MDIM 2.0: A REVISED GLOBAL DIGITAL IMAGE MOSAIC OF MARS. R. L. Kirk, E. M. Lee, R. M. Sucharski, J. Richie, A. Grecu, and S. K. Castro, U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001 USA (rkirk@usgs.gov).

Introduction: In the late 1980s, the USGS, Flagstaff, produced the first in what would become a series of very large, global digital image mosaics of solar system bodies [1, 2]. This Mars mosaicked digital image model (MDIM) incorporated roughly 4600 Viking Orbiter images. The global mosaic, at a scale of 1/256 degree or ~231 m/pixel, was widely distributed on a set of six CD-ROMs produced in 1991. As the highest resolution global map of Mars, the MDIM is vital for both scientific studies and planning of current and future missions. Unfortunately, it has significant shortcomings, particularly in the accuracy of geodetic control (i.e., the accuracy of positioning of features). Geodetic accuracy is a particular concern for mission planning, which involves targeting of observations and navigation of landers to specific ground points. The original mosaic, which we refer to as "MDIM 1.0," also suffers from cosmetic shortcomings (contrast mismatches between images and only a few gray levels of detail in some areas). We are therefore undertaking the production of revised and improved global image mosaics of Mars as part of a significant team effort by members of multiple institutions, coordinated by the Mars Surveyor Program Geodesy and Cartography Working Group (MSGCWG), to revise the martian geodetic and cartographic systems. The reader is referred to our previous abstract [3] for a fuller description of the problems with MDIM 1.0 and our plans for a series of three revised versions of the mosaic. In this abstract we describe our first revised global mosaic of Mars ("MDIM 2.0"), which will be presented in our poster.

Geodetic Control: The process by which MDIM 1.0 was controlled [2, 3] is more than usually complex and we will not describe it again here. Important points are that the root-mean-square (RMS) random positional error was substantial (~5 km) and that a systematic longitudinal error of ~ 0.2° (10-15 km) was introduced at some point. These errors are significant compared to the 5-km swath width of the high resolution Mars Orbiter Camera (MOC) and the desired precision for future landers. Improving the positional accuracy of the mosaic was therefore our primary objective, to be achieved by tying the mosaic to the RAND two-dimensional control network of Mars. The RAND network [4] previously contained 2958 Mariner 9 and Viking images arranged in a "ladder" of meridians and parallels (see figure in [3]). We supplied RAND with image coordinates of pass-points that tie the images of the MDIM mosaic to one another and to the RAND net (1017 images were common to both), thus both making the control net more solid and insuring that subsequent RAND calculations would generate updated pointing parameters for every image in the mosaic. During the past year, the RAND net also has been improved by incorporating more accurate measurements of the three US Mars landing sites (see [5]) and constraining the elevations of about 2/3 of the net points with data from the Mars Orbiter Laser Altimeter (MOLA). RMS residuals in the current network are 10 μm or 0.8 pixel, equivalent to about 200 m on the ground at the typical resolution of the images used [6].

In order to obtain the camera pointing angles used to produce the new mosaic, a secondary adjustment was performed, in which the latitudes and longitudes of all points were fixed at their values from the primary adjustment [6], their elevations were fixed not at the MOLA-derived values but on the surface of a reference ellipsoid, and only the pointing angles were adjusted. This process insures production of the best possible mosaic with software that projects the images onto an ellipsoidal reference surface rather than a detailed topographic surface for mosaicking. Because a new official reference surface for Mars has yet to be defined based on MOLA data, we adopted an interim ellipsoid with polar radius 3376.8 km and equatorial radius 3396.0 km based on the best fit to current MOLA data (D. Smith, written communication, November 1999).

We have not attempted to quantify the relative or absolute positional errors of the new mosaic (as opposed to the control net on which it is based) but detectable (≥1 pixel) mismatches between adjacent images are extremely rare in the areas of the planet where we have completed mosaicking so far (see for example Figure 1). Comparison of the mosaic with MOLA data in the Mars Polar Lander zone (72°–78°S, 170°–230°W) showed excellent agreement in the horizontal positions of features between the two independently derived datasets (note that only MOLA elevations, not horizontal coordinates, have been used in the RAND network to date). MDIM 1.0 contains both multi-pixel internal discontinuities and a net longitudinal offset of ~8 km relative to MOLA in this area.

Photometric and Cosmetic Processing: Improving the cosmetic quality of the MDIM in order to make surface features more visible has been a secondary focus of our recent work. The photometric model used to match contrast between images taken under different conditions is described in more detail in a companion abstract [7], but in essence involves three steps: (1) subtract a model of the scattered light from the atmosphere from the radiometrically calibrated image; (2) divide the result by a lowpass-filtered version of itself to suppress surface albedo variations, which are assumed to be broadly varying compared to topography; and (3) stretch the result to achieve the same contrast for an equal topographic slope in all images. (We are currently experimenting with reducing the apparent brightness of the polar caps by applying a nonlinear stretch between the first and second steps of the photometric processing, in order to avoid contrast saturation at the cap boundaries.) This procedure works well, provided that a reliable estimate of the atmospheric optical depth is available for each image. We estimate optical depth for each set of images obtained on a single Viking orbit (assuming it is constant over the short time span and for the limited region covered by the images) by measuring and modeling the brightness of shadows in multiple images from that orbit. Comparing the results from multiple shadow observations and using the lowest optical depth that results is essential because some apparent shadows are not in fact fully shadowed and give erroneous results. Small mismatches in contrast and brightness between image sets from different orbits that remain after the photometric correction process are further suppressed by contrast-stretching; the stretches needed to equalize contrast are calculated by simultaneous least-squares fitting of all the overlapping image data. The processing is carried out on 32-bit floating-point data so that no information is lost because of brightness saturation in intermediate steps as occurred in MDIM 1.0. The earlier mosaic was processed in 8-bit format because of limited computer resources and contains areas of both excessive and deficient contrast. As a final step the global dataset will be converted to 8-bit format so that it can be distributed in a compact format precisely compatible with the earlier map.

Future Work: When completed, MDIM 2.0 will be given PDS formatting identical to version 1.0 but, rather than being distributed on CD-ROM, will be written to CD-R and made available online. We plan to produce an incrementally improved mosaic of Viking Orbiter images ("MDIM 2.1") later in 2000, incorporating further refinements to the geodetic control network. MOLA data will be used to constrain the elevations of all points in the RAND network, to which Viking images and point measurements are still being added. MOLA-derived horizontal coordinates of new features that can be identified in both the altimetry and image datasets [8] will also be added. Rather than performing a secondary adjustment to obtain camera angles for MDIM 2.1, we plan to modify the map-projection software to reproject images onto a MOLA-derived model of the topographic surface.

Software is currently being developed that will allow us to produce a significantly improved mosaic ("MDIM 3.0") from global coverage generated by the wide-angle MOC during the "geodesy campaign." The MOC images have a resolution close to that of the Viking data used in earlier MDIMs, but both resolution and illumination are more uniform. Production of a mosaic of MOC data will depend on the availability of a geodetic control solution that provides the required updated pointing information. Such MOC-based control work is currently in progress or proposed by several groups, and we expect to be able to produce MDIM 3.0 late in 2000 or early in calendar 2001.

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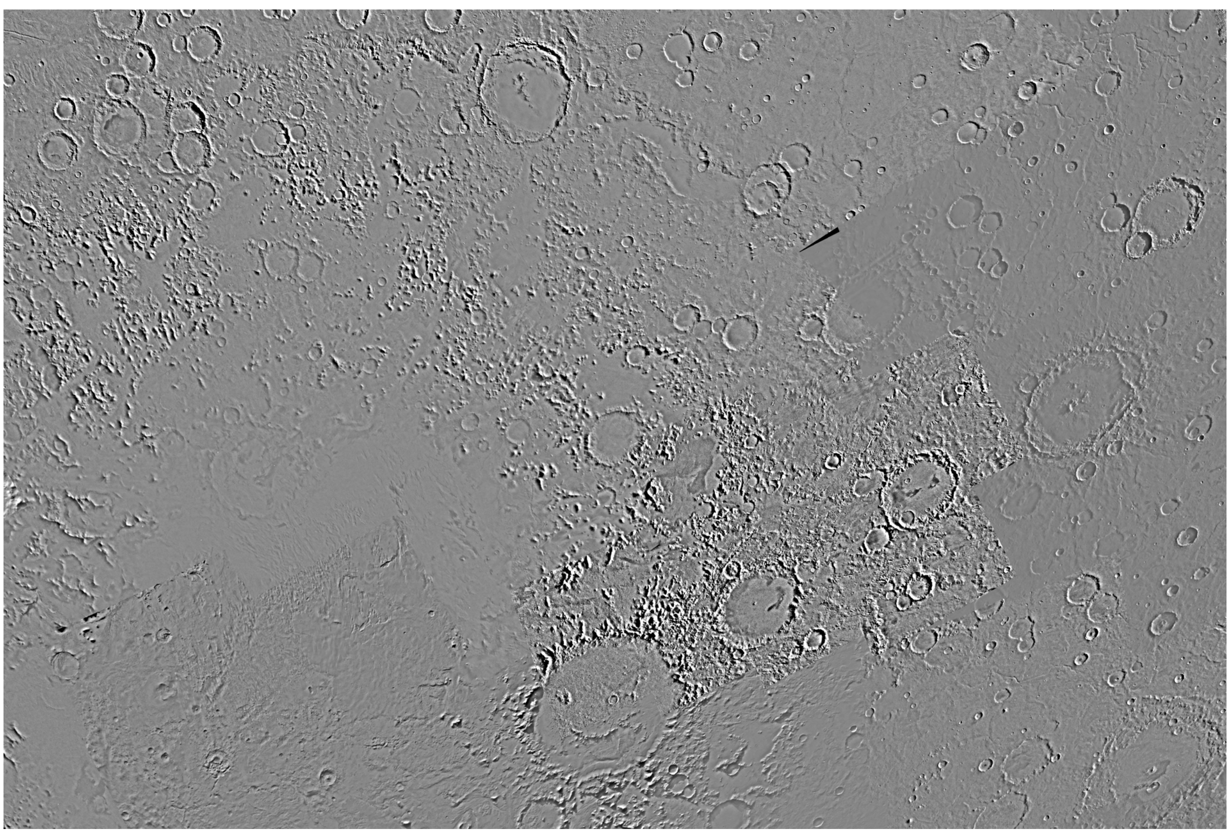

Figure 1. A portion of the revised global mosaic of Viking Orbiter images covering latitudes 54°–34°S, longitudes 16°–52°W in Sinusoidal equal-area projection with center longitude 45°. Scale shown is 1/64° per pixel, 4 times coarser than the actual mosaic. Photometric variations in this area are among the most severe on Mars; residual brightness and contrast variations visible in this preliminary product can and will be further reduced by least-squares adjustment as described in text. The complete, global mosaic will be displayed in our poster.