

A DATABASE OF VIKING ORBITER IMAGE COVERAGE OF MARS FOR CARTOGRAPHIC AND SCIENTIFIC USE. R. Kirk, J. Barrett, E. Howington-Kraus¹. ¹U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, Arizona, 86001 USA, rkirk@flagmail.wr.usgs.gov.

Introduction: Viking Orbiters 1 and 2 collectively returned more than 46,000 images of Mars between 1976 and 1980 [1]. Numerous observation sequences with different objectives resulted in an extremely complex and heterogeneous image set which is difficult to exploit fully in cartographic and scientific studies. Digital databases of the VO images include flat tables of metadata on CD-ROM with the images [2] and the PDS Mars Geoscience Navigator (<http://wundow.wustl.edu/marsnav/>), which allows graphical and forms-based searching for particular images but does not provide an easy way to compare images and identify stereo pairs. A hardcopy catalog of potential stereopairs exists [3] but is difficult to use and does not show stereo coverage in relation to surface features. Unpublished hemispheric maps of the highest resolution image coverage provide another fragment of useful information. None of these resources incorporate updated information about image locations that is generated as a byproduct of mapping. To better support our activities in topographic mapping [4] and global geodesy/cartography [5] we have therefore created a simple yet flexible database of the VO images by extracting a subset of geometric metadata from the most up-to-date records at the USGS, Flagstaff, and writing customized software to analyze and display selected aspects of these data.

Data Sources and Data Restoration: The types of metadata required for assessing VO image coverage are the spatial coverage or "footprint" of each image, resolution in km/pixel, incidence and emission directions (azimuths as well as angles from the vertical), and spectral filter number. We initially attempted to determine footprints from the IRPS online catalog [6], which contained latitude-longitude coordinates of nine "principal points" in each image, including the corners. (IRPS has been superseded by the Mars Geoscience Navigator, which includes similar capabilities.) The remaining parameters were obtained from datafiles maintained as part of the USGS ISIS software system [7] and updated in the course of mapping; these files include predicted parameters for those images that have not been used in mapping. Corresponding images in the two catalogs were matched by their PICNO, a six-character identifier indicating orbit number, spacecraft, and exposure within that orbit. We found, however, that ISIS and IRPS did not contain all the same images, and that a subset of the IRPS footprints were clearly in error. Furthermore, updating of the camera pointing during mapping can significantly change the footprint location compared to the predicted location contained in IRPS. We therefore decided to calculate the corners of each image footprint within ISIS.

The USGS datasets also suffered from erroneous and missing data, of which we were able to restore a part. Of 51,812 images recorded in the files, 1717 had PICNO 000000 and 53 had 000A00; only two of these could be identified by their FSC clock count (another unique identifier, redundant to PICNO) in the catalog of images archived on CD-ROM [2]. The correct PICNOs of these two images were restored. The unidentifiable records were eliminated, as were ninety redundant copies of the data for image 485S24. Duplicate records with the same PICNO were found in 22 cases. By comparing PICNO, FSC, observation time, and geometric parameters with the Supplementary Experimental Data Record (SEDR) printouts, we were able to determine the identity of 11 of these images, of which 5 were already in the system and 6 were new. The other 11 records with erroneous PICNOs could not be identified and were deleted. At this stage the datafiles contained 49,938 images correctly identified by PICNO. Of these, 98 had an invalid filter number of 0. Valid filter numbers were found in the SEDR for 39 of these images.

A simple reformatting program was used to extract data from the corrected ISIS files and write it out as two ASCII tables, each with one line per image indexed by PICNO and sorted in order of ascending image resolution. The first of these files contains the incidence and emission geometry parameters, and the second the computed coordinates of the four image corners. Images with one or more corner off the limb of Mars were eliminated at this step, leaving

46,629 entirely on the planet. It would be possible to compute an approximate footprint for images partially on the planet but we did not do so because the large emission angles of these images make them of relatively low scientific value.

Inclusion of Mariner 9 images (which provide higher resolution coverage of some south polar regions than VO) and MOC narrow-angle images (as they become available) into our system is a straightforward generalization. Determination of potential stereopairs involving one MOC and one Viking or Mariner image may be especially valuable. Our system is not suitable for analysis of MOC wide angle camera images, because the large extent of these images leads to complex footprint shapes and significant variations of geometric parameters within a single image.

Data Manipulation and Display: To manipulate and display the data we wrote a series of simple, special-purpose FORTRAN programs. This approach was at least as efficient as using general-purpose geographic information system (GIS) software, given the modest number of products desired. We approximated the coverage of images by a polygon in map projection (simple cylindrical or polar stereographic, depending on latitude) with the same corners as the actual footprint. This greatly simplified spatial calculations compared to modeling the exact shapes of the images; because even the biggest images are small compared to the size of Mars, the error is negligible. The most important operations implemented to date are the following.

- Matching the database files to a list of PICNOs to extract images on (or not on) the list.
- Extracting data for images that intersect a given latitude-longitude zone (e.g., map sheet or candidate landing site).
- Creating a raster map of Mars showing the value of one of the geometric parameters (e.g., incidence angle) or a quantity computed from those parameters for the "best" image at each point, where "best" is defined by the extreme value of the same or another parameter (e.g., smallest resolution).
- Examining all possible pairs of images and creating a database of those that form acceptable stereo pairs. This is discussed in more detail below.
- Creating a raster map showing the quality of stereo imagery.
- Standard ISIS tools can be used to manipulate the raster maps further, for example, to color-code parameter data and superimpose them on a base image, or to calculate histograms of the parameters from maps in equal-area projection.

Evaluation of Stereo Coverage: Our determination of usable stereo coverage and quantification of its quality closely follows that of Cook et al. [8] for Clementine imagery of the Moon. To identify Viking Orbiter stereo pairs, we compared all overlapping pairs of images and selected those meeting the following criteria.

- 1) Acquisition with specific filters, and/or with the same filter for both images, can be required. At present we are allowing all filter combinations, because the relatively low color contrast of Mars will not lead to stereomatching problems.
- 2) Resolutions differing by no more than a factor of 2.5.
- 3) Illumination differing by less than 45 degrees in azimuth and 10 degrees in incidence angle.
- 4) Parallax-height ratio between 0.01 and 1.0.

Potentially important criteria excluded from this analysis are the clarity of the atmosphere [3] and seasonal changes in the appearance of the polar regions. The parallax-height ratio is calculated by using the emission geometries at the centers of the two images with no correction for curvature of the planet between these two points. It is calculated three-dimensionally, i.e., the differential parallax between the two images is calculated for a feature of unit height. For example, oblique images obtained from the same side of the feature combine to yield a small residual parallax. Large parallax-height ratios are rejected because of the difficulty of matching features in such

image pairs. For each stereopair selected, the polygonal intersection of the two images is recorded, along with their PICNOs and the expected vertical precision (EP). This is a figure of merit for stereo imagery and consists of the height difference that corresponds to a differential parallax that is barely measurable (in practice, 0.2 pixel) in the lower-resolution image of the pair. Figure 1 is a global map of EP based on the best of ~232,000 possible image pairs. Once areas of favorable stereo coverage are identified from such maps, the images needed for further analysis are readily determined from the database of stereopairs.

Other Applications: We have also calculated the distribution of a figure-of-merit (FOM) for photoclinoetry [9] for comparison with stereo coverage. We define the FOM as resolution divided by the tangent of incidence angle, the denominator accounting roughly for the relative contrast of topographic features, from which photoclinoetry determines elevations. This FOM (Figure 2) applies to qualitative morphologic analysis of surface features as well as to photoclinoetry.

Simpler presentations of image resolution and photometric angles can be useful in planning geodesy and mapping. As described in companion abstracts [5] we are currently collaborating with the RAND group to incorporate the MDIM images into their control network. The strengthening of this network that can be expected as a result of filling in voids in the coverage is apparent from the figure in [10], which shows the incidence and emission angles and resolution of images in the RAND 2D control network for Mars [11], the global mosaicked digital image model [12], and the USGS 3D control network [13]. More complex parameters such as the horizontal error for given uncertainty in the elevation can likewise be mapped.

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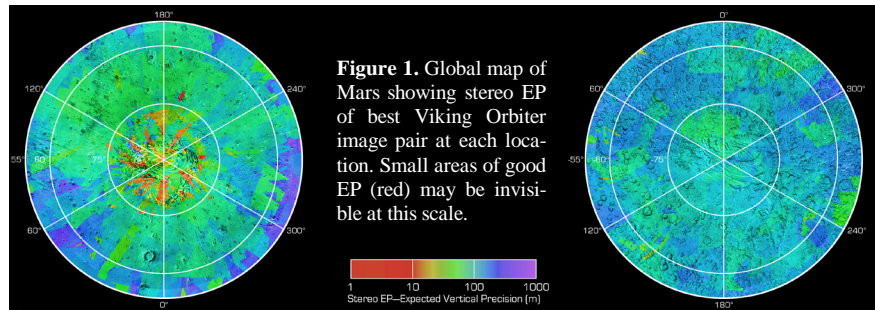


Figure 1. Global map of Mars showing stereo EP of best Viking Orbiter image pair at each location. Small areas of good EP (red) may be invisible at this scale.

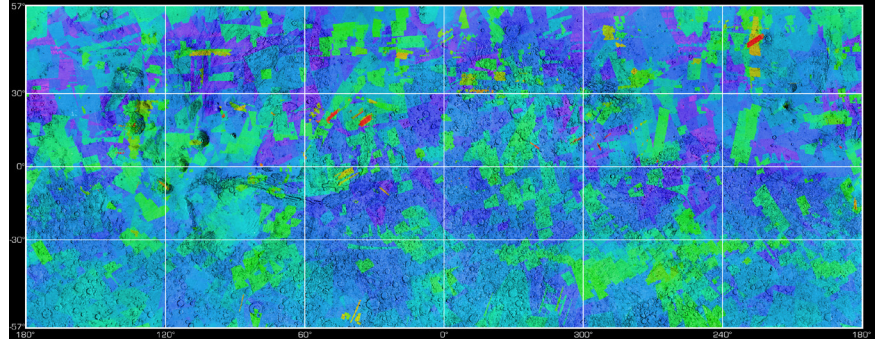
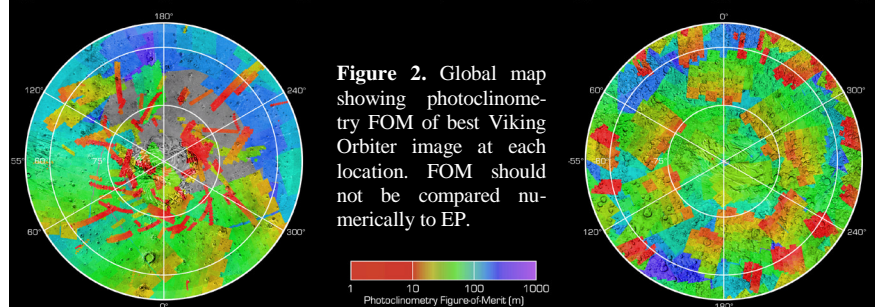


Figure 2. Global map showing photoclinoetry FOM of best Viking Orbiter image at each location. FOM should not be compared numerically to EP.



1 10 100 1000
Photoclinoetry Figure of Merit (m)