec>