"SUPER RESOLUTION" OF THE MARS PATHFINDER LANDING SITE, USING MANUAL TECHNIQUES. T. J. Parker, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, tparker@jpl.nasa.gov.

During its three months of surface operations on Mars, the Imager for Mars Pathfinder (IMP) camera acquired over 16,000 images of the landing site. Standard imaging sequences included acquisition of four essentially complete 360° panoramas in multiple filters and in stereo. These were the "Insurance Pan," the "Monster Pan," the "Gallery Pan," and the "Super Pan." Imaging sequences intended specifically for super resolution processing using automated techniques (1) were also acquired, but because of the large number of images needed (typically 25 frames with one filter), they cover very small target areas of specific science interest. The results of this processing can be somewhat sharper than those using manual techniques, however (1). Because of their relatively low data compression, the Insurance and Super Pans retain the greatest amount of detail of the full panoramas, and so produce the best super resolution results over broad regions using manual techniques, which have been successfully applied to the multispectral data. The Insurance Pan is multispectral in the right eye only, however.

For manual super resolution, the Super Pan was chosen because it was acquired with low compression (nearly lossless, 2:1) with all 15 filters, and with both IMP "eyes." Super resolution takes advantage of slight misregistrations from one image to the next, so that they can be co-registered at sub-pixel scales. The planned super resolution imaging sequences achieved this by moving the camera away from and back to the target between exposures, using the backlash in the gearhead assembly to ensure that subsequent images will not overlap exactly. For the multiple-filter Super Pan frames, which were acquired in succession without moving the camera, slight shifts from one frame to the next were nonetheless achieved due to slight optical misalignments from one filter to another and actual small displacements in pointing due to motion of the filter wheel causing the camera head to shift within the backlash of its gearhead assembly.

To manually construct a super resolution frame, a series of IMP images are first converted from their original 16-bit format (actually acquired as 12-bit images with 4096 gray levels) to 8-bit, then imported into Adobe Photoshop. Next, each image from each eye is enlarged, using bicubic interpolation, by 1000 percent. They are then sharpened using an "unsharp mask" filter with a 5 pixel radius, a threshold value of 0, and a contrast between adjacent pixels of up to 100 percent. These values were selected after experimentation as producing the best overall results. (For specific targets, such examination of texture on a nearby rock, it may be desirable to use higher radius values or run the unsharp mask filter more than once with some IMP filters, to better bring out the detail within a rock face. This usually produces more objectionable artifacts at high-contrast edges, however, and so doesn't work well in the farfield).

Each image is co-registered at a one-tenth pixel scale by "blinking" it on and off (in the layers palette) and moving it

1/10th pixel at a time. When all filters are registered, they are averaged together by weighting their opacities in proportion to the total number of frames. To maintain a manageable file size, the result is reduced by 50 percent, so that it is 5 times larger than the raw frame. The result is probably two to three times sharper than a raw frame.

It should be noted that, by averaging the filtered images in this way, the output is a panchromatic image, and that the left and right eye views differ in tonal ranges. For this reason, these products are most useful to studies of geomorphology and rock texture, and may not be useful for spectral studies, except as a means of locating the source of a spectral feature in the sharper, higher-resolution view.

Figures 1 and 2 (next page) illustrate the usefulness of applying manual super resolution processing to the Super Pan to help to address questions about the texture of rocks and soil morphologies at the landing site. Do try this at home.
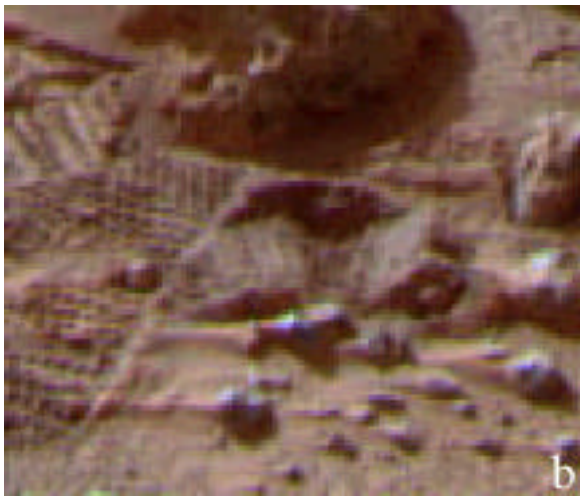
REFERENCE: (1) Kanefsky et al., this volume.

Figure 1: "Raw," standard-resolution frame of the surface adjacent to the rear rover ramp. This image was assembled by merging the separate color channels into a single RGB file. No special co-registration was applied. a) Full frame, showing ramp surface, and rover tracks and trenches. b) Enlargement of upper center portion of frame. IMP images: 0182010203 (red), 0182010213 (green), and 0182010205 (blue).
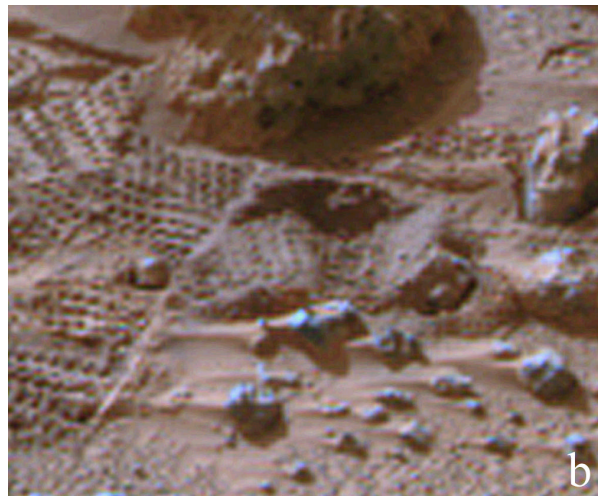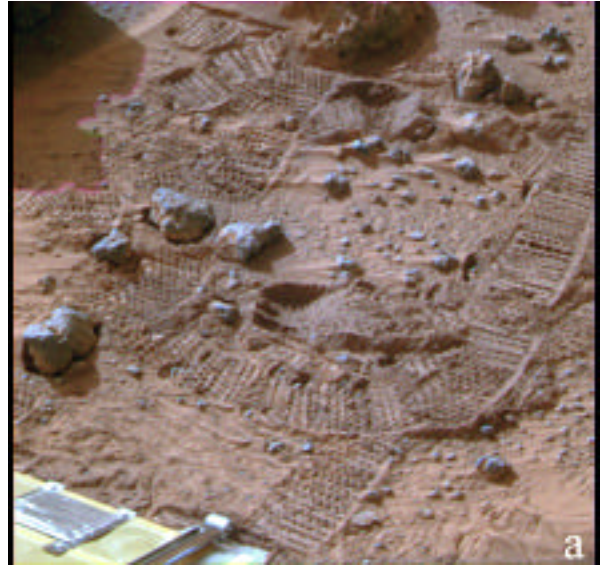

Figure 2: This image is was produced through manual "super resolution," which involves combining the Super Pan frames from the IMP camera. The composite color frame consists of 7 frames from the right eye, taken with different color filters that were enlarged by 1000% and then co-registered and co-added using Adobe Photoshop to produce, in effect, a super-resolution panchromatic frame that is approximately 2 to 3 times sharper than the raw frame. This panchromatic frame was then colorized with the red, green, and blue filtered images from the same sequence. a) Full frame. Note marked increase in clarity of scene, even at this print scale. b) Enlargement of upper center portion of frame. In this view, increase in resolution over raw frame is obvious in separation of rover cleat impressions, and resolution of very small granules at bottom of frame and in rover wheel trench and very small wind tails in lee of pebbles. IMP images: 0182010203-0182010215 (odds).