Data Introduction: New Horizons Spacecraft, MVIC Instrument

This is an abbreviated guide to the main elements of this MVIC data set that provides an overview and a quick path to viewing the data. Many details and subtleties regarding these data have been excluded here for the sake of brevity and clarity; those who plan to perform scientific analysis on these data must first read the documentation referenced by or provided in this data set.

Instrument: The Multi-spectral Visible Imaging Camera (MVIC) is part of the RALPH instrument suite; MVIC has seven separate CCD arrays in its focal plane. The Pan Frame CCD is a framing imager of 5024x128 pixels, with the middle 5000 pixels optically active, and is under a panchromatic filter. The remaining six CCDs are each 5024x32 pixels and under a filter: two panchromatic filters (Pan 1 and Pan 2 CCDs); Near InfraRed filter (NIR); methane filter (CH4); red filter (RED); blue filter (BLUE). The six CCDs operate in a Time Delay and Integration (TDI) mode, similar in some ways to a line camera as explained below. N.B. the number of rows in TDI detectors ***is unrelated to*** the number of rows in TDI products. The four CCDs under the narrow band filters (RED, BLUE, NIR, CH4) are designated *Color TDI*; Pan 1 and Pan 2 TDI CCDs are designated *Pan TDI*.

Operation and measurements (images): All MVIC detectors operate in continuous modes, where the size of the data product is dependent on the duration of the observation. The Pan Frame detector takes a series of complete 5024x128 pixel images or frames, which are stored as an image cube (3-dimensions). The first and second dimensions are the column and row numbers, respectively, of each image frame within the observation, the third dimension is the image number within that observation; the third dimension is also an analog for time, which means the scene can change from frame to frame if the spacecraft attitude is changing. To take an observation with the TDI arrays, the spacecraft rotates around an axis parallel to the TDI CCD rows (the longer, 5024-pixel dimension), while clocking the charge through each of the 32 rows continuously at a rate that matches the spatial scan rate of the target across the CCD. When a row's charges have transferred across all rows and are measured, they represent the light from a ***single*** pixel-high row projected onto the target (like a slit), and integrated across all 32 rows, and those integrated measurements are written to ***ONE*** row of the resulting image product. So although a TDI CCD has 32 rows, it operates similar to a line CCD detector with one row, and they produce a two-dimensional image that is always 5024 pixels across but can be arbitrarily long in the row direction. The coordination of the spacecraft G&C attitude scan rate with the TDI charge transfer rate can happen automatically with a commanded scan rate passed to the G&C subsystem, which then 1) measures the actual inertial scan rate once the scan has started, 2) calculates a Target Motion Compensation (TMC) value to account for spacecraft-target translational motion, and 3) passes the net scan rate to RALPH to set the MVIC charge transfer rate. Alternatively, scan rates can be manually commanded independently to G&C and to MVIC; the latter case is necessary near the Time of Closest Approach (TCA) during a flyby. This is because MVIC will be scanning up-track and down-track from the nominal target position to account for uncertainty in the trajectory to ensure capture of the target, and the nominal target range used in the automatic algorithm will cause G&C to calculate, and send to RALPH, a charge transfer rate that may result in smeared imaging.

Finding the data: Archival data are stored in directories with names of the form ***data/yyyymmdd_kkk/*** where ***yyyy***, ***mm***, and ***dd*** are the year, month, and day on which data taking started and ***kkk*** is the 6-digit mission elapsed time (MET) prefix. Data filenames have the form ***mxx_mmm_0xaaa_nnn.fit***, where ***mxx*** is the type of MVIC image, ***mmm*** is the 10-digit spacecraft clock time suffix, ***aaa*** is the telemetry application identifier (ApID), ***nnn*** is the processing level identifier. An additional version number suffix, ***_v,*** follows the processing level in some data sets. The ApID may take any of several values, and indicates 1) the detector type (Pan Frame, Pan TDI, Color TDI), 2) whether lossless compression, lossy compression or no compression (packetization) was used to packetize the image data for downlink, and 3) whether the data were stored on side 1 or 2 of the spacecraft Command and Data Handling (C&DH) and Solid State Recorder (SSR) subsystems; refer to the data set documentation for more detail. The MVIC prefix and processing level are as follows:

mxx = ***mpf*** *(Pan Frame);* ***mp1*** *(Pan 1 TDI);* ***mp2*** *(Pan 2 TDI);* ***mc0/mc1/mc2/mc3*** *(Red/Blue/NIR/CH4 Color TDI);*
nnn = ***eng*** *(raw data);* ***sci*** *(calibrated);*

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_mvic_...)***. 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_mvic_*.lbl)*** for more detail.

Reading the data: Each file contains data from one observation. All data files are in FITS format and readable with standard FITS viewers and software libraries. All FITS files have records with 2880 bytes. Refer to the NASA FITS Support Office (currently http://fits.gsfc.nasa.gov/) for FITS standard details. All sections in FITS files start on 2880-byte boundaries and are padded to a 2880-byte boundary with spaces or nulls. A detached PDS label file named ***mxx_mmm_0xaaa_nnn_v.lbl*** accompanies each FITS data file and describes its structure; a selectively edited example label fragment for a raw data file is shown below. The black section describes the entire file as comprising 128 2880-byte records. The red section has pointers locating six sections in the file: three headers interleaved with one image and two tables; tables and images contain data; FITS HEADERs describe the data sections and contain ancillary information, but are generally redundant with information in the PDS label (not shown here). The **^IMAGE** pointer indicates the image starts at the eighth 2880-byte record in the file. The yellow

section describes the image as 5024 samples wide by 132 lines high, and a pixel value is a 16-bit, MSB-first binary integer.

```
PDS_VERSION_ID        = PDS3
RECORD_TYPE           = FIXED_LENGTH
RECORD_BYTES          = 2880
FILE_RECORDS          = 128
^HEADER = "MCO_0287692247_0X536_ENG.FIT"
^IMAGE = ("MCO_0287692247_0X536_ENG.FIT", 8)
^EXTENSION_HK_HEADER = ("MCO_0287692247_0X536_ENG.FIT", 120)
^EXTENSION_HK_TABLE = ("MCO_0287692247_0X536_ENG.FIT", 126)
^EXTENSION_WINDOW_MISMATCHES_HEADER = ("MCO_0287692247_0X536_ENG.FIT", 127)
^EXTENSION_WINDOW_MISMATCHES_TABLE = ("MCO_0287692247_0X536_ENG.FIT", 128)
OBJECT                          = IMAGE
  DESCRIPTION                   = "Color TDI Image Lossless (CDH 1) - Raw"
  UNIT                            = "DATA NUMBER"
  SAMPLE_BITS                     = 16
  SAMPLE_TYPE                     = "MSB_INTEGER"
  LINE_SAMPLES                    = 5024
  LINES                           = 132
END_OBJECT                      = IMAGE
```

Summary of the EDR (raw) data files: The first section after the HEADER will always be a 2-D image (or 3-D image cube for Pan frame data). After that, a Housekeeping (HK) table contains miscellaneous engineering values. Some files will end with a WINDOW_MISMATCHES table, which keeps track of merged windows. Refer to the PDS data label and the ICD document for more detail.

Summary of the data calibration: There are four processing steps applied to the EDR (raw) MVIC data to produce RDR (calibrated) data (more details for each step can be found in the documentation referenced by or provided in this data set):

1. Remove bias and flat-field pattern
   a) This converts pixel values from raw DN to calibrated DN
2. Add calibration divisors to the FITS header to be used to convert pixel values to physical units
   a) Pixel values remain in calibrated DN units
   b) Multiple divisors are provided; which to use depends on the image source (target) spectrum and geometry (point source or resolved object)
3. Calculate error for each pixel and construct the error array in a new extension
4. Construct data quality extension.

There will not be any correction for scattered light in the RDR products. A complete assessment of the scattered light field will be made in flight, and corrections will be implemented if necessary. There is no correction for cosmic rays in the RDR product. We do not apply the Level 2 calibrations to the non-optically active pixels of the detector to maintain our high-speed header data that is encoded in some of these pixels. Geometric and motion distortion (for the TDI arrays) corrections are higher level products and not part of the calibration pipeline, nor part of any PDS data sets, as resampling is required.

Summary of the RDR (calibrated) data files: All of the MVIC RDR FITS files have a Primary data unit and two extensions. The bias-subtracted, flattened data is stored in the Primary data unit. The first extension has the error array for the Primary data. The second extension has the data quality array for the Primary data. The image data for the TDI observations is stored in a two-dimensional array. The number of columns in the array is always 5024. The number of rows in the array depends on the duration of the observation and the scan rate. The image data for the pan frame observations is stored in a three-dimensional array (an image cube). The number of columns is always 5024, the number of rows is always 128.