MAPPING THE SAGAN MEMORIAL STATION SITE WITH THE IMP CAMERA. R. Kirk, J. Anderson, J. Barrett, K. Becker, T. Becker, A. Bennett, J. Blue, D. Cook, E. Eliason, L. Gaddis, P. Garcia, M. Gordon, T. Hare, A. Howington-Kraus, C. Isbell, J. Johnson, E. Lee, H. Morgan, B. Redding, T. Rosanova, L. Soderblom, R. Sucharski, T. Sucharski, K. Thompson, J. Torson, W. Ward[1], E. Dorrer[2], P.Smith, D. Britt[3] and the Pathfinder Science Team. [1]U.S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, Arizona, 86001 USA, rkirk@flagmail.wr.usgs.gov, [2]Univ. der Bundeswehr München, D-85577 Neubiberg, Germany, [3] University of Arizona, Lunar and Planetary Lab, Tucson, Arizona 85721.

Summary

This abstract describes plans for cartographic processing of data from the Imager for Mars PathÞnder (IMP) [1, 2] by the U. S. Geological Survey, cartographic products to be distributed, and progress to date in creating those products.

Cartographic Datasets

The IMP camera returned more than 16,000 images. Premission plans to obtain two panoramic datasets from which to map the whole landing site were expanded because of the supranominal data return rate to allow the return of Þve such panoramic sets (Table 1) containing over 3,500 images [2].

Table 1—Panoramic IMP Datasets for Cartography

Camera Position	Lossy Data Compression		Lossless Data Compression	
Undeployed	First Look (F)	• right camera red (5) • 1/2 by azimuth right camera RGB (5,9,0) • <1/2 azimuths red stereo	Insurance (I)	• blue stereo • right filters 6, 8, 9
Deployed	Monster (M)	• red stereo • 1/2 by elevation right RGB • quadrants at 4 times of day	Super (S)	• RGB stereo • all remaining filters 2:1 near lossless • “patchwork” of times of day
	Gallery (G)	• right camera RGB • continuous time of day		

The super pan and our processing of it are described in greater detail in a companion abstract [3].

Planned Data Products

We consider as cartographic those image products that have been geometrically transformed by using our knowledge of coordinates in the landing site, either the location of an assumed ground plane (giving “projected” products) or a detailed three-dimensional site model from stereogrammetry (for “rectiÞed” products). Cartographic products may also be divided by their coordinate system (point-perspective as per the input images, panoramic, or planimetric, i.e., in Cartesian “top” view); by analog and hardcopy mode of distribution; and by content (images or topographic data).

We plan to archive all spectral bands from image sets in the form of digital panoramas, along with 3D coordinate and surface-normal data. Digital planimetric products and hardcopy products will be restricted to a smaller, representative subset of the data. To minimze degradation of spectral data by reprojection, stereo-coregistered sets of 15-Þlter images from the super pan will also be provided (with topographic data) in the form of individual image “cubes” with the point-perspective geometry of the right camera.

Software

Cartographic processing is being carried out with a combination of the USGS/Flagstaff in-house software system ISIS and LH Systems’ commercial digital photogrammetric system with SOCET Set software. ISIS is being used for data ingestion, calibration, and mosaicking. SOCET Set incorporates similar capabilities, but is being used for its unique stereomapping functions: stereo image/graphics display, automatic and manual generation of digital terrain models (DTMs), contouring, feature extraction, and fully 3D geometric transformations such as orthorectiÞcation.

Because of the unique and complex geometry of the IMP camera, a dedicated ISIS program (IMPJIG) was written to perform block adjustment, i.e., simultaneous improvement of the camera pointing information for sets of images. Pass-point coordinates needed as input data for block adjustment can be collected _exibly by a combination of manual and automated processes in both ISIS and SOCET Set. We are also constructing an independent control net as an accuracy check, collecting points in SOCET Set and performing the block adjustment with a modified version of the commercial CAPS package.

Uncontrolled and Semicontrolled Products

Cartographic products can be classiÞed as uncontrolled (using a priori estimates of camera positions and pointing), semicontrolled (using pointing information adjusted ad hoc to improve the appearance of mosaics), or controlled (using pointing adjusted by rigorous block adjustment). Our ultimate goal is to create controlled products of the highest possible quality, but because this is a time-consuming process, a variety of uncontrolled mosaics were created to support science and planning during the primary and extended missions. Semicontrolled planimetric and panoramic mosaics were also created for the mission’s 30-day science report [2].

We have also compiled a preliminary topographic map of the landing site that can be considered semicontrolled. Angular and parallax coordinates of ~700 points were measured manually on a large (5 m length) anaglyphic uncontrolled mosaic and used to calculate Cartesian coordinates. Errors in azimuth on the order of 1° are therefore likely; elevation errors were minimized by referencing elevations to the local horizon. The uncertainty in range measurements increases quadratically with range. Given a measurement error of 1/2 pixel, the expected precision in range is ~0.3 m at 10 m range, and ~10 m at 60 m range. Repeated measurements were made, compared, and edited for consistency to improve the range precision. The points were then interpolated to form a DTM with 0.5 m spacing, from which the Þgure was generated.

Control Network

A major focus of our activity to date has been the compilation of a control network, needed for controlled mosaic and DTM products. To maximize the quality of the control network, we have measured points primarily on the losslessly compressed super pan images; we required that every point be measured on both images of a stereo pair in order to constrain its 3D position. The super pan was only about 90% complete at the end of the extended mission [2, 3] necessitating the use of additional stereo pairs from the monster pan to Þll gaps in the control network. Gallery pan images were also added to bridge gaps between sectors of the super pan. Measurement of points has been completed only for the red-Þlter images of the super pan (Table 2). The RMS residual for these image measurements is 0.7 pixels, which can probably be reduced by remeasuring a few blundered points; tests with data from the prototype IMP camera show that automated matching can achieve a RMS precision of 0.22 pixel for losslessly compressed images.

Table 2—Status of Control Network

	Completed	Projected	
	S-pan Red	**S-pan Red/Blue/IR**	**Plus I-Pan Blue**
S-pan image sets	124	124	124
M-pan image sets	29	29	29
G-pan image sets	2	2	2
I-pan image sets	0	0	*100*
Total	155	155	*255*
Unknowns	**2601**	**2601**	***2900***
Pass points	712	712	*712*
Measurements	2475	*6500*	*8900*
Knowns	**4950**	***13000***	***17800***
Redundancy	**1.9**	***5***	***6***

Quantities in italics are estimated, assuming current average of 3.5 images/point and no new points needed for insurance pan.

Automatic transfer of point measurements to the blue and infrared stereo images is partially complete and will add independent measurements without adding new unknowns, because all images from the same set share the same camera pointing parameters. (The relative pointing of images in different Þlters was calibrated separately from the block adjustment of camera head pointing, by automatic matching of all super pan image sets.) Adding images from the insurance pan will further increase the number of measurements, and, more importantly, greatly improve the geometric convergence of the measurements.

Once the control network based on the S and I pans is complete, and these datasets have been block-adjusted, we will not attempt to transfer these points to the other image sets. Instead, we will measure convenient points on both the S and (say) M pans, and then perform a second block adjustment in which only the M-pan pointing is updated. The control point coordinates and updated pointing (SPICE kernels) for all images will be documented and archived.

Digital Topographic Model (DTM) Extraction

We are collecting topographic data concurrently with the control net. In the current release of SOCET Set, DTMs are measured on a uniform coordinate grid, and it is necessary to do this in separate “local” (camera head) coordinates for each stereopair. Transformation of the results to global coordinates, resampling to panoramic or planimetric formats, and mosaicking will be done after the image sets are controlled. About 75% of the super pan DTMs have been collected and edited so far.

Forthcoming releases of SOCET Set will include major improvements to the automatic stereomatching module and ability to collect data in triangulated irregular network (TIN) form rather than on a grid, and should signiÞcantly reduce the time spent on DTM editing.

Photometry and Photoclinometry

The stereo-derived DTMs, which are interpolated from independent x,y,z measurements every few pixels, will also serve as input for detailed photometric studies and higher resolution topographic mapping. By calculating local surface normals from the DTMs, we will be able to correct the multispectral images for the effects of varying amounts of direct (solar) and diffuse (sky) illumination [4]. Such an analysis is scientifically useful because it distinguishes real spectral/compositional differences from apparent differences caused by the different colors of sun- and skylight. Comparison of the DTMs with the images will also permit fitting of photometric functions (including normal albedo) to individual regions of the site, and segmentation of the images into areas of uniform albedo. With this information, we will be able to refine the DTMs by using two-dimensional photoclinometry (shape-from-shading), yielding topographic models with single-pixel resolution and high accuracy for local slopes [5].

References: [1] Smith, P., et al., 1997, The Imager for Mars Pathfinder Experiment, *JGR—Planets*, 102, 4003–4025; [2] Smith, P., et al., 1997, Results from the Mars Pathfinder Camera, *Science*, 278, 1758–1765; [3] Gaddis, L., et al., 1998, The Mars Pathfinder “Super Pan”: A U.S.G.S. Cartographic Product, this volume; [4] Johnson, J., et al., 1998, Photometric Image Sequences and Analysis at the Mars Pathfinder Landing Site, this volume; Kirk, R., 1987, III. A Fast Finite-Element Algorithm for Two-Dimensional Photoclinometry, Ph. D. Thesis (unpubl.), Caltech, pp. 165–258.

Table 3—Planned Cartographic Data Products

Distrib. Format	Point-Perspective Images		Panoramic (Cylindrical) Projection		Cartesian (Overhead) Projection	
	Projected	**Rectified**	**Projected**	**Rectified**	**Projected**	**Rectified**
Digital		• 15-band S-pan cubes • x,y,z, surface normal for cubes	• all pans, multi-band mosaic for each camera • x,y,z coords reg. to each camera	• 15-band S-pan mosaic • x,y,z, surface normal		• I-pan color @ 1 mm/pixel • G-pan color @ 2, 8 mm/pixel • z @ 8 mm/pixel
Hardcopy	• aligned and aspect corrected vertical stereo pairs (horizon)		• all pans, right red filter B&W • M-pan anaglyph • G-pan RGB • S-pan false color	• B&W or color base with contours and nomenclature	• 1:25 and 1:50 M-pan color, G-pan B&W (interim)	• 1:50 color • 1:50 with contours, nomen. • <1:50 shaded relief & contours