INITIAL GROUND REGISTRATION OF NEAR MSI IMAGES TO ASTEROID (433) EROS. K. J. Becker[1], D. N. DellaGiustina[1], C. A. Bennett[1], D. R. Golish[1], [1]Lunar and Planetary Laboratory, University of Arizona (1415 N. 6th Ave., Tucson, AZ, 85705, kbecker@orex.lpl.arizona.edu

Introduction: The Near Earth Asteroid Rendezvous–Shoemaker (NEAR) [1] mission acquired images of asteroid (433) Eros. Images acquired by the Multispectral Imager (MSI) instrument were used to construct a global digital terrain model (DTM). An image-based stereophotoclinometry (SPC) [2] technique was used to derive the highest resolution shape model of Eros containing more than 3 million facets. One of the preliminary steps in the SPC process is to register all the images used and correct their pointing attitude and spacecraft position errors. The updated orientation and position data are stored in a SUMFILE for each MSI image. These SUMFILEs can be applied to image cubes in the Integrated Software for Imagers and Spectrometers (ISIS) [3] system using the *sumspice* application. This procedure results in a global coverage subset of images that are directly registered to the shape model. The advantages of this approach are: 1) by definition, images are registered to the shape model which results in excellent orthorectified cartographic maps, 2) it relieves the user of the burden to register images that often require complex control/bundle adjustment techniques, 3) processing time from raw experiment data record (EDR) to cartographic (map) products is greatly reduced, and 4) it provides a ground control resource from which additional images can be added to the set. We intend to use this technique to register additional Eros MSI images to the DTM and produce high quality, orthorectified, cartographic products.

Discussion: Image registration and bundle adjustment control processes are generally required to correct pointing and position errors in remotely sensed data. This is particularly true in older orbital image data sets as a priori ephemeris data was of poor quality. Building a high-quality image-to-image control network is tedious, complex, iterative and error prone. If a DTM exists for the target body, it will add additional challenges as it serves as the ground truth against which the control network must be registered. However, development of the DTM also requires image registration, whereby some applications may be able to make use of these ephemeris corrections in other systems. We have developed techniques to utilize control *byproducts* of the SPC DTM processes so that this work can be applied effectively and quickly using the ISIS system to create higher level orthorectified, cartographic products.

The SPC process produced more than 21,000 SUMFILEs, one for each MSI image registered to the Eros shape model. We have acquired these SUMFILEs and tested them in ISIS. However, some of the ISIS NEAR/MSI support software required modification before SUMFILEs could be effectively applied to ISIS image cubes.

ISIS Modifications. The ISIS system currently provides support for the NEAR/MSI instrument. Initial testing of *sumspice* with SPC SUMFILEs on MSI images failed due to faulty spacecraft clock (SCLK) start/stop time formatting in the PDS image headers. These values are incompatible with the NAIF SCLK kernel as they exist in the image headers and were therefore not utilized in the ISIS MSI camera model. The SCLK start/stop times are required by *sumspice*.

msi2isis: As a result, the ISIS MSI ingestion application, *msi2isis,* was modified to properly format the SCLK times after propagation from the PDS label. For example, the SCLK value in the PDS label from m0136738494f4_2p_iof_dbl.lbl is 136738494.851. The proper form of the SCLK is 136738494851. The new modification to *msi2isis* multiplies the SCLK by 1000.0 and converts it to an integer for NAIF compatibility.

ISIS MSI Camera Model: In addition, the ISIS MSI camera model was modified to use SCLK times rather than the Coordinated Universal Time (UTC) from the labels. With these modifications, the *sumspice* application successfully updates the ISIS MSI image cubes with the pointing attitude and spacecraft position adjustments contained in the SUMFILE.

Results: The PDS archive of the NEAR/MSI data [4] acquired of Eros contains a total of 248,996 images comprised of all 8 filters. From this archive, there were ~21,135 images selected to construct the Eros shape model using SPC methods. We also used the PDS archive to correlate the SPC SUMFILEs with MSI filter 4 images resulting in 10,110 pairings with I/F, deblurred images. Only images that have a pixel resolution higher than 21 meters were selected.

Initial ISIS processing consists of ingestion/conversion of PDS images to ISIS format via *msi2isis* and application of a priori SPICE kernels using *spiceinit.* Then, *sumspice* was applied to the SUMFILE and ISIS MSI image pair to update pointing and position, thus registering the image to the Eros DTM. Completion of this processing procedure is equivalent to ISIS control development as described in the creation of the (101955) Bennu global basemap [5].

Figure 1 is an image depth map that shows the count of how many of the 10,109 images (one image was corrupted) to provide coverage at each pixel location. Note that you can clearly see Eros surface features, such as craters and boulders, in the map. This is a result of enhanced ray tracing processing techniques [6] that determine occlusion areas, or shadows, that are caused by foreground topography. These areas are masked out of image data prior to projection into a global equirectangular map. An *average* mosaic produces two map planes, one being the average of all the image data numbers (DN), in this case I/F, and a count of all images that map to the pixel center latitude/longitude coordinate. Areas of occlusion (shadows) in each image added to the mask do not contribute to either map plane.

Future Work: These results provide a basis of image ground control to the Eros DTM. Using established feature matching and control techniques [5], additional MSI images will be registered to the DTM. We intend to use the filter 4 ground control to register additional MSI filter images to produce high quality color map products. SPICE CK and SPK kernels will then be created and archived specifically for direct application to MSI images, particularly in the ISIS system, that is included in this work.

References: [1] Cheng, A. F. et al. (1997) *JGR Planets* 102. [2] Gaskell, R. W. (2007) LPS XXXVIII, #1333. [3] Anderson, J.A., et al. (2004) LPS XXXV, #2039. [4] NEAR/MSI PDS Archive, https://sbn.psi.edu/pds/resource/near/msiinst.html. [5] Bennett, C.A., et al. (2020) *Icarus*, 113690, ISSN 0019-1035. [6] DellaGuistina, D.N., et al. (2018) *Earth Space Sci.,* 5, pp. 929-949.
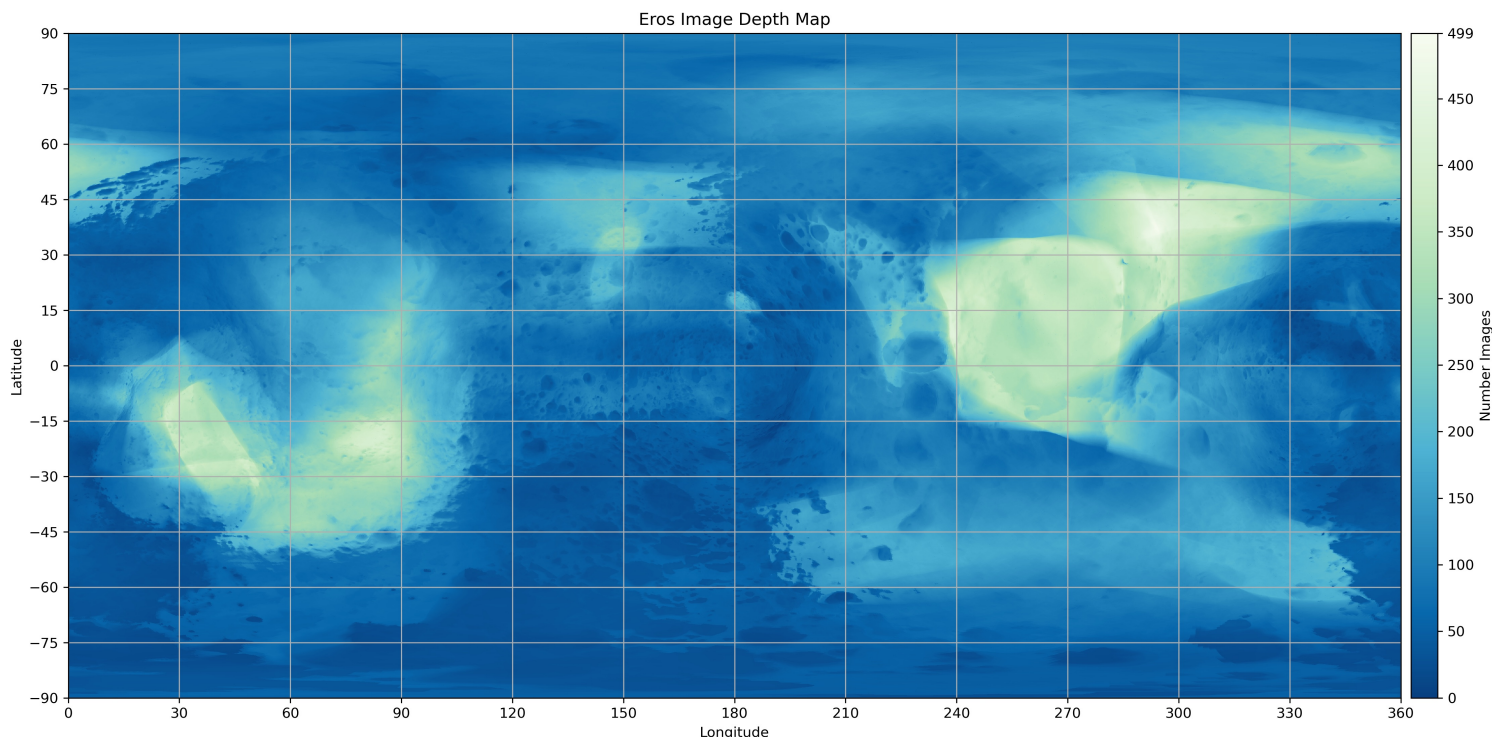

Figure 1. Image average mosaic that records the number of images that provide coverage at that pixel location in the map. Note that some surface features are identifiable in the map. These features are consistent with occlusion areas in original images that are masked out before projection.