Mars Transverse Mercator (MTM) Map series updated with Planetocentric Grid. M. R. Rosiek, E. Howington-Kraus, T.M. Hare, and B. L. Redding, U.S. Geological Survey, Astrogeology Research Program, 2255 N. Gemini Dr., Flagstaff AZ 86004. (mrosiek@usgs.gov).

Introduction: The Mars Transverse Mercator (MTM) Map Series has been used to publish geologic and controlled photomosaic maps of Mars since 1984. Traditionally maps were published using planetographic coordinates with positive west longitude [1]. In recent years planetocentric coordinates with positive east longitude have become more widely used for some Mars planetary data. The MTM map series has been updated to use planetocentric coordinates with positive east longitude as the primary grid with a secondary grid showing the planetographic coordinates with positive west longitude. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Data sources: During cartographic processing, data from different sources are brought together for processing and extracting data to be placed on a map in the same scale and map projection. Ideally all the data would be registered and in the same coordinate system, unfortunately this is rarely the case. Mars data have been collected and produced as our knowledge of the shape of Mars has changed. Also the systems used to extract data can place limits on the coordinate systems.

Imagery. Stereo imagery data can be used photogrammetrically to extract elevation data. Currently the best image source for maps at the 1:500,000 scale is Viking imagery. However, the expected precision and coverage across Mars of the Viking dataset is not uniform [2]. Data from the wide-angle Mars Orbiter Camera (MOC WA) provides stereo coverage at ~240 m/pixel resolution [3]. These data could be used to extract elevation data.

The Mars Digital Image Map (MDIM) 2.0 [4] is a controlled mosaic that provides horizontal control for cartographic processing. It does not use the IAU 2000 [5] definitions for the shape of Mars. The MDIM is being updated and when the new version is available that version will be used for horizontal control [6].

Elevation data. The Mars Orbiter Laser Altimeter (MOLA) has produced a global altimetric dataset (http://wufs.wustl.edu/missions/mgs/mola/index.html) with phenomenal absolute accuracy and excellent vertical and along-track (north-south) spatial resolution but a larger inter-track separation that limits the overall resolution of gridded products [7]. The MOLA dataset label files (meg0015t.lbl and meg0015c.lbl) describe the 1/64-degree MOLA grid and density files. MOLA nadir observations are used for the most part except in the polar regions (87° N. to the north pole and 87° S. to the south pole). Additionally, the data were adjusted using a first-order crossover solution for radial, along-track, and across-track position. The track data were binned into square cells that are 0.015625º on a side. The density of MOLA shots per cell are lowest near the equator, 45% of the bins contain no MOLA observation. Gaps up to 12 km exist between cells that contain a MOLA observation.

Processing: Image processing for the Viking imagery is carried out on UNIX workstations using the ISIS (Integrated Software for Imagers and Spectrometers) software system [8, 9, 10]. The images are radiometrically and geometrically corrected and converted to 8-bit raw format. The images, along with position and orientation data, are imported into SOCET SET (® BAE SYSTEMS). The MDIM imagery is obtained as 8-bit TIFF images from the Map-a-Planet Web Site (http://astrogeology.usgs.gov/Projects/Map-a-Planet) and translated to align with the MOLA data. The MOLA data are obtained as track information and processed as points. This elevation information is brought into ArcMap (® ESRI) and processed into a gridded dataset and exported as an ASCII file that can be imported into SOCET SET. Both SOCET SET and ArcMap are used primarily for Earth-based data and are designed to use data in a geodetic coordinate system with longitude values as ± 180° and positive east.

Imagery. When importing an image in SOCET SET, the known camera position and orientation can be supplied. Camera positions and orientations exist on the labels of ISIS images but in coordinate systems not recognized by SOCET SET. ISIS stores the camera position as a vector in Earth Mean Equatorial (EME) coordinates. EME is an inertial coordinate system in which the equations of motion for the solar system may be integrated. EME is specified by the orientation of the Earth's mean equator and equinox at a particular epoch – typically the J2000.0 epoch. The J2000.0 epoch is noon on January 1, 2000 Barycentric Dynamical Time. For use in SOCET SET, the ISIS camera positions are converted to planetographic coordinates (specifically, longitude and latitude relative to the center of a planet, and height above the planet datum). Attention must be given to the resulting longitude coordinate of the camera position. For many planets, the direction of positive longitude is defined to be positive-west, whereas SOCET SET expects longitudes to be entered as positive-east, such as is the definition on Earth. When positive longitudinal direction conflicts with that of Earth, the positive longitude direction must be converted upon import to and export from SOCET SET. As for camera orientation angles, these are stored in ISIS as right ascension, declination and twist (RA, Dec, Twist) angles, which define the transform between EME coordinates and camera coordinates. SOCET SET expects camera orientation angles that define the transformation from ground space (planet surface) to image space, so the ISIS camera orientation angles are converted to the photogrammetrically familiar omega-phi-kappa rotation system.

The MDIM 2.0 imagery is obtained as a TIFF image formatted in a simple cylindrical projection. This image is then translated to align with the MOLA data using the tools within ArcMap. This process allows using the MDIM for horizontal control but takes advantage of the improved horizontal accuracy of MOLA. An improved version of the MDIM (version 2.1) is being developed that is tied to the MOLA data; as soon as that version is available it will be used for horizontal control.

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Elevation data. The MOLA elevation data are obtained as track information and are processed to yield point data that are based on the planet shape definition that is used within SOCET SET. This allows the input of the semi-major and semi-minor axis, and an adjustment to the prime meridian if necessary. The point data are transformed into a grid and is exported to SOCET SET.

Data extraction: SOCET SET is used to photogrammetrically extract elevation data using the Viking imagery. The MDIM provides horizontal control and the MOLA data are used to provide vertical control. Within SOCET SET the data are in a geographic coordinate system with longitude values as ±180° and positive east. A digital terrain model (DTM) is collected that is slightly larger than the final map. An orthophotomosaic is produced using this DTM and the Viking imagery.

Data Projection: The DTM and orthophotomosaic are exported from SOCET SET back to ISIS. Routines within the SOCET SET libraries and ISIS programs are used to project the data from planetographic coordinates in an Equidistance Cylindrical projection into planetocentric coordinates in a Mars Transverse Mercator projection. The DTM and orthophotomosaic are trimmed to the map boundaries of the project and are brought into ArcMap where the contours are automatically drawn based on the DTM. These data are exported to an Illustrator (® Adobe) format where the map is finalized.

Map finalization: The map finalization process brings together the orthophotomosaic, contour lines, grid lines, nomenclature, and collar information. Grids are produced using the ISIS program "lev2grid" which generates a grid to scale in either the planetocentric or planetographic latitude system. Boundaries, increment, projection and scale for the grid are defined by "lev2grid" parameters. Grids are generated in an Illustrator compatible format. To align the planetographic grid to the planetocentric grid, a bounding box is created on the planetographic grid using calculated planetographic coordinates that match the latitude and longitude ranges for the planetocentric grid.

Final Products: The final map product is published as a USGS I-map, which will be available through the Western Region GeoPubs Web Site. The orthophotomosaic image and DTM will be available through a web site at Flagstaff. To distinguish between MTM maps in planetocentric and planetographic, the map designator has been modified. MTM 500k –05/287 E would refer to a Mars Transverse Mercator Map 1:500,000 scale centered at 5° S. latitude and 287.5° E. longitude. This would correspond to MTM 500k –05/072 in the planetographic system, Mars Transverse Mercator Map 1:500,000 scale centered at 5° S. latitude and 72.5° W. longitude.

References: [1] Inge J.L. and Batson R.M. (1992) Indexes of Maps of the Planets and Satellites, NASA Tech Memo 4395. [2] Kirk R. L. et al. (1999) *LPS XXX*, #1857. [3] Caplinger M. A. and Malin M. C. (2001) *JGR.*, 106, E10, 23595-23606. [4] Kirk, R.L et al. (2000) *LPS XXXI*, # 2011. [5] Seidelmann P. K et al. (2002) *Celestial Mechanics and Dynamical Astronomy*, 82, 1, 83-111. [6] Kirk, R. et al. (1999) *LPS XXX* #1849. [7] Smith, D.E. et al. (2001) *JGR*, 106, E10, 23689-23722. [8] Eliason, E.M. (1997) *LPS XXVIII* 331-332. [9] Gaddis, L. et al. (1997) *LPS XXVIII* 387-388. [10] Torson J. and Becker K., (1997) LPS XXVIII 1443-1444.