MARS DIGITAL IMAGE MODEL (MDIM) 2.1 CONTROL NETWORK. B. A. Archinal[1], R. L. Kirk[1], T. C. Duxbury[2] E. M. Lee[1], R. Sucharski[1], and D. Cook[1], [1]U. S. Geological Survey (Astrogeology Team, 2255 N. Gemini Drive, Flagstaff, AZ 86001, USA, barchinal@usgs.gov), [2]Jet Propulsion Laboratory (4800 Oak Grove Drive, M/S: 264-379, Pasadena, CA 91109, USA, Thomas.C.Duxbury@jpl.nasa.gov).

Introduction: USGS is currently preparing a new version of its global Mars digital image mosaic, which will be known as MDIM 2.1 [1-3]. As part of this process we are completing a new photogrammetric solution of the global Mars control network. This is an improved version of the network established earlier by RAND and USGS personnel [4-6], as partially described previously [7].

MDIM 2.1 will have many improvements over earlier Viking Orbiter (VO) global mosaics. Geometrically, it will be an orthoimage product, draped on Mars Orbiter Laser Altimeter (MOLA) derived topography, thus accounting properly for the commonly oblique VO imagery. Through the network being described here it will be tied to the newly defined IAU/IAG 2000 Mars coordinate system [8,9] via ties to MOLA data. Thus, MDIM 2.1 will provide complete global orthorectified imagery coverage of Mars at the resolution of 1/256º of MDIM 2.0, and be compatible with MOLA and other products produced in the current coordinate system.

Control Network Improvements: Improvements over previous Mars control networks are as follows.

New IAU/IAG 2000 coordinate system: The IAU/IAG Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites has adopted new constants, which define the Mars body fixed coordinate system for locations on Mars. The constants as adopted were recommended via the NASA Mars Geodesy and Cartography Working Group to the IAU/IAG WG [8,9]. The changes include the specification of new constants to define the spin (e.g. W_0 =176.630º) and pole position of Mars

New derivation of VO image acquisition information. New values for the exposure epochs and derived camera pointing and spacecraft position information have been determined by NASA NAIF personnel [10]. These values have been adopted for use in the control solution here for all VO images (except for images FSC 39151122, 52128638, and 52653629, where it was necessary to use older values to get a reasonable solution). This better *a priori* camera station information should result in a better solution, particularly since we do not adjust the exposure epoch or spacecraft position. Solutions using this new information do indeed show at least a 5% (17.8 µm to 16.9 µm) lower overall RMS.

New camera reseau finding procedure. An improved algorithm has been created in the USGS ISIS [10] software for determining the locations of the reseau marks on VO images. In the cases where we have the original RAND and USGS pixel VO image measurements of control points (which is the case for 77,225 measurements) these new locations have been used to recalculate (mm) control point locations in the image plane prior to adjustment. In addition a number (329) of measurements of control points near the edge of the images and outside the available reseau information and therefore of questionable value have been removed. Solutions with these changes also show a 4% (16.9 µm to 16.2 µm) lower overall RMS although some of this is simply due to a reduced number of observations.

The radii of all control points have been derived by interpolation of a MOLA global radii grid (see http://wufs.wustl.edu/missions/mgs/mola/egdr.html). The MOLA radii should be accurate to ~10 m vertically and ~100 m horizontally [12]. This procedure has been iterated a number of times, so that as changes are made in the solution or new data are introduced and new horizontal coordinates are derived for control points, new *a priori* radii information is obtained from the MOLA dataset. Again, that there is an improvement in using the MOLA data in these successive steps is shown by an 11% decrease in the overall control network solution RMS.

Measures from additional images are included. Measures of 52 images that were used in MDIM 2.0 but not rigorously included in the previous RAND adjustment for MDIM 2.0 are now being included in this solution. There are 406 such measurements of 203 control points on 102 images (including the new images and images that overlapped them). It is also possible that measures from some additional new images will be included in our final solution.

Horizontal positions of a number of control points have been fixed to MOLA derived values. This in effect provides equally spaced "ground control" for Mars globally. Our procedure is to match high resolution MOLA DIMs (as derived by Duxbury) with VO images, and measure the positions of existing and new control points on both. Such measurements are made using an annulus cursor centered on a crater rim in order to avoid parallax problems in measuring the position of the center of a crater. In the network solution, the latitude and longitudes of these points, as derived from the MOLA DIMs, are held fixed. A grid of such points has been measured globally on Mars, with 15º latitude and 30º longitude spacing (Figure 1). We anticipate that at the locations of these points the horizontal positions are therefore similar in accuracy to the inherent accuracy of the MOLA DIMs, or about 100 to 200 m, with most of the uncertainty resulting in the correct measurement of the VO images and the MOLA DIMs. The accuracy will obviously be less as one moves to areas away from these MOLA tie points, but we are planning to verify (below) that the horizontal positional accuracy does not degrade substantially from these estimates.

Existing and new image measurements have been verified. Measurements with solution residuals having pixel values over 4-5 mm are carefully checked in order to reduce such residuals. This is in comparison to previous (RAND) solutions where the largest residuals were about 7.5 pixels. Many have been redone; while others have been removed from the solution in cases where it was felt the control point in question cannot be adequately remeasured (e.g. because of a poorly defined feature, a low contrast image, or a point near the edge of an image). We are additionally preparing large area MDIM 2.1 test mosaics based on our current solutions, which are being carefully examined for any problems. These mosaics have MOLA derived contours added (Figure 2) to allow checking of how well they are registered to the MOLA data. In cases where the registration shows differences (at the more than a few hundred meter level) or in cases where there appears to be any misregistration of VO images with each other, we are making additional image and MOLA control point measurements, and improving the solution with these measurements in order to eliminate the problems.

Results: We have completed all of the steps described above, and are now in the process of generating additional test mosaics in order to check whether any additional control point measurements are needed. We plan to do additional checks on the overall horizontal accuracy of the control network by checking the location of additional MOLA tie points and also of the Viking and Pathfinder landers (whose horizontal positions are also known to high accuracy via spacecraft tracking [13]). This will be done by *not* fixing their coordinates in the control network adjustment but rather comparing their solved-for coordinates with the known locations.

The current Mars control network solution contains 90,204 measurements of 37,645 control points on 6,371 images. Of these measurements, 77,687 are on 5,317 VO images, whereas 12,517 of the measurements are on 1,054 Mariner 9 images, as a carry-over from the original RAND networks. The Mariner 9 image measurements continue to have generally lower residual values than the VO image measurements, so are maintained in the solution both to add geometrical strength and also to allow for the production of updated Mariner 9 camera pointing information. A total of 1,216 control points have been tied to MOLA DIM tiles, and it is the coordinates of these control points that are held fixed (to the appropriate MOLA derived latitude and longitude). The solution RMS is 16 µm or about 1.4 Viking pixels.

Conclusions: We are completing a new global Mars control network, extending earlier work done at RAND and USGS. This new network will be consistent with the IAU/IAG 2000 Mars body-fixed reference system and in particular topography derived from MOLA data in that system. The overall accuracy of positions derived is expected to be similar to that of MOLA in both the horizontal (~250 m) and vertical (~10 m). This network and the associated solved-for VO camera angles will be used to create the USGS MDIM 2.1 mosaic, thus assuring that mosaic will have a similar level of accuracy and that it can be used directly with MOLA derived products. A further product will be camera angles in the IAU/IAG 2000 system for 1,054 Mariner 9 and 5,317 VO images, which will also (e.g.) allow for their direct registration on MOLA topography.

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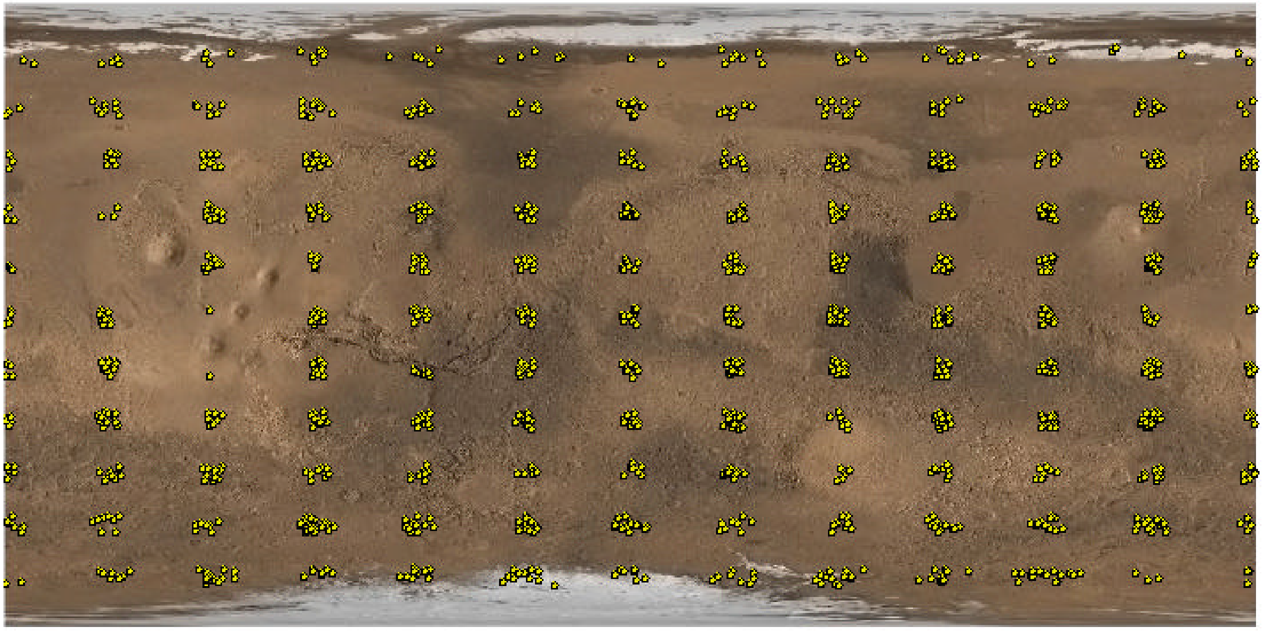

Figure 1: 1,216 MOLA (tie) control points, measured in groups with spacing of 30º in longitude and 15º in latitude. The background is a global MOC Mars mosaic. Simple cylindrical projection with 0º longitude at center, north up, and east to the right.

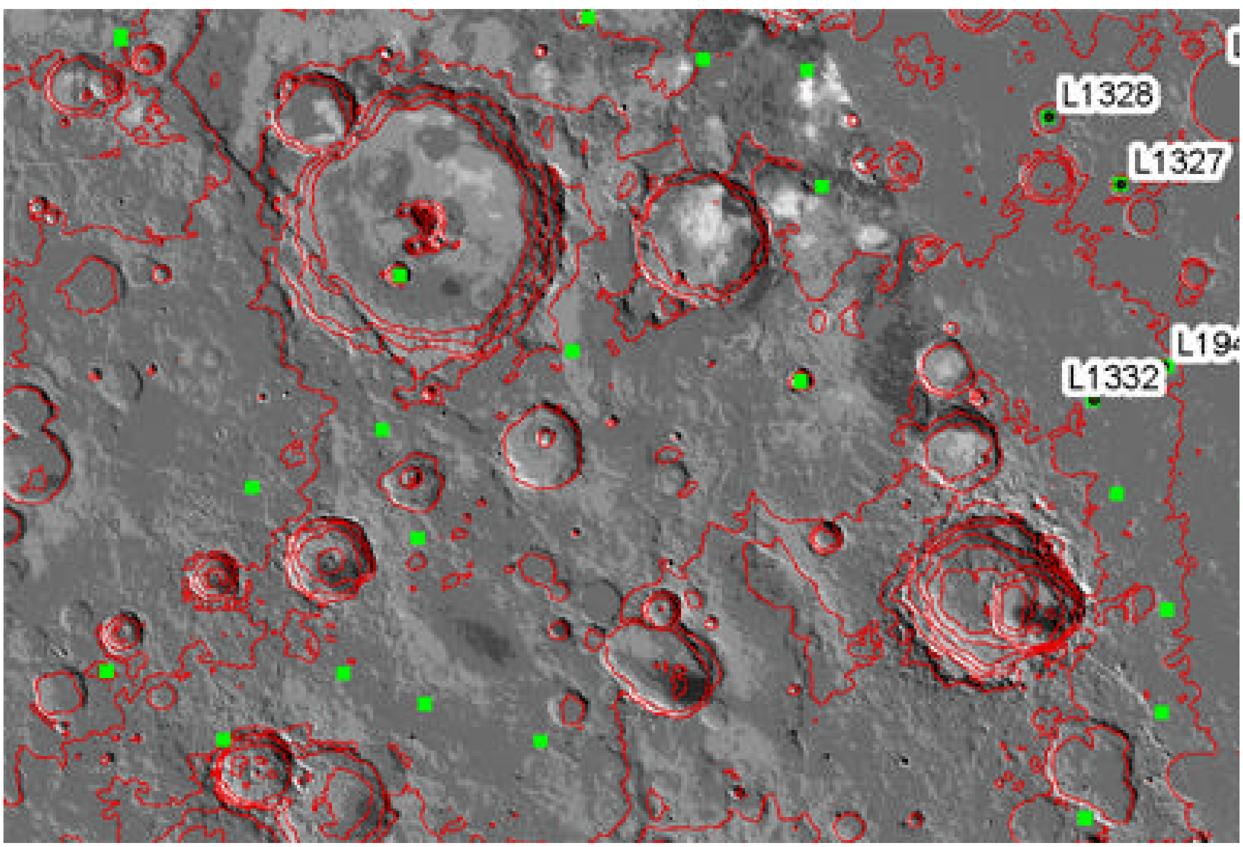

Figure 2: Portion of test MDIM 2.1 mosaic with MOLA 500 m contours (red) superposed. ~400 km wide region in Daedalia Planum. Control points are squares (green) and MOLA tie points are labeled. No photometric corrections have yet been made to the mosaic. Simple cylindrical projection with north up and east to the right.