Lunar and Planetary Laboratory
The University of Arizona

Memorandum

Subject: **EUV Plate Scales and Camera Overlaps**	
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0 Summary

Using measurements of the position of the Moon in EUV images, we have improved our understanding of the geometrical characteristics of the EUV cameras. With this information, we have determined new estimates of the plate scales in the elevation direction for the three cameras, and we have refined our technique for overlapping the images from the three cameras to form a single image.

1 Moon Observations

We have analyzed more than 5000 EUV images that include the Moon. Using the Moon's ephemeris and knowledge of the orientation of the IMAGE spin axis, we computed the true elevation of the Moon for each image. Then we compared this to the elevation inferred from the EUV image. For each of the three cameras, we fit a straight line to plots of measured vs. expected elevation. We find that the best estimates for the elevation position ρ of a specified pixel in a particular camera is given by

$$\rho(c,p) = \frac{0.6(24.5 - p) + o_c - a_{c,0}}{a_{c,1}} \quad \text{(degrees)}, \tag{1}$$

where c ($0 \le c \le 2$) designates the camera and p ($0 \le p \le 49$) designates the pixel position within the camera. Table 1 lists the regression coefficients a and the offsets o.

Table 1. Regression Coefficients and Offsets

Camera	Regression Coefficients*		Offsets
c	$a_{c,0}$	$a_{c,1}$	o_c
0	-1.74556	0.996648	27
1	-1.64623	1.03942	0
2	-1.02636	1.02954	-27

*not all digits are significant

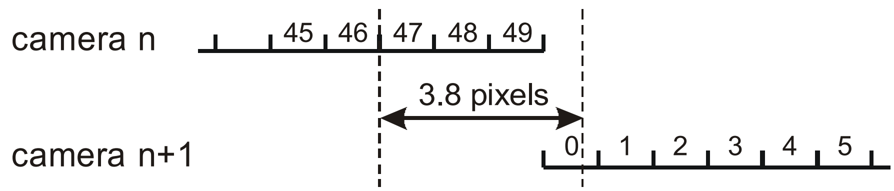

Figure 1. Overlap inferred from full-field Moon observations

[These results apply only to the elevation (cross-spin) direction. This is the horizontal dimension in images displayed by *euv_imtool*. The plate scale in the spin direction comes mainly from the knowledge of spin phase transmitted from CIDP to EUV. Optical effects play a minor role in the spin direction, but dominate in the elevation direction.]

2 *Camera Overlaps*

Using the data in the table above, we see that the optimum value for the overlap between adjacent cameras is 3.8 pixels, rather than the nominal value of 5 pixels used up to now. For example, an elevation of 15.30° corresponds to pixel 47.0 in camera 0 and to pixel 0.74 in camera 1. Similarly, an elevation of –11.4° corresponds to pixel 47.0 in camera 1 and to pixel 0.78 in camera 2. Figure 1 is a graphical illustration of the situation (neglecting the difference between 0.74 and 0.78). According to this analysis, the optimum overlap to use when combining cameras is ~3.8 pixels.

Next we consider a second line of evidence that supports a ~4-pixel overlap. We have analyzed the signals in pairs of cameras while the Moon crossed the boundary between them. During these times, the Moon appeared in both cameras simultaneously. Figure 2 shows an example of one

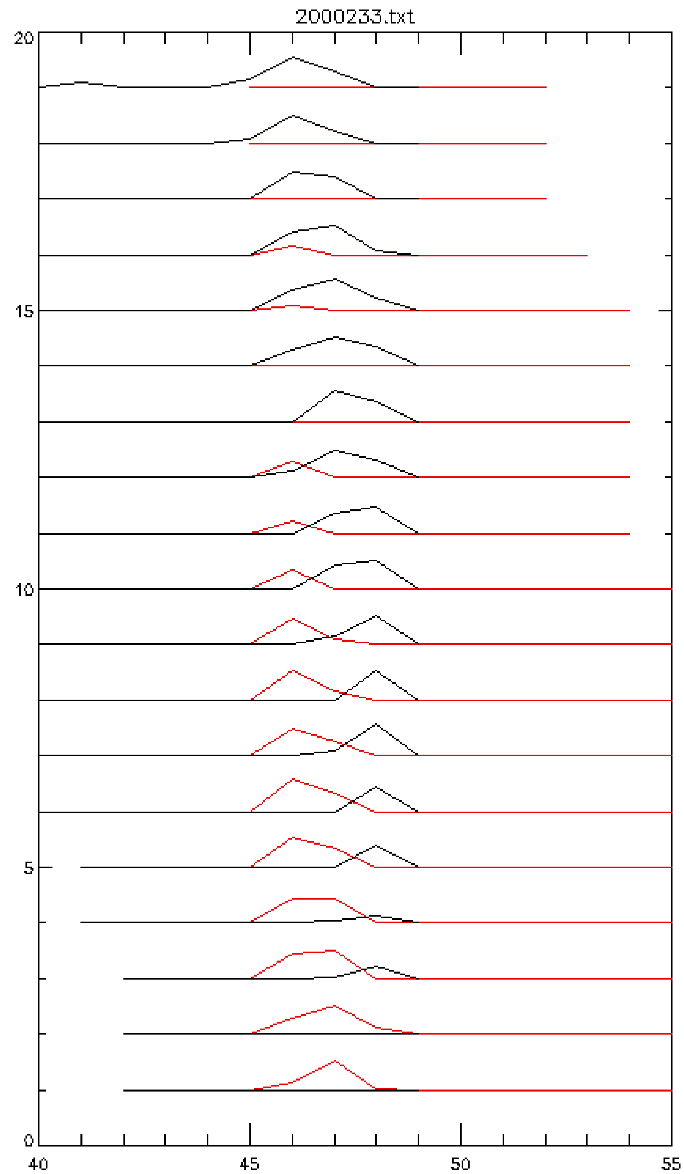

Figure 2. Sequence as Moon moves from camera 0 (black) to camera 1 (red). The overlap is the nominal value of 5 pixels.

such event. The traces from the two cameras are overlapped by the nominal value of 5 pixels. The maxima in the red and black curves would coincide if the 5-pixel overlap were correct. Instead, at the times of strongest signal in both cameras (lines ~5-10), the maxima are separated by about 1.5 to 2 pixels. The direction of the separation indicates that the 5-pixel overlap is too large. This means that the real overlap is 3 to 3.5 pixels, which is consistent with the results above. For a more quantitative evaluation, we have computed the correlation between the signals in the two cameras as a function of the assumed overlap.

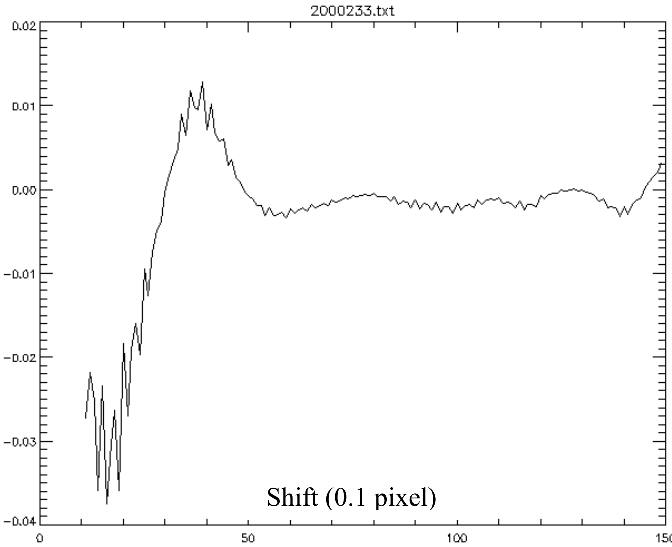

Figure 3. Correlation between cameras for a range of shifts (pixel overlaps).

We have considered 4 separate crossing times for boundaries between both cameras 0 and 1 and cameras 1 and 2. Figure 3 shows one of the eight examples. In that figure, the correlation between the two cameras is maximum at a shift of ~3.8 pixels. The average values of the shifts for the four sets of data are 3.5 pixels (camera 0 and camera 1) and 3.6 pixels (camera 1 and camera 2). These values are within a fraction of a pixel of the overlaps implied by the regression coefficients, so we have reasonable confidence in these determinations.

We adopt a new overlap of 4 pixels (the nearest integral value to the optimum overlap) between both pairs of cameras instead of the earlier "nominal" value of 5 pixels.

Figure 4 shows the new method of combining images from the three cameras to make a single image using the 4-pixel overlap. Decreasing the overlap between cameras would normally have increased the size of the final composite image. However, in our case, the outermost pixels were always zero, so we now omit those pixels. Therefore the

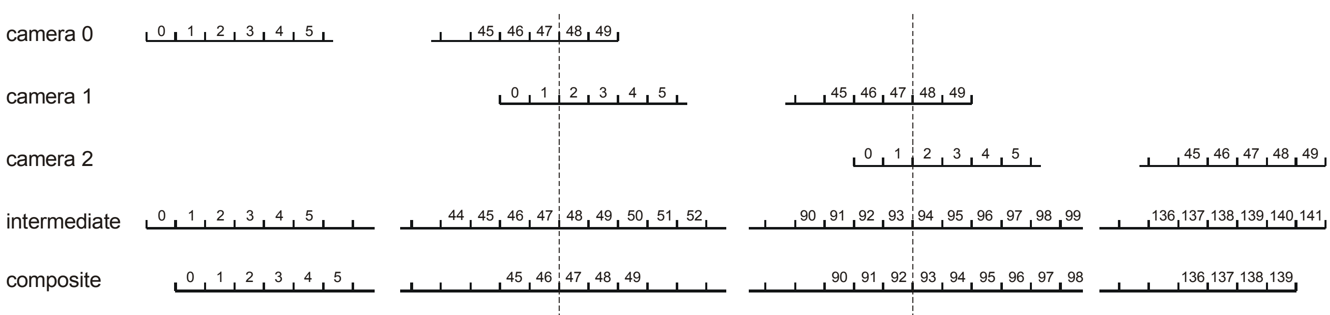

Figure 4. Method for combining images from the three cameras into a single composite image with 4-pixel overlap.

width of the composite image remains at the earlier value of 140 pixels. The last two lines of Figure 4 show the transition from the intermediate array of width 142 pixels to the final composite image array of width 140 pixels.

3 Plate Scales

Our work so far has used a plate scale of 0.6°/pixel in both the spin and cross-spin (elevation) directions. The Moon measurements show that the plate scales of the three cameras in the elevation direction differ slightly from the nominal value and from each other.

The first order coefficients $a_{c,1}$ in the table differ from their nominal values of unity in the sense that elevation pixels in cameras 1 and 2 are 3-4% smaller than their nominal value of 0.6°, whereas pixels in camera 0 are within 0.5% of the nominal value. Figure 5 compares the old and new position conversions. It applies to the elevation (cross-spin) direction only, because there is no change in the spin direction. The plot shows the difference between two elevation positions computed like this:

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do over old elevation pixels:
     compute line of sight for old pixel
     compute new pixel for that line of sight
     plot the difference between the two pixel positions.
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According to Figure 5, the maximum relative difference between the two methods is not quite 3 pixels.

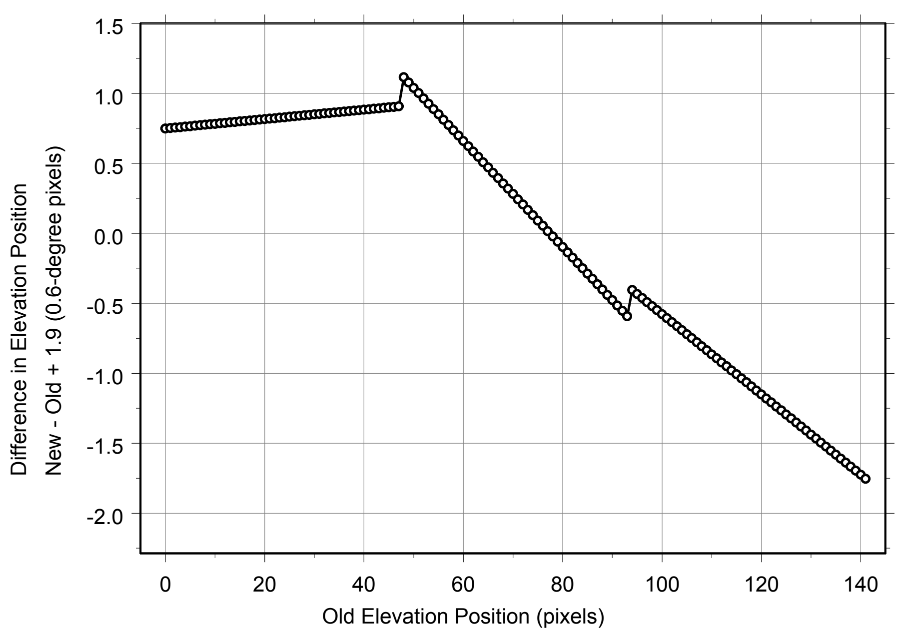

Figure 5. Comparing old and new pixel positions for the same lines of sight.

4 Changes in Processing Associated with 4-Pixel Overlap and Variable Plate Scales.

A new flat-fielding correction is needed for the new 4-pixel overlap interval. This is implemented by a modification to the VIDFs. Merging data from the three cameras into a single image according to the scheme in Figure 4 is performed by *euv_imtool* versions 1.26 and later and by other routines that assemble FITS images from the UDF system, such as the Web-based FITS file extractor. The differences in plate scales are accounted for in the line-of-sight calculations included in *euv_imtool* versions 1.26 and later.