THEMIS GEODETICALLY CONTROLLED MOSIACS OF MARS. R. L. Fergason[1], E. M. Lee[1], L. Weller[1], Astrogeology Science Center, [1]U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001, rfergason@usgs.gov.

Introduction: The objective of this work is to geodetically control and mosaic Thermal Emission Imaging System (THEMIS) [1] daytime infrared (IR) and nighttime IR images. We have also investigated how best to register THEMIS images to a known reference coordinate frame (such as that of the Mars Orbiter Laser Altimeter (MOLA) data set [2;3]). The results of this work are controlled, orthoprojected daytime IR and nighttime IR mosaics of Mars at 100 m/pixel scale for selected regions (Figure 1). These mosaics, and the associated network, have improved registration of the THEMIS IR data set, enhance our knowledge (position, precision, and accuracy) of image placement and the location of small-scale surface features, and provide for improved targeting for current and future orbital acquisition of data and spacecraft landings and planning of spacecraft surface operations.

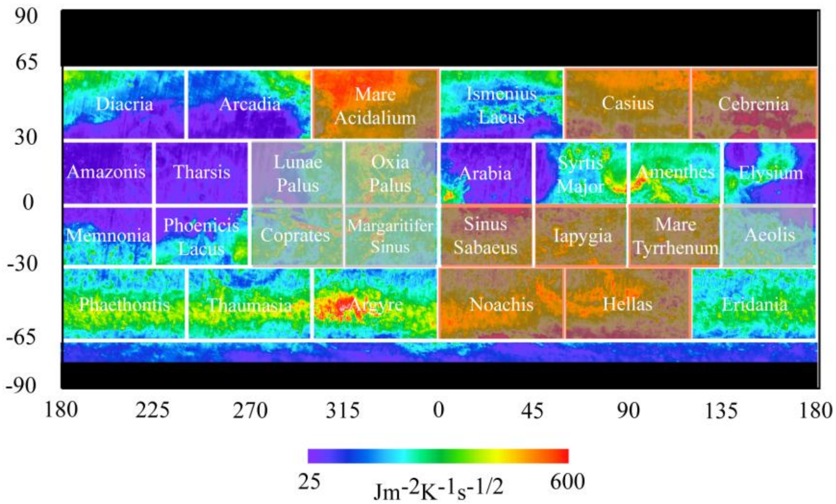

Figure 1. The standard mapping format of Mars at 1:5,000,000 scale overlaid onto a Thermal Emission Spectrometer global thermal inertia map (*Putzig and Mellon*, 2007). The five tiles generated in FY12 are shaded in light gray. The eight tiles to be generated in FY13-FY14 are shaded in orange.

Background: The THEMIS instrument onboard the 2001 Mars Odyssey spacecraft [1] has attained near global coverage of Mars in the daytime and nighttime IR at a scale of ~100 m/pixel, providing the needed images to geodetically control (i.e., precisely and accurately register in a consistent solution with estimates of uncertainty) these data into a common reference coordinate frame at the sub-pixel level. Registration to single-pixel precision is essential for comparison of multiple data sets, and sub-pixel precision reduces the possibility for misinterpretation and increases the information extracted from individual images. Precise coregistration and the knowledge of the precision and accuracy of that registration is necessary for several types of analysis designed to extract valuable information from the subtle differences between multiple images, such as topography, composition (through multispectral analyses), surface texture, and surface albedo change detection. We have generated control networks for five regions of Mars (gray areas in Figure 1) and have achieved sub-pixel registration (precision) in all cases. THEMIS is the highest resolution near global data set currently available, and being able to accurately register other data sets to a controlled global THEMIS mosaic would enhance the science return from the THEMIS instrument and most other past and future instruments as well.

THEMIS global daytime and nighttime IR mosaics have been created by Arizona State University using the ISIS 3 camera model and dead-reckoning camera pointing (i.e. no individual image adjustment to match features or an attempt to correct for uncertainties in the camera model) [4]. These mosaics are not controlled; spacecraft ephemeris and attitude have not been adjusted geometrically for consistency with the collected image information and with known error estimates. Therefore, the current global mosaics do not reach their full potential precision (sub-pixel average error at ~100 m/pixel) and accuracy. Errors in image position on the 2-4 pixel level (but as large as 30 pixels) are apparent (Figure 2) and are likely to be primarily due to uncertainties in the image start time. This uncertainty is random, and there are no future plans to improve the THEMIS IR camera model further. Controlling the pointing will enable the correction of these errors and improve both the registration between images and registration to a known coordinate reference frame (e.g., MOLA) at known levels of precision and accuracy. In all tiles generated to date, the accuracy of image position is less than a single pixel, and the 3-sigma residual is also less than a single pixel.

Products Generated: We also investigated the feasibility and accuracy of tying THEMIS images to the gridded MOLA DTMs [2; 3], Viking MDIM 2.1

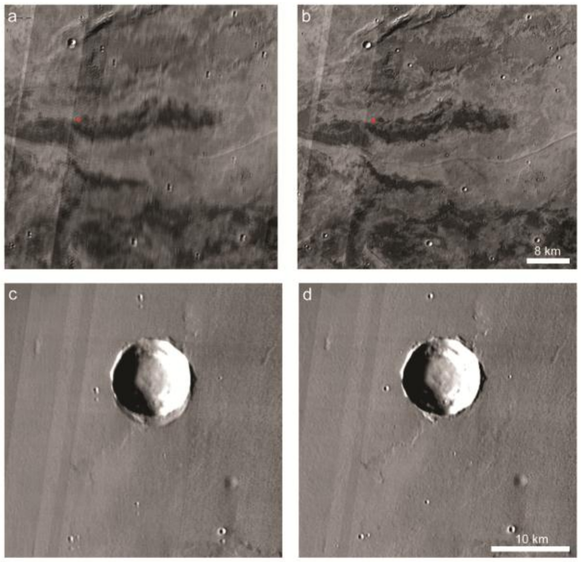

Figure 2. Comparison of uncontrolled (left column) and controlled (right column) image averaged mosaic products. A portion of the uncontrolled (a) and controlled (b) mosaic within the Coprates tile at 28.75° S, 73.0° E. A six pixel shift was necessary to match features in this area, which is a common amount of correction. A portion of the uncontrolled (c) and controlled (d) mosaic within Lunae Palus at 17.3° N, 279.6° E. A 14 pixel shift was necessary to match features in this area. Although this correction is relatively large, corrections of this magnitude were necessary in all tiles.

[5; 6], High Resolution Imaging Science Experiment (HiRISE) stereo digital terrain models (DTMs) [7], and High/Super Resolution Stereo Colour Imager (HRSC) [8] level four data (which have been well controlled to the MOLA reference frame). We determined that a combined approach was the best choice in order to take advantage of the high accuracy HRSC data and the geometric strength of the global MDIM. We reprocessed the original MDIM 2.1 network using HRSC level 4 data as additional ground control. Forty HRSC DTMs evenly distributed on the Martian surface were chosen to provide global coverage. Over one hundred additional HRSC DTMs were used as dense coverage around the boundaries of the tile areas. Elevations of all points that did not already have MOLA derived elevations were constrained to be near the MOLA DTM. These additions allowed the accuracy of the over one thousand manual grid ties from the original MDIM 2.1 to be better estimated, and error propagation showed that 80% (~2700 points) of the final enhanced MDIM solution tie points have horizontal accuracies better than 200 meters. The published horizontal accuracy of the MOLA gridded data (probably the most commonly used geodetic reference on Mars) is 250 meters [9]. However, the accuracy of the MOLA data in a particular area has not been well quantified and varies significantly with location. For example, at the equator the data may have been interpolated between MOLA tracks for multiple kilometers. The improved MDIM 2.1 network therefore has comparable, and in many areas superior, horizontal accuracy compared to the MOLA gridded data. This improved MDIM network can now be utilized to tie THEMIS images (or any other martian image dataset) into a MOLA provided reference frame, using reliable and often automatic image to image ties. THEMIS tiles were tied to the improved MDIM network ground points.

THEMIS daytime IR and nighttime IR control networks and mosaics for the following regions (i.e., tiles) are complete: Aeolis, Coprates, Lunae Palus, Margaritifer Sinus, and Oxia Palus (gray areas in Figure 1). These mosaics will be distributed to the planetary science community through publicly available websites, such as the Planetary Cartographic Catalogue and Web Services (Astropedia; http://astrogeology.usgs.gov/astropedia) in ISIS 3 cube, GeoTiff, and PNG data formats. These formats are easily utilized by ArcGIS, ENVI, and JMars data analysis software tools.

Future Work: We are currently generating additional THEMIS daytime and nighttime IR control networks and mosaics for the following regions: Casius, Cebrenia, Hellas, Iapygia, Mare Acidalium, Mare Tyrrhenum, and Sinus Sabaeus (orange areas in Figure 1), and expect these tiles to be publicly available by September 2014. This project is phase two of a multi-year effort to geodetically control and generate mosaics for the ±65˚ latitude region of Mars. In addition to mosaics, updated image pointing kernels of all THEMIS images included in the control networks will be released to the community. We anticipate that the new kernels will be added to the standard ISIS distribution. This option will allow it to be used in the ISIS3 "spiceinit" program, where the user has the option of selecting predicted, reconstructed, or updated SPICE kernels. We may also deliver this product to the Navigation and Ancillary Information Facility (NAIF) team so they can include it on the PDS NAIF FTP site.

References: [1] Christensen P. R. et al. (2004) *Space Sci. Rev.*, *110*, 85-130. [2] Smith D. et al. (1999) *Science*, *284*, 1495-1503. [3] Smith D. E. et al. (2001) *JGR*, *106*, 23,689-23,722. [4] Edwards C. S. et al. (2011) *JGR*, *116*, doi:10.1029/2010JE002755. [5] Archinal B. A. et al. (2003) *LPS* XXXIV, Abstract #1485. [6] Archinal B. A. et al. (2004), *XXth ISPRS Congress*. [7] Kirk R. L. et al. (2008) *JGR*, *113*, doi:10.1029/2007JE003000. [8] Jaumann R. et al. (2007) *Planet and Space. Sci*., *55*, 928-952. [9] Neumann G. A. et al. (2001) *JGR*, *106*, 23,752-23,768.