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PREPARING FOR THEMIS CONTROLLED GLOBAL MARS MOSAICS:

Characterizing THEMIS Pointing Accuracy

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Introduction: We have begun work to prepare for producing controlled 2001 Mars Odyssey THEMIS infrared (IR) and visible (VIS) global mosaics of Mars. This effort is being coordinated with colleagues from Arizona State University and on the THEMIS team who plan to address radiometric issues in making such mosaics. We are concentrating on geometric issues.

Several areas of investigation are now in progress, including: a) characterizing the absolute pointing accuracy of THEMIS images; b) investigating whether automatic tie point matching algorithms could be used to provide connections between overlapping THEMIS images; c) developing algorithms to allow for the photogrammetric (bundle) adjustment of the THEMIS IR (line scanner) camera images. Our primary goal in this pilot study effort will be to make several controlled THEMIS test mosaics and better determine which methods could be used, which require development, and what level of effort is required, in order to make large regional or global controlled THEMIS mosaics.

In this poster, we discuss primarily some initial results in characterizing absolute pointing accuracy. Further details on our other work in this area are given in the full abstract.

Camera Pointing Characterization: Estimates of both the "average" and worst case absolute camera pointing of the THEMIS cameras are highly desirable. A knowledge of the magnitude of the possible pointing error for any given image will assist in determining whether any given pair of images overlap. Prediction of image overlap is necessary in turn to initialize any automatic (or manual) tiepoint measurements. These are measurements of the line and sample positions of features common between overlapping images that are used as input to the photogrammetric adjustment ("control") calculation used to estimate precise camera pointing for the specific images in question, and other parameters of interest. Quantification of pointing errors would also help to characterize the accuracy of any uncontrolled image mosaics, both in the determination of absolute coordinates of such mosaics, and in the magnitude of seam errors between adjacent/overlapping images. Finally, these error estimates will be useful in planning the acquisition of images so that pointing errors do not open up gaps between the images.

We are using two methods in order to estimate this type of camera pointing information. First, at a higher level of accuracy, we have begun to measure the positions of features on THEMIS images relative to their positions on an illuminated (shaded relief) MOLA [1] digital image model (DIM). Secondly, we are also simply looking at the image shifts necessary to match images to features on such MOLA image models, e.g. during mosaic generation for other purposes (such as that described in [2]). The MOLA DIM serves as an absolute reference for surface feature coordinates. Its estimated absolute accuracy, at least at its likely one standard deviation level, is 100-200 m (including both the positional accuracy of the MOLA data [3], and errors due to the creation of an illuminated DIM from a gridded product and matching with THEMIS images).

Consideration of different areas on Mars and times during the mission will allow us to assess the importance of changing conditions such as season, lighting, tracking accuracy, operational changes, etc.

Preliminary Results: Figures 1 and 2 show simple, uncontrolled mosaics of several THEMIS IR images, in the areas of the MER landing sites at Meridiani Planum and Gusev Crater respectively, where we have begun making such comparisons. Plotted on these mosaics are vectors, *exaggerated by a factor of 10* so they are clearly visible at this scale, of the offsets from "truth" (MOLA DIMs) of these images. The offsets measured from discrete features are shown in red, with the vector starting at the given feature. The offsets measured by simply shifting entire images are shown in blue (at the location of the image center). Offsets shown in yellow are derived from a few measurements of the shifts required for THEMIS VIS images to line up with MOLA DIMs. Figure 6 shows a close-up of Figure 2, in the vicinity of the Spirit landing site. Here, particularly at the vertical seam in the right center of the image, one can actually see an example of the (few to several pixels) offsets in the images.

Figures 3 to 5 show plots of the measured offsets, in terms of image across track (sample) vs. along track pixel locations. Maximum offsets appear to be at the 10-13 pixel level (1.0-1.3 km), although the majority of the measurements show that the offsets are at the 5 pixel level or below. Figure 3 shows the measurements plotted by type (orange indicates feature measurements, blue indicates image shift measurements). There is some indication here that the image shift measurements given slightly worse results than that from feature measurements. This might be expected simply because a point measurement is likely to be more accurate than an average shift determined for an entire image. Figure 4 shows the measurements plotted by area (red - Meridiani, blue - Gusev). Figure 5 shows the measurements plotted by whether they are daytime (red) or nighttime (blue) images. These later figures indicate that a few nighttime measures at Gusev seem to have higher offsets than that determined for other images, but the number of measurements (only about 3 of 55) is too small to be sure of this. The total set of measures has a mean and standard deviation of the mean of 0.4 ±0.5 and -1.4 and ±0.7 in sample and line respectively.

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IR Mosaic of Meridiani Planum Area with Offsets to MOLA Shown

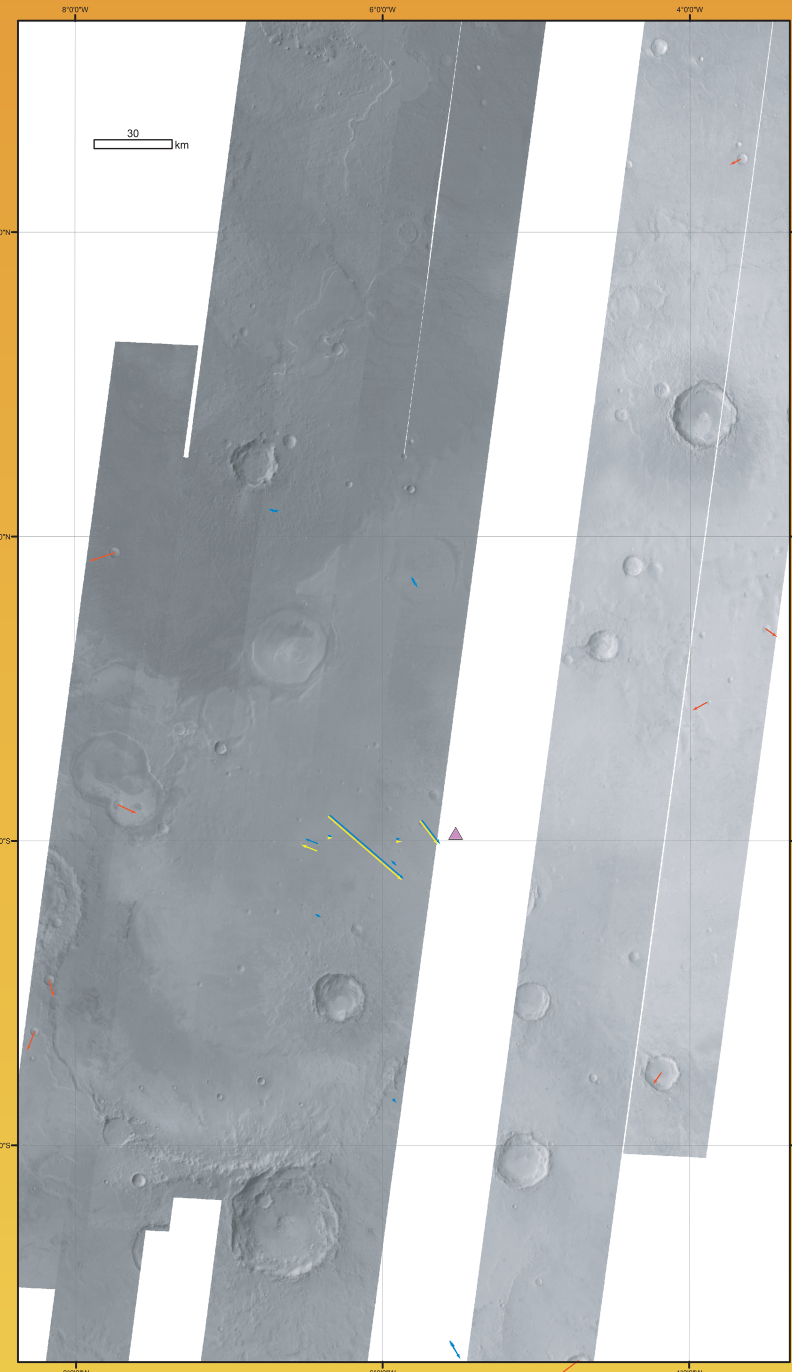

Figure 1: Uncontrolled THEMIS IR image mosaic of Meridiani Planum MER (Opportunity) landing site area. Vectors show the offset - with *10x exaggeration* - between the locations of features visible on the images to their locations on an illuminated MOLA DIM (i.e. their "truth" location). Red vectors are based on direct IR to MOLA DIM image measures at the point shown. The blue (IR images) and yellow (VIS images) vectors are based on the translation necessary to manually fit the image to a MOLA DIM. The purple triangle is at the location of the Opportunity Lander. Note that even though this is an uncontrolled projection of the images (using only as measured spacecraft pointing information), at this reduced resolution the images appear to be positioned perfectly.

IR Mosaic of Gusev Crater Area with Offsets to MOLA Shown

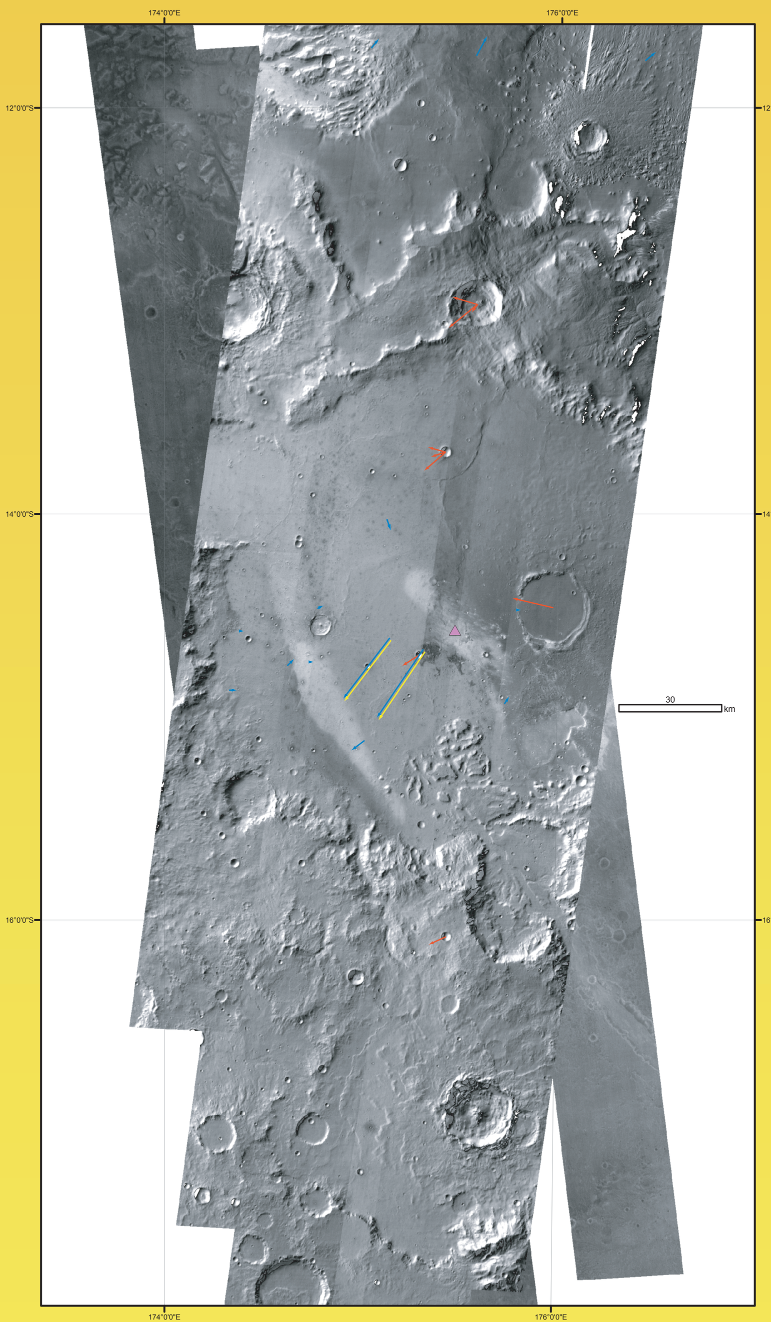

Figure 2: Uncontrolled THEMIS IR image mosaic of Gusev Crater (Spirit) landing site area. Vectors are as described in Figure 1. Images shown trending from lower left to upper right are daytime IR images, while images (in background) trending from the lower right to upper left are nighttime IR images. The purple triangle is at the location of the Spirit Lander.

Conclusions: The number of measurements and images measured so far is small enough these results are clearly only preliminary. Still, we can say that THEMIS IR camera pointing errors are often several pixels, and the maximum errors appear to be in the range of ± 10 to 13 pixels.

This bodes well both in the creation of uncontrolled THEMIS IR mosaics, where pixel errors at this level (i.e. a maximum of about ~ 1 km) can be tolerated.

However, for mosaics that must have higher accuracy absolute registration, the images must be controlled, i.e. tied in some way to the MOLA reference surface, whether directly, or indirectly by tying together overlapping THEMIS images, some of which in turn are tied to MOLA.

This result will also be of value if or when newly targeted THEMIS IR images are obtained with the express purpose of covering areas not yet imaged. The magnitude of the maximum errors should be taken into account both to make sure that gaps are not left in the image coverage, and also if adequate overlap is to be obtained so that tie point measurements can be made between overlapping images.

We plan to continue making these measurements both in these areas and for different areas on Mars and times during the mission in order to better quantity these pointing errors and to assess the importance of changing conditions such as season, lighting, tracking accuracy, operational changes, etc.

References: [1] Smith, D. E., et al. (2001) JGR 106(E10), 23,689. [2] Kirk, R. L., Soderblom, L. A., Cushing, G., and Titus, T. (2004) this conference. [3] Neumann, G. A., et al. (2001) JGR 106(E10), 23,753.

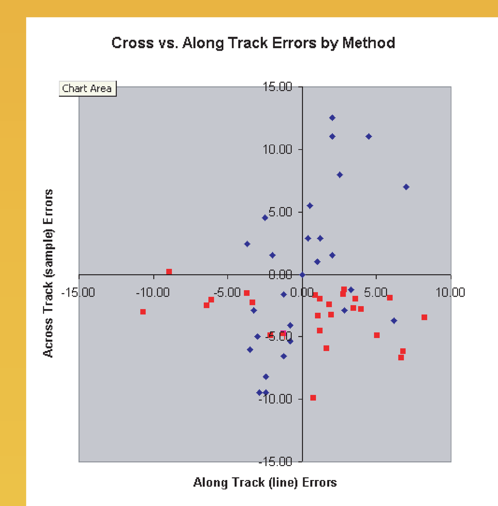

Figure 3: Measured across track (sample) vs. along track (line) offsets, for all IR images. 1 pixel is ~100 m. Measurements in orange were determined through manual measurements of features common to THEMIS IR images and an illuminated MOLA DIM. Measurements in blue were determined from shifts required to manually register IR images with such a MOLA DIM.

Figure 4: Same as Figure 3, except measurements in red are for Meridiani Planum areas, while measurements in blue are for Gusev Crater areas. The data are limited, but there is some indication of larger image pointing errors in the across track direction at Gusev and in the along track direction at Meridiani.

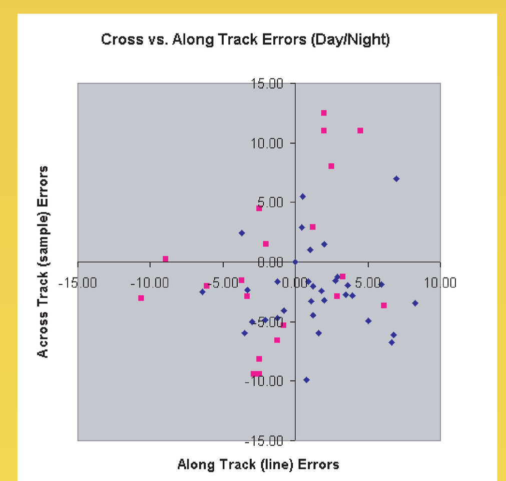

Figure 5: Same as Figure 3, except measurements in red are for daytime images, while measurements in blue are for nighttime images. Again, the data are limited, but there is some indication of higher uncertainties - either in the pointing or the measurements here - for the nighttime images.

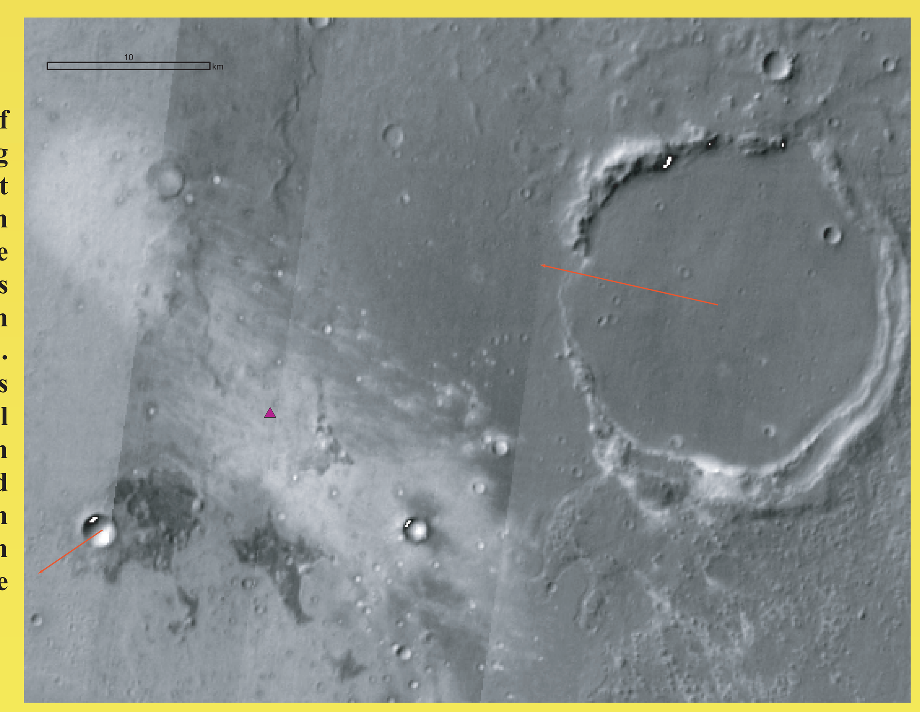

Figure 6: Detail of Figure 2, showing the area of the Spirit Landing site (shown with a purple triangle). Vectors are as before, with *10x exaggeration*. Note that at this scale the ~few pixel mismatches between these uncontrolled image locations can now often be seen along the image seams.