Support for New Horizons Instruments within ISIS3. Kristin L. Berry[1], Stuart C. Sides[1], Kenneth L. Edmundson[1], Tracie L. Sucharski[1], and Timothy N. Titus[1], [1] Astrogeology Science Center, United States Geological Survey, Flagstaff, AZ 86001 (kberry@usgs.gov)

Introduction: The New Horizons spacecraft completed its flyby of the Pluto-Charon system in July 2015 and is on its way further into the Kuiper Belt to explore the Kuiper Belt Object (KBO) 2014 MU69 [1]. Data obtained during the Pluto flyby are still being returned from the spacecraft. Some of these data can be reduced and analyzed using new extensions to the Integrated Software for Imagers and Spectrometers (ISIS) [2] to support New Horizon's Long Range Reconnaissance Imager (LORRI), Multispectral Visible Imaging Camera (MVIC), and Linear Etalon Imaging Spectral Array (LEISA).

Overview of ISIS3: ISIS3 is developed and maintained by the U. S. Geological Survey Astrogeology Science Center to support the scientific community in processing and analyzing remotely sensed data. Many NASA and international spacecraft mission instrument teams have used ISIS3 such as the High Resolution Imaging Science Experiment (HiRISE), the Lunar Reconnaissance Orbiter Camera (LROC), MESSENGER, and now New Horizons. In addition to many standard image-processing routines, ISIS3 provides a model for each camera/instrument which is used to convert data from (sample, line) or (x,y) image space to map-projected (longitude, latitude) space for many different map projections [3]. Updated spacecraft position and orientation can be estimated by identifying common points within multiple images to create a control network and using the ISIS3 bundle adjustment program *jigsaw* [4] to calculate a best fit solution. This can then be used to improve image mosaics and maps of Pluto and Charon.

MVIC instrument overview: MVIC is a visible and near-infrared (NIR) imaging camera composed of seven separate charged-coupled devices (CCDs). Of these, six are identical 5024 x 32 pixel detectors operated in time-delay integration (TDI) mode. The seventh is a 5024 x 264 pixel frame-transfer CCD. Four of MVIC's TDI CCDs are combined with filters to produce blue (400-550 nm), red (540-700nm), NIR (780-975 nm), and narrow-band methane (860-910 nm) images. The remaining two provide panchromatic (400-975 nm) images [5].

In TDI mode, the motion of the image across the detector's surface is synchronized with the transfer rate of the CCD so that large-format, high signal-to-noise images can be obtained [5].

MVIC images are provided in the FITS image format and are available on the Planetary Data System (PDS) Small Bodies Node [6] at http://pdssmallbodies.astro.umd.edu/data_sb/missions/newhorizons/index.shtml.

LEISA instrument overview: LEISA [5] is an infrared mapping spectrometer sensitive in the 1.25 - 2.5 micron range. Light passes through a wedged linear variable filter to a 256 x 256 pixel PICNIC detector array. Much like a TDI system, spacecraft motion is used to scan a section of the surface across all spectral channels.

LEISA images are also provided in FITS format and are available on the PDS along with their associated PDS label (.lbl) files. LEISA FITS files contain several FITS extensions with calibration information.

LORRI instrument overview: LORRI is a high-resolution panchromatic imager with a narrow (0.29°) field of view. LORRI is sensitive to light from 350–850 nm and focuses this light onto a 1024 x 1024 pixel frame-transfer CCD [7].

Data Ingestion: To analyze image data in ISIS3, it is necessary to first convert the data to ISIS3 standard image format, an ISIS3 cube. A specialized ingestion application is developed for each instrument to accomplish this task.

LORRI ingestion: The *lorri2isis* application is provided to ingest LORRI FITS files. In addition to the primary data array, users can import the ERROR and QUALITY fits extensions for further data processing.

MVIC ingestion: The *mvic2isis* application is provided to ingest MVIC FITS files. MVIC images from different CCDs/filters are provided as single FITS files, so they are imported as separate ISIS3 cubes. In addition to the primary data array, users can import the UNDISTORTED, ERROR, and QUALITY FITS extensions as separate cubes to use for data reduction.

LEISA ingestion: The *leisa2isis* application was developed to ingest LEISA FITS files and can optionally replace "data" pixels in the input FITS file with null valued pixels in the generated output cube. The FITS QUALITY extension controls which pixels are set to null.

In LEISA FITS images, each band of the image represents a single data frame acquired simultaneously from the PICNIC array. In each of these bands, wavelength changes along the line-direction. During ingestion, the image cube is reorganized such that each wavelength is stored in a separate band. Then, the sample/line coordinates on each band represent different spatial locations in a single wavelength band.

Processing with ISIS3: After images are ingested into ISIS3, information about the position and orientation of the spacecraft must be attached to the ISIS3 cubes. Ephemeris information is provided by the New Horizons navigation team in the form of Navigation Ancillary and Information Facility (NAIF) spacecraft, planet, instrument, camera-matrix, and event (SPICE) kernels [8]. These data can also be obtained from the PDS. The ISIS3 *spiceinit* application will attach this information to the cube to provide geometric rectification for creating cartographic map products.

The desmile application: An additional application was developed to aid in the processing of LEISA images. LEISA has a distortion common to spectral imagers called spectral smile, in which the light from a single spectral channel curves upward (or downward) at the edges of the image, causing spectral misregistration. The *desmile* application spectrally resamples images given a calibration file which provides the shape of spectral smile (for LEISA, this is available in the WAVELENGTHS FITS extension) and a spectral definition file which describes the ideal spectral characteristics of the detector. For more information, please see: https://isis.astrogeology.usgs.gov/Application/presentation/Tabbed/desmile/desmile.html. (*desmile* and its documentation will be available in ISIS version 3.4.12, which will be released in February 2016).

Acquiring ISIS3: ISIS3 can be freely downloaded from http://isis.astrogeology.usgs.gov, and is available for several different versions of Linux and Mac operating systems. Documentation is provided both on the listed website and off-line with your ISIS3 installation [3]. For New Horizons application documentation, see: https://isis.astrogeology.usgs.gov/Application/index.html#New_Horizons.

For help, questions, or concerns with ISIS3, please visit our new support and issue-tracking system located at: https://isis.astrogeology.usgs.gov/fixit.

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