UPDATES TO INTEGRATED SOFTWARE FOR IMAGERS AND SPECTROMETERS (ISIS3). J. W. Backer[1], K. Becker[2], T. Becker[1], K. L. Berry[1], K. L. Edmundson[1], A. Goins[1], I. Humphrey[1], C. E. Isbell[1], L. Keszthelyi[1], J. Mapel[1], M. P. Milazzo[1], C. Neubauer[1], A. Pacquette[1], M. Shepherd[1], S. Sides[1], T. Titus[1], L. Weller[1], K. Williams[1], and T. J. Wilson[1], [1]U.S. Geological Survey, 2255 N Gemini Drive, Flagstaff, Arizona 86001, USA, jwbacker@usgs.gov, [2]Lunar and Planetary Laboratory, University of Arizona, 1415 N. 6th Avenue, Tucson, AZ 85705, USA.

Introduction: The Integrated Software for Imaging and Spectrometers (ISIS3) is a cartographic software package used for processing planetary images [1]. In the last year, several new programs and capabilities have been added to the ISIS3 package.

Currently Available in ISIS3: The following sections list recent additions and modifications to ISIS3:

Field of View Improvements for Pixel Mapping. The *pixel2map* program is designed to individually map project each pixel of a cube (Figure 1). Functionality has been added to allow the user to choose between mapping instantaneous field of view or full field of view [2]. This program is useful for pixels that do not spatially overlap, data that is smeared from long exposure times and drifting, and in some cases, data that is captured from spectrometers.
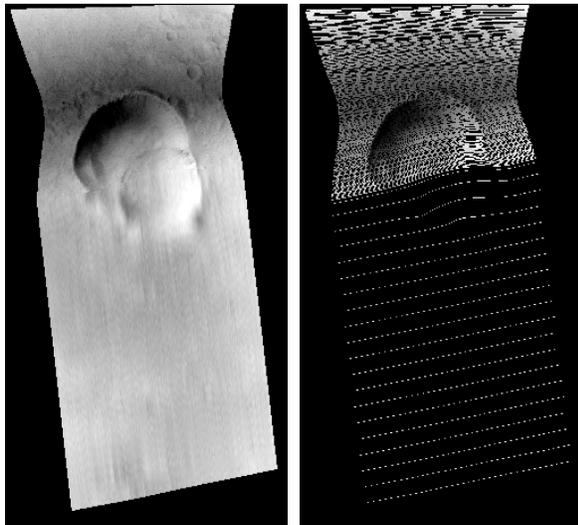

Figure 1. As a comparison for map projecting a Mars Reconnaissance Orbiter CRISM image, the left image shows a *cam2map* run, in which the scan lines have been interpolated/filled. The image on the right shows the same image resulting from a *pixel2map* run where the gaps are maintained in the output and the pixels are spatially correct.

Shape Model Improvements. Functionality has been added to allow the user more options in finding target intersections when using the Navigation and Ancillary Information Facility's (NAIF) digital shape kernel (DSK) shape models [3]. When a user passes a NAIF DSK filename into the program *spiceinit* MODEL parameter, the default functionality of ISIS3 uses the NAIF DSK Toolkit to determine surface intersections. With the latest changes, the user may choose to use the Bullet Physics [4] or the Embree [5] ray tracing libraries for finding intersections on the surface. In most cases, the usage of these alternative libraries reduces the time it takes to intersect the surface. In addition, changes have been made to improve occlusion detection using these ray tracing engines (Figure 2).
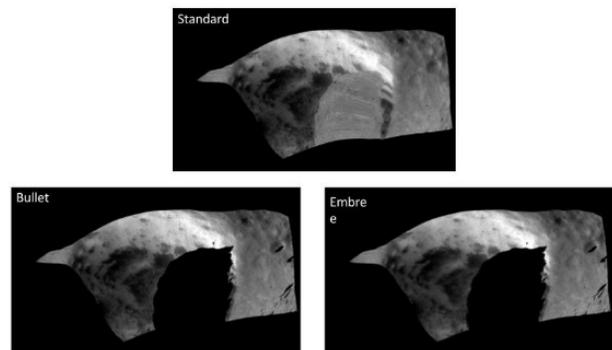

Figure 2. This is an image of Eros, acquired by the Near Earth Asteroid Rendezvous' Multi-Spectral Imager (MSI). The top image, using the NAIF toolkit, shows smeared pixels in an area of the asteroid that is occluded where false positive intersections were found. The lower images were processed using the Bullet (left) and Embree (right) libraries.

Cassini Support. Cassini's Visual and Infrared Mapping Spectrometer (VIMS) experienced a wavelength calibration shift as a function of time [6]. New calibration files were generated and are now used by *vimscal*, the ISIS3 radiometric calibration program for this instrument, to correct for this shift. The *vimscal* program also updates the BandBin:Center keyword in the cube's label to reflect the new knowledge concerning wavelength shifts.

ExoMars Trace Gas Orbiter Support. Several new programs have been added to the ISIS3 package to specifically support processing images from Trace Gas Orbiter's (TGO) Colour and Stereo Surface Imaging System (CaSSIS) [7]. New applications include *tgocassis2isis* (imports CaSSIS' PDS4-labeled images to ISIS3 cubes), *tgocassisstitch* (stitches images that were acquired simultaneously into a single cube), *tgocassisunstitch* (separates the subwindows of a stitched product into individual cubes)**,** and *tgocassisrdrgen* (exports from ISIS3 cube to a PDS4 compatible product)**.**

Hayabusa 2 Support. ISIS3 has new programs to ingest images from Hayabusa 2 Optical Navigation Cameras (ONC) and radiometrically calibrate them [8]. These programs, *hyb2onc2isis* and *hyb2onccal,* respectively, support the wide-angle cameras, ONC-W1 and ONC-W2, and the telescopic camera ONC-T.

Juno support. The ingestion program, *junocam2isis***,** will ingest images acquired by the JunoCam instrument [9], allowing the user to choose between full frame images and individual filter images [10].

PDS4 Label Import and Export. As more missions will need to archive their products using Planetary Data System's PDS4 standards [11], we have added preliminary support for importing and exporting PDS4 compatible labels. General ISIS3 cubes can be exported to PDS4 using *isis2pds* by setting the parameter PDSVERSION=PDS4. These output products have detached labels that are currently not entirely PDS4 compliant. Some required enumerated values need to be determined and inserted by the user. The *isis2pds* program will write "TBD" anywhere in the labels where an enumerated value must be determined and replaced by the archiver. There is no generalized import functionality for PDS4 labels added to pds2isis as of this writing. The import functionality that has been added is is currently tied to only supported missions.

Expected in Release of ISIS3.5.2: Some projects currently in the works:

ISIS3 Control Network Improvements. Control Networks will be improved by increasing efficiency of memory usage and reducing on-disk file sizes. This project is currently in progress. As of this writing, memory usage when reading networks has been reduced by approximately 33%.

ISIS3 Bundle Adjustment (BA) Improvements. We continue to improve the ISIS3 BA (*jigsaw*) [12]. Most recently we have implemented piecewise polynomials in the BA to represent the position and attitude of images from time dependent sensors (e.g. line scanners, radar). Previously, position and attitude could be modeled only as single polynomial functions of time. Low-order polynomials cannot accurately represent complex spacecraft motions induced by, e.g., thruster firings, operation of other instruments, or anomalous events. Modeling such motion requires high-order polynomials, but these can cause instability in the BA. A piecewise polynomial model in which the image is divided into segments, each with a low-order polynomial, offers a better approach [13].

References: [1] Sides, S. C., et al. (2017) LPSC XLVIII, Abstract #2739. [2] USGS, https://isis.astrogeology.usgs.gov/Application/presentation/Tabbed/pixel2map/pixel2map.html. [3] Acton, C., et al. (2016). Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLI-B4, pp. 357-359. [4] Coumans, E., et al. http://bulletphysics.com. [5] Wald, I., et al. (2014) ACM Transactions on Graphics, Vol. 33, No. 4, Article 143. [6] Clark, R. et al. (2016) NASA Planetary Data System. [7] Thomas, N., et al. (2014) Eighth International Conference on Mars. [8] JAXA, http://global.jaxa.jp/projects/sat/hayabusa2/. [9] Hansen, C. J., et al. (2014) Space Sci Rev., DOI 10.1007/s11214-014- 0079-x. [10] Milazzo, M. P. et al. (2018) LPSC XLVIV, Abstract. [11] Crichton, D. et al. (2011) EPSC Abstracts Vol. 6, EPSC-DPS2011-1733. [12] Edmundson, K.L. et al. (2012) *ISPRS Annals, I-4,* 203208. [13] Poli, D. (2005) Dissertation #15894, ETH Zurich.

Additional Information: **F**or further documentation on ISIS3 programs, go to https://isis.astrogeology.usgs.gov//Application/index.html.

To report any bugs or request features, go to https://isis.astrogeology.usgs.gov/fixit/.