New Horizons MVIC Instrument Overview

This Multispectral Visible Imaging Camera (MVIC) description was originally adapted from Reuter et al. (2005), the MVIC section of the Science Operations Center (SOC) Instrument Interface Control Document (ICD), Reuter et al. (2008), and the New Horizons website. During the migration to Planetary Data System's (PDS) PDS4 data standards, this current description was adapted from the PDS3 MVIC instrument catalog file, providing light edits to the text, format, and flow.

Instrument Overview

MVIC is an imager that operates at both visible and near-infrared (NIR) wavelengths using seven separate Charge-Coupled Device detectors (CCDs). On one of those CCDs, the Pan Frame array, operates as a single-frame array that is exposed to light and then transfers all of its lines to an image with the same dimensions as the CCD. The other six CCDs all use Time Delay and Integration (TDI; i.e. multi-line push broom; see TDI section below) to construct images of fixed width and of variable height, the height being dependent on the scan rate and time duration of the observation.

Four CCDs have color filters (methane, red, blue and near-infrared) for producing color maps and three CCDs have panchromatic filters for observations where maximum sensitivity to faint light levels is required. In all cases, the light passes from the telescope through a filter and is focused onto the CCDs.

MVIC is integrated with another instrument, Linear Etalon Imaging Spectral Array (LEISA), into a composite instrument package named Ralph, which supplies Analog-to-Digital (A/D) conversion, command and data handling, and power to both MVIC and LEISA.

Specifications

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NAME:                      MVIC (Multispectral Visible Imaging Camera)
DESCRIPTION:               Imaging camera
PRINCIPAL INVESTIGATOR:    Alan Stern, SwRI
WAVELENGTH RANGE:          (Note 1)
FIELD OF VIEW:             100 x N mRad (Note 2); 100 x 2.6 mRad (Note 3)
ANGULAR RESOLUTION:        0.02 mRad/pixel
WAVELENGTH RESOLUTION:     See filter bandpasses (Note 1)

Note 1:  See Filters section below for Wavelength
         ranges and filter bandpasses.

Note 2:  Time-Delay and Integration (TDI; color and two panchromatic
         arrays; see TDI section below). The scan rate and time
         duration of
         the observation determines the dimension of the scan
         denoted by N.

Note 3:  Pan frame array only.
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General Description

MVIC uses two large format (5024x32 pixel; samples by lines) TDI CCD arrays to provide panchromatic hemispheric maps of Pluto at a double-sampled spatial resolution of 1 km by 1 km or better. Four additional 5024x32 TDI CCDs provide hemispheric maps in blue, red, Near InfraRed (IR) and narrow band methane color channels. These 6 arrays all operate in Time Delay and Integration (TDI; see the next section) mode to increase sensitivity. In addition to the TDI arrays, MVIC has a 5024x128 pixel frame transfer array. For each of the arrays, the 12 pixel samples (columns) at either end of the lines (rows) are not optically active.

N.B. The count of 32 lines in each TDI array has ***nothing*** to do with the number of lines in TDI image data generated by that array; see the TDI description in the next section.

N.B. The MVIC calibration collection contains flat fields for the panchromatic and color TDI filters that measure 5024x1 pixels. What comes out of the detector has gone through all 32 TDI rows so the flat is a one dimensional array that compensates for the flat effects across all the TDI pixels.

TDI

A Time Delay and Integration (TDI) Charge-Coupled Device (CCD) is an image sensor for capturing images of objects at low light levels.

The principle is similar to that of a line-scan (a.k.a. pushbroom) CCD which uses a single line of photo-sensitive elements to sequentially capture one-dimensional strips of a scene to be imaged, while moving that line of elements relative to that scene and perpendicular to the line, and then to combine those multiple 1-D strips into a two-dimensional image. For any given scan rate, a single-line-scan CCD needs to have adequate illumination of the scene in order to register the light in the time the line of elements moves one line-height across the scene; increasing the per-line exposure time to compensate for low illumination would require the scan rate to decrease to avoid smearing of the image in the scan direction.

The TDI CCD overcomes this [illumination/scan rate] limitation by having multiple lines of elements, and having each shift its partial measurements, of that line projected onto the scene, to the adjacent line synchronously with the motion of the imaged scene across the array of elements; the shifting accomplishes integration (summing) of the partial measurements made by each line for each strip of the imaged scene. In effect, by having multiple lines of elements integrating simultaneously, the instrument can scan more quickly for a given level of illumination. This provides high sensitivity for moving images unobtainable using conventional CCD arrays or single-line-scan devices. A requirement of this method of imaging is that the image scene geometric motion across the CCD must equal the electronic line shift of pixels across the same CCD to minimize smear.

Scientific Objectives

- Hemispheric panchromatic maps of Pluto and Charon at a resolution better than 0.5 km/pixel
- Hemispheric 4-color maps of Pluto and Charon at a resolution better than 5 km/pixel

- Search for and map atmospheric hazes at a vertical resolution better than 5 km/pixel
- High resolution panchromatic maps of the terminator region
- Panchromatic, wide phase angle coverage of Pluto, Charon, Nix, and Hydra
- Panchromatic stereo images of Pluto and Charon, Nix, and Hydra
- Orbital parameters, bulk parameters of Pluto, Charon, Nix, and Hydra
- Search for rings
- Search for additional satellites

Detectors

MVIC comprises seven independent CCD arrays on a single-substrate focal plane. It uses two of its large format (5024x32 pixels; i.e. 32 lines each 5024 pixels wide) CCD arrays, operated in TDI mode, to provide panchromatic images. Four additional 5024x32 CCDs, combined with the appropriate filters and also operated in TDI mode, provide the capability of mapping in blue, red, near-IR (NIR) and narrow-band methane channels.

TDI operates by synchronizing the parallel transfer rate of each of the CCD lines to the relative motion of the image across the surface of the detector. In this way, very large format images are obtained as the spacecraft scans the Field Of View (FOV) across the surface of a target. The count of 32 lines on the CCD has ***nothing*** to do with the line count of the final image; rather 32 sequential measurements across the 32 lines are combined (summed) into one line in the final image; thus the presence of 32 lines increases the effective integration time by that same factor, providing high signal-to-noise measurements. The measured spacecraft rotation rate can be fed back to the instrument to optimize the frame transfer rate. That is, after a scan has been initiated, the spacecraft determines the actual rotation rate and sends that information to Ralph, which uses it to calculate the frame rate that minimizes smear in the along-track direction.

MVIC always produces image data in correlated double-sample (CDS) mode; that is, the reset level is subtracted from the integrated level and the difference is returned as the image.

Electronics

The Ralph control electronics comprise three boards: the Detector Electronics (DE) board; the Command and Data Handling (C&DH) board; the Low Voltage Power Supply (LVPS) board. These are contained within an Electronics Box (EB) mounted directly on the spacecraft, and operate essentially at the spacecraft surface temperature, which is near ambient. The DE board provides biases and clocks to both MVIC and LEISA focal planes, amplifies the signals from the arrays and performs the A/D conversion of the electrical charge of each pixel to a digital number with 12 bits of resolution. The C&DH board interprets the commands, performs the A/D conversion of the low-speed engineering data and provides both the high-speed image data interface and the low-speed housekeeping data interface. The LVPS converts the 30V spacecraft power to the voltages required by Ralph.

In a long-duration mission such as New Horizons, reliability of the electronics is of paramount importance, particularly for a core instrument that addresses all major mission objectives. To ensure that Ralph is robust, almost all of the electronics are redundant. Ralph can operate on two separate sides (side A or B) which have very few components in common. The only common elements are: 1) the relays that choose whether side A or side B is to be powered, 2) The arrays themselves and 3) the interface to the spacecraft. However, the spacecraft interface has two identical circuits and is inherently redundant. For MVIC, the potential single point failure mode of the arrays is mitigated by dividing the six TDI arrays into two groupings, each containing two color CCDs and one panchromatic CCD. The first grouping comprises a pan band and the red and CH4 channels. The second grouping comprises the other pan band and the blue and NIR channels. If either group should fail, the other would still be able to meet the science requirement of observations in two color bands and one panchromatic band.

Filters

From Reuter et al. (2008):

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_Bandpass__  Filter designation

400 - 975nm  Panchromatic (PAN)
400 - 550nm  Blue
540 - 700nm  Red
780 - 975nm  NIR
860 - 910nm  CH4
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The individual filter transmission curves are found in the MVIC calibration collection.

Optics

See description above. Also:

The FOV of a single MVIC pixel is 20x20 microradian^2. The panchromatic (pan) channels of MVIC will be used to produce hemispheric maps of Pluto and Charon at a double-sampled spatial resolution of 1 km^2 or better. The static FOV of each of the TDI arrays is 5.7 degrees x 0.037 degrees. In addition to the TDI arrays, MVIC has a 5024x128 element, frame transfer panchromatic array operated in staring mode, with an FOV of 5.7 degrees x 0.15 degrees. The primary purpose of the framing array is to provide image data for optical navigation of the spacecraft.

Operational Modes

Ralph-MVIC modes are intertwined with Ralph-LEISA modes. See Reuter et al. (2008), Section 7.0 'IN-FLIGHT INSTRUMENT OPERATION' for details.

Ralph housekeeping data is included as part of the data. There is a long list of parameters, however only a few are relevant for ensuring the validity of the data. The SOC Instrument ICD gives these parameters and their meanings. When reviewing the data, conversion coefficients translate the raw data into meaningful values and limits as given in the ICD. Most should be used as straight multiplication factors, but the thermal coefficients are polynomials. These coefficients are:

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POS_12V    -0.14298
NEG_12V    -0.14298
POS_5V     -0.058588
NEG_5V     -0.058588
POS_30V    -0.35356
MVIC_VRD   -0.19686
MVIC_VOD   -0.29002
MVIC_VOG   -0.02344
MVIC_BSPAR -0.02344
MVIC_TEMP  -8.77E+01,1.72E-02,-1.52E-07,9.37E-12,0,0,0,0
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Calibration

See Reuter et al. (2008), especially sections 5 and 6.

The choice of radiometric calibration keywords (PPLUTO, PCHARON) is dependent on the color of the target. For targets where the color is not known, one can assume a neutral color and would therefore use the PSOLAR keyword.

Measured Parameters

Radiance; errors less than one DN (data number) as of 20.April 2007. See Reuter et al. (2008) section 6.0, Combined Pre-Launch and In-Flight Instrument Calibration Results, for more details.

References

Reuter, D., A. Stern, J. Baer, L. Hardaway, D. Jennings, S. McMuldroch, J. Moore, C. Olkin, R. Parizek, D. Sabatke, J. Scherrer, J. Stone, J. VanCleeve, and L. Young, Ralph: a visible/infrared imager for the New Horizons Pluto/Kuiper Belt Mission, Proc. SPIE 5906, Astrobiology and Planetary Missions, 59061F, 2005. https://doi.org/10.1117/12.617901

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Further Reading

SOC Instrument Interface Control Document (ICD): urn:nasa:pds:nh_documents:mission:soc_inst_icd, NASA Planetary Data System.

MVIC Calibration Collection, urn:nasa:pds:nh_mvic:calibration_files, NASA Planetary Data System.