REPORT TITLE WISE Post-Environmental Focus Test Results	DOCUMENT NUMBER SDL/09-450 REV: -
PREPARED BY Harri Latvakoski	DATE August 12, 2009

1. INTRODUCTION

This document describes the results of WISE focus testing performed after the hydrogen and vibration testing. WISE focus testing prior to the environmental testing is discussed in the *WISE Focus Verification Report* (SDL/09-157). The post-environmental focus testing was done using MIC2 on March 27 to 31, 2009 and the Blue Tube setup on April 16 and 17. The focus testing on MIC2 is used to compare the position of the band 2, 3 and 4 focuses to the band 1 focus; Blue tube testing is used to find the location of the band 1 focus. For a complete description of the test setups and their use see the Focus Verification Report.

2. BAND 1 FOCUS

Figure 1 below shows the band 1 shim increment as measured in the final pre-environmental Blue tube test and is identical to the figure presented in the Focus Verification report.

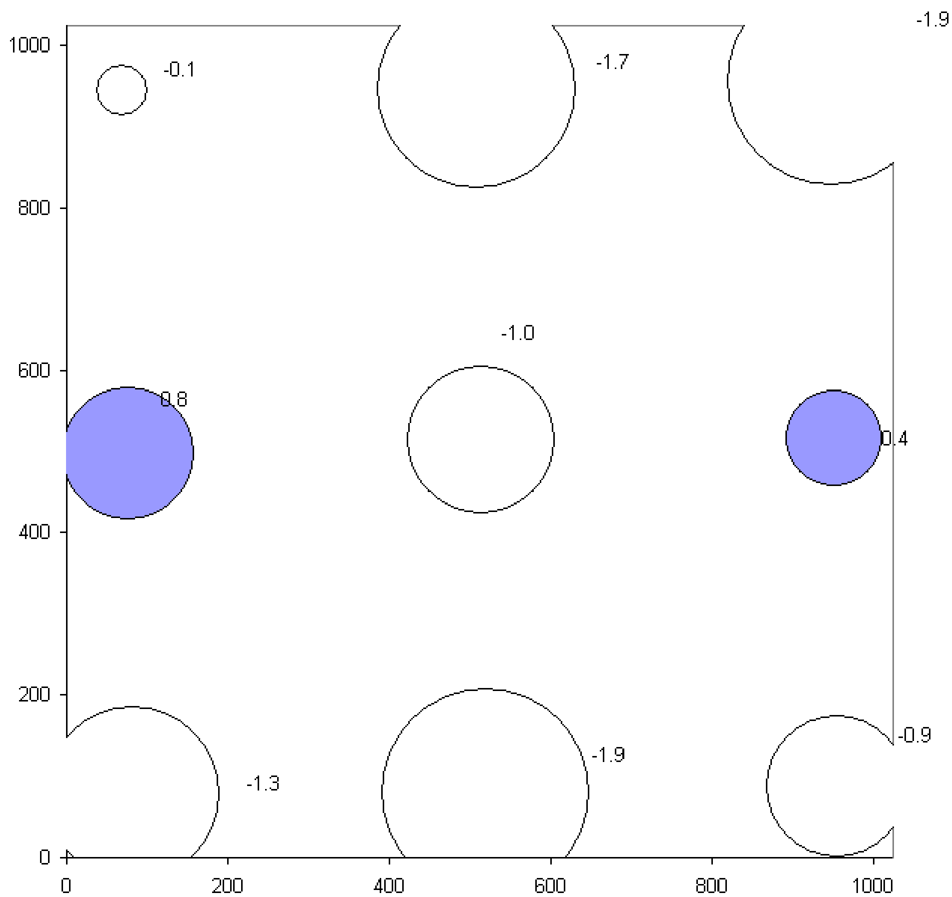

Figure 1: The band 1 shim increment from the final pre-environmental Blue Tube test. The plot shows the focus at several locations on the focal plane, with locations being what you would see if your head was at the WISE aperture looking out. E.g. the focus result when the collimator spot was to the upper left of center is shown is shown on the upper left of this plot. The value is the increment required to the WISE shim, in mils, to bring that point into focus, with a positive number meaning a thicker shim is required.

The Blue tube focus data collection for the post-environmental testing was collected the same way as the previous Blue tube data. Briefly, data is collected at several collimator aperture positions, a focus curve is made by plotting the noise pixels and ensquared energy, and best focus is taken to be the average of the maximum ensquared energy and minimum noise pixels. This position is compared to the position of collimator focus, corrected for drift in the collimator focus due to room temperature variation, converted into a shim increment at the focal plane, and finally corrected for the Blue Tube window focusing effect.

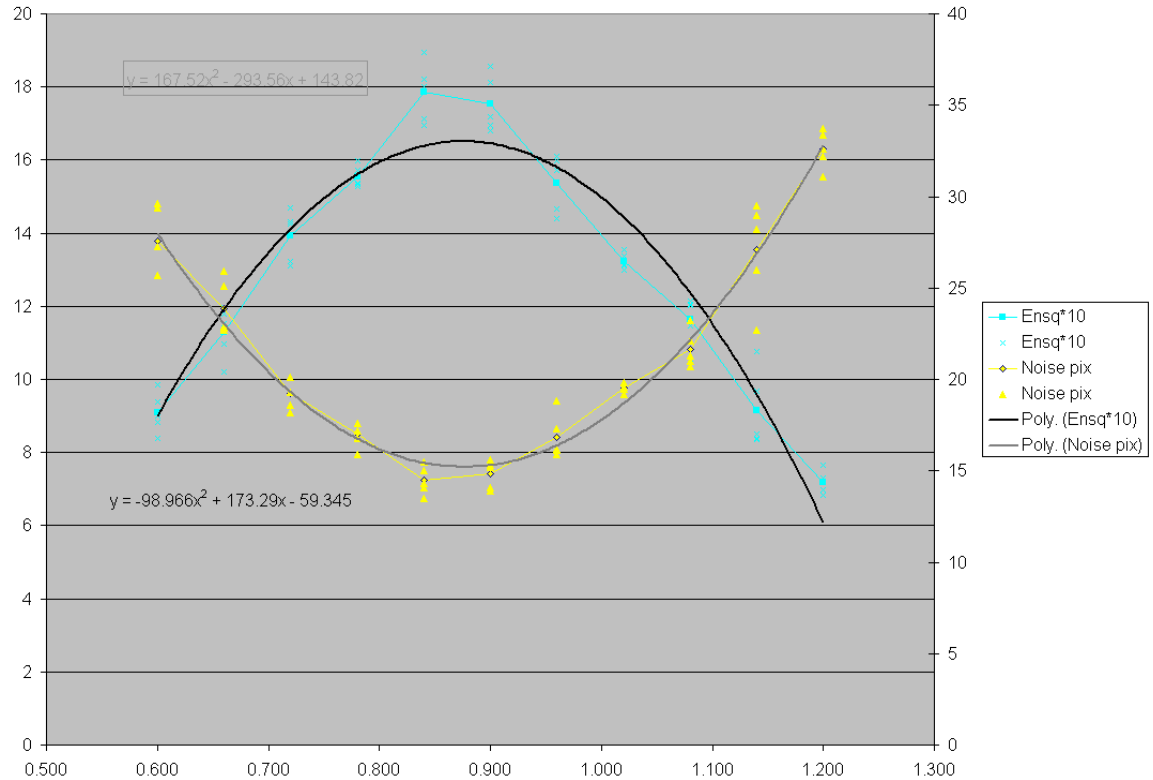

Figure 2: The 3rd post-vibe Blue Tube focus curve. The left axis is ensquared energy times 100 with noise pixels on the right.

Twenty focus curves were collected (figure 2 shows a sample curve). During this test, all focus curves were collected using 11 collimator aperture settings with a 0.060" step roughly centered on the position of best focus. Room vibration, which has always been problematic, was noticeably worse during this test compared to prior tests. This did not seem to affect measurement repeatability, as successively repeated measurements showed the repeatability is better than 0.5 mils which consistent with the prior testing. Since it was clear this could affect our ability to find the collimator focus with the LUPI, we made 4 separate measurements of collimator focus during focus testing.

The collimator temperature correction was determined from LUPI measurements of focus position while the room temperature changed during this and prior Blue Tube tests. We have observed during all Blue Tube testing that temperature correction is simple over a few hour time period, but can't be accurately determined over a longer term (there are fast and slow response components to the temperature correction). For this test the LUPI measurements of collimator were frequent enough that a simple temperature correction could be applied to all data. During a portion of this data collection, we turned off the climate control system in the room, which stabilized the temperature, and thus eliminated the temperature correction altogether. The data taken with and without temperature correction required are consistent to within expected uncertainties.

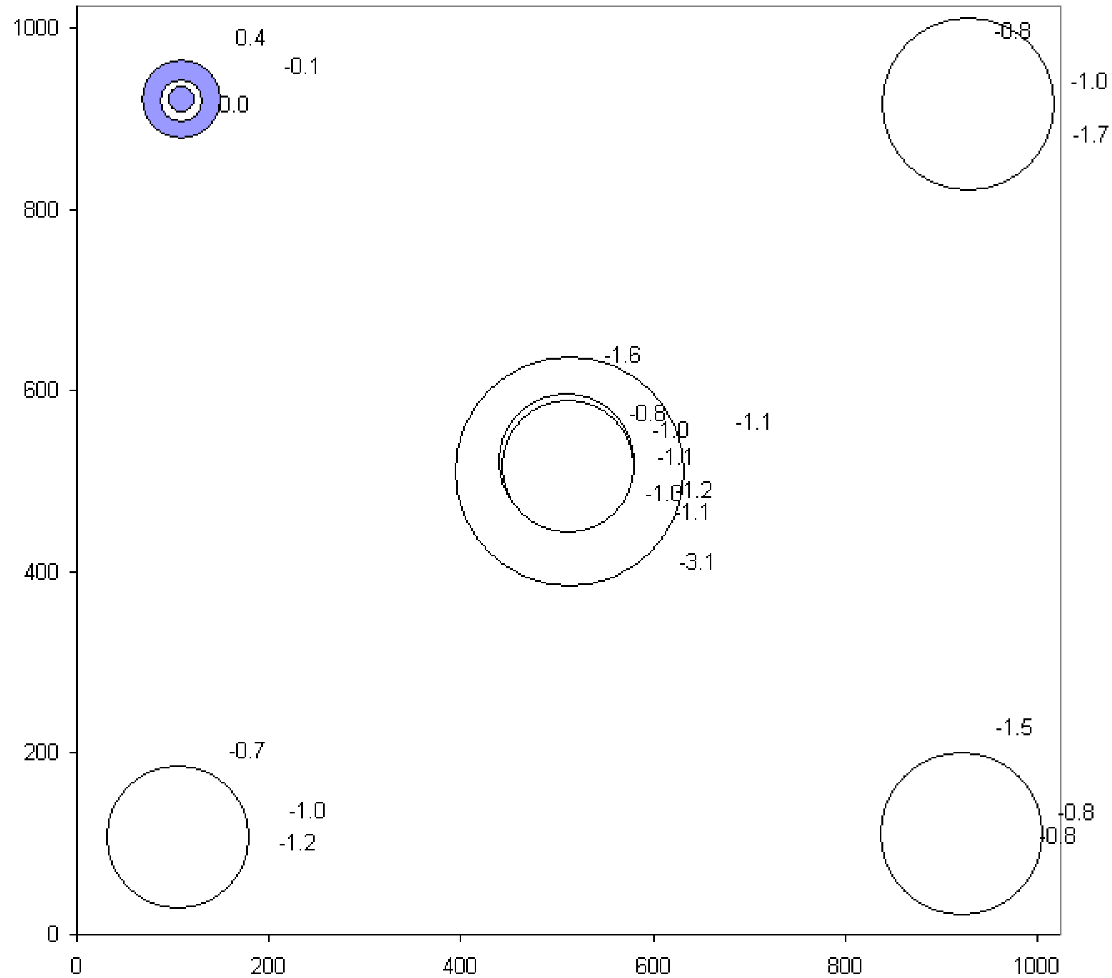

Figure 3: The post-vibe Blue tube shim increment bubble plots showing all collected data.

Figure 3 shows the focus results for all collected post-vibe focus data. One point at the center is clearly an outlier. We suspect an error in data collection and exclude this one point when averaging data. The focus result with data at each position averaged is shown in Figure 4.

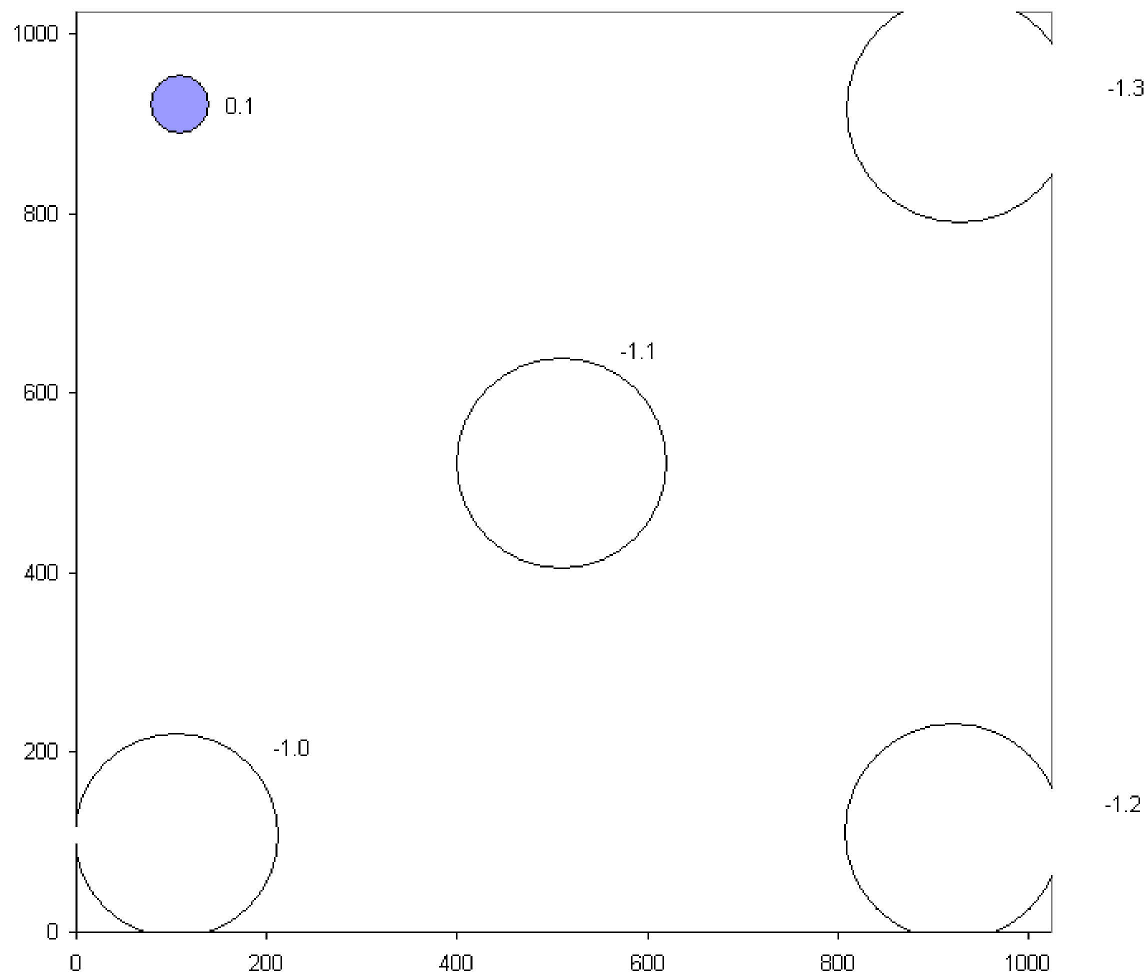

Figure 4: Post-Vibe Band 1 shim increment.

Comparing figure 4 with Figure 1 shows there is no significant change in band 1 focus due to the environmental testing, as all difference are consistent with the ~0.5 mil uncertainty in each plot (see Focus Verification Report). The array locations where the data was collected do not coincide exactly for the post-vibe and pre-vibe tests, and can differ by ~40 pixels (the pre-vibe corner points are closer to the corners). This is not a significant difference.

The requirement is for band 1 to be within ±2.0 mils of focus is clearly still met post-vibe.

3. BANDS 2, 3, AND 4

For the post-vibe MIC2 tests, the data was collected similarly to the pre-vibe data. As before, focus data was collected simultaneously for band 1 and 2 and simultaneously for bands 2, 3 and 4, as it was not possible to collect data in all bands simultaneously. The band 2, 3, and 4 data must be collected over a larger range of focus probe positions to show the curve in bands 3 and 4. During the post-vibe test, focus probe positions for data collection were chosen based on the pre-vibe data to give a long enough travel for the band 2, 3 and 4 data set while simultaneously matching as many points as possible with the band 1 and 2 data set. (For the pre-vibe tests the positions were similar, but this matching was not as good.) During this test, the room vibration was significantly better than observed in the previous MIC 2 test. Figure 5 shows an example focus curve that can be directly compared to that in the Focus Verification report. Here the noise pixels and ensquared energy measured in each of the 5 images taken at each focus probe position agree very well.

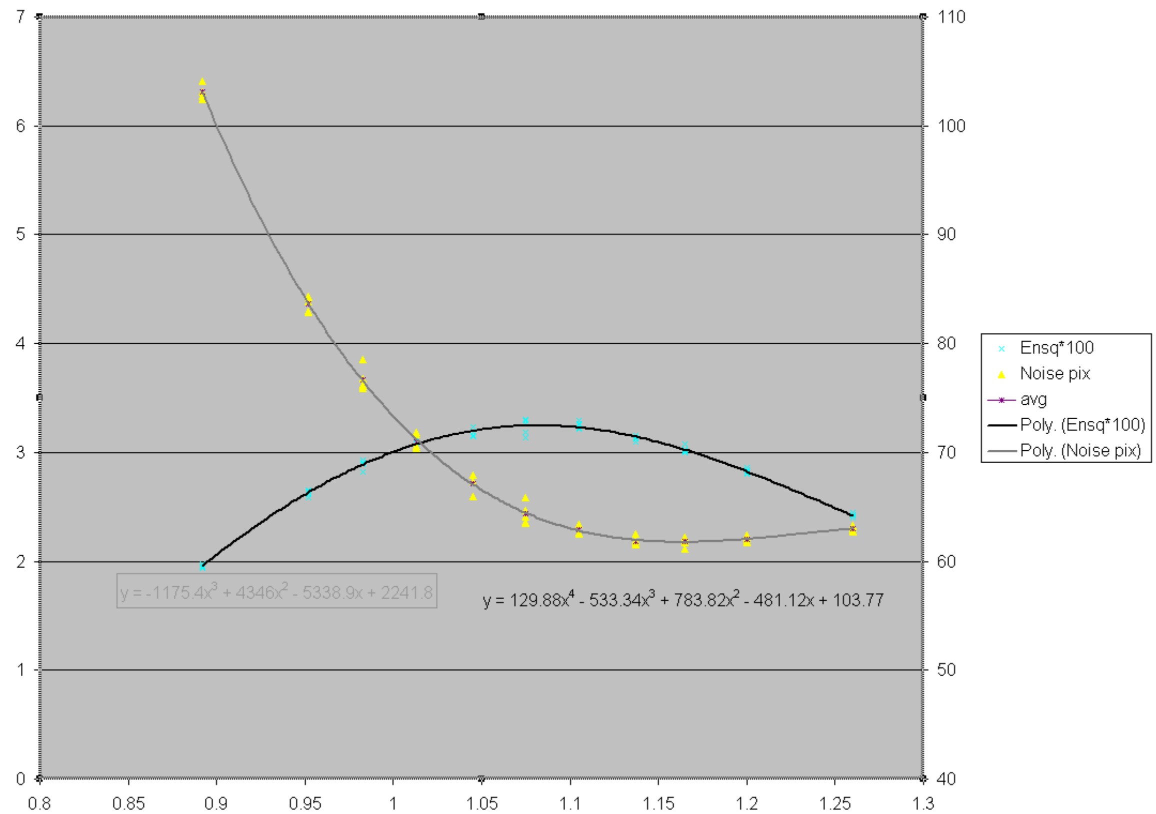

Figure 5: Band 2 focus curve #2 from the post-vibe data. The left axis is ensquared energy times 100 and the right axis is noise pixels. The red dots are the average of noise pixels for each focus probe position, and the polynomial fit to noise pixels lies on top of these.

As before the spots from band 1 and 2 show a similar, irregular shape throughout the curve, while the spots for bands 3 and 4 are much more circular. For bands 1 and 2 the focus positions could be compared using a minimum of a cubic fit to the noise pixels, but because of the similar shape of the spots, the exact fitting method did not matter. The maximum of a 4^{th} order fit to ensquared energy is equally valid and gives a similar result. Because of the different spot shapes, comparing band focus 2 to band 3 or 4 requires using the noise pixel minimum. (The noise pixel minimum is the position of best focus even for the irregular spots, see the Focus verification report.)

The better quality of the post-vibe data made clear the order of polynomial required to properly fit the data. In all cases the polynomial used for the pre-vibe data was correct, except for band 3 where a parabola is not a good fit to the noise pixel data. A 4^{th} order polynomial is required to properly fit this curve.

It also became clear that exactly how the noise pixels are measured is significant. We measure the noise pixels in a box or circle of some size centered on the spot. This area must include most of the source at all positions in the focus curve, but does not need to be large enough to include all power from the source for a focus measurement, and there is also a limit to area size because a larger area adds noise. For further discussion of how to measure noise pixels, see the Band 1 Image Quality Post-Vibe report (SDL/09-308) and WISE Image Quality and Near Angle scatter (SDL/09-289). To calculate the noise pixels, the image background must be determined from another area on the image and subtracted off from the spot data. This is necessary even for the background subtracted images used here because of variation in the MIC background over time for bands 3 and 4. Even without this variation, the observed small variations in the array background level can significantly affect the noise pixel calculation. The noise pixel calculation used for the Blue Tube tests is not adequate for the MIC3 testing.

For bands 1 and 2, because the spot shape is similar in both cases, the exact areas used to find the background and noise pixels do not affect the measured difference in focus between bands. This was verified by directly comparing results using different backgrounds in the post-vibe focus data (the results are the same with a small variation). The method used is a 12 pixel radius circle for the noise pixel calculation with the background found from a 20 to 30 pixel annulus around the spot. The band 2 relative focus was found using the maxima of ensquared energy, instead of noise pixel minimum because this has a sharper peak than the noise pixel minima and thus should have the least uncertainty (again, this agrees with relative focus found from noise pixel minima with a small variation).

For bands 3 and 4 this is more complex as a there is significant background structure from MIC2 in the images. The areas are chosen to avoid these (15 pixel circle, 23 to 29 pixel annulus for band 3; 9 pixel circle, 11 to 15 pixel annulus for band 4). These images also clearly show some signal from the warm focus probe tip intertwined with the signal from the aperture on the tip. This should have no effect on the focus measurement except to somewhat broaden the focus curve.

To compare band 2 to 3 and 4, we determined the best method is to fit the band 2 noise pixel data that is taken with band 3 and 4 data with a forth order polynomial (the higher order is needed for the longer focus probe travel of the curve collected here). This minimum is then compared to the noise pixel minimum for bands 3 and 4 using 4^{th} order and 2^{nd} order polynomial fits, respectively. Figures 6 shows one set of band 1 and band 2 data used to obtain a relative focus between 1 and 2, and Figure 7 shows band 2, 3, 4 data used to obtain the relative focus between bands 3 and 4 and 2.

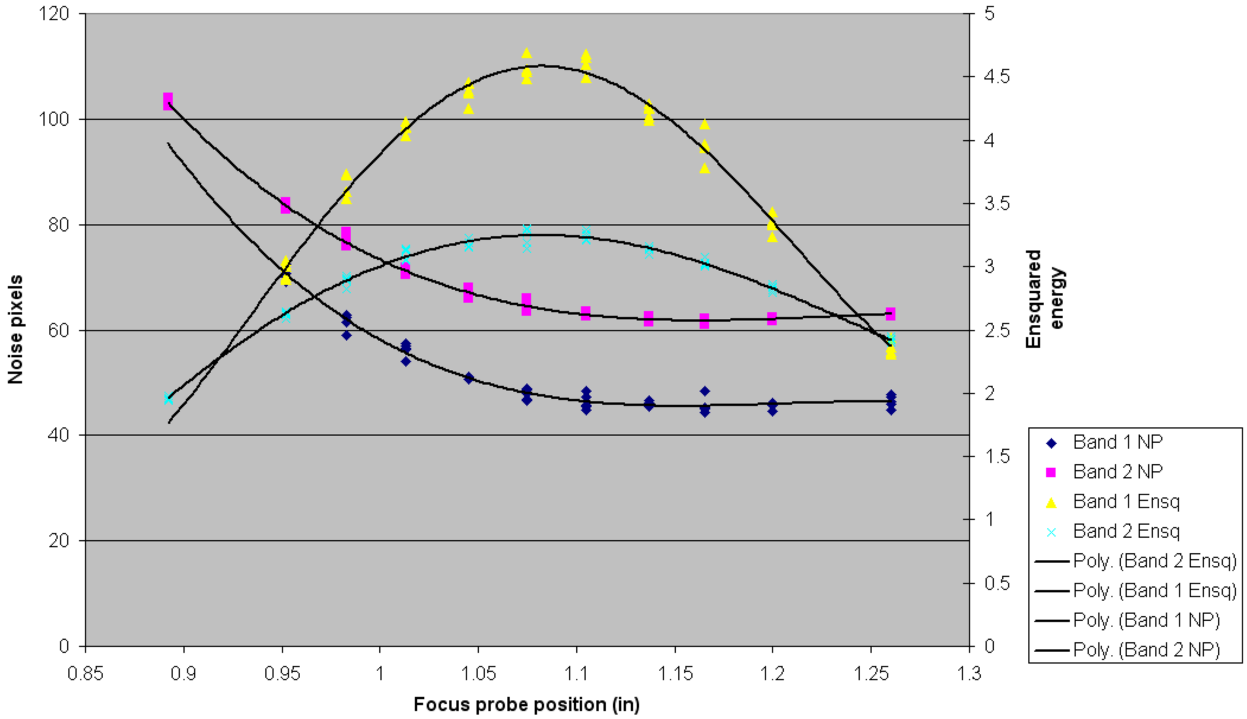

Figure 6: Band 1 and 2 focus curves at the center position. These are used to calculate the relative focus between band 1 and 2.

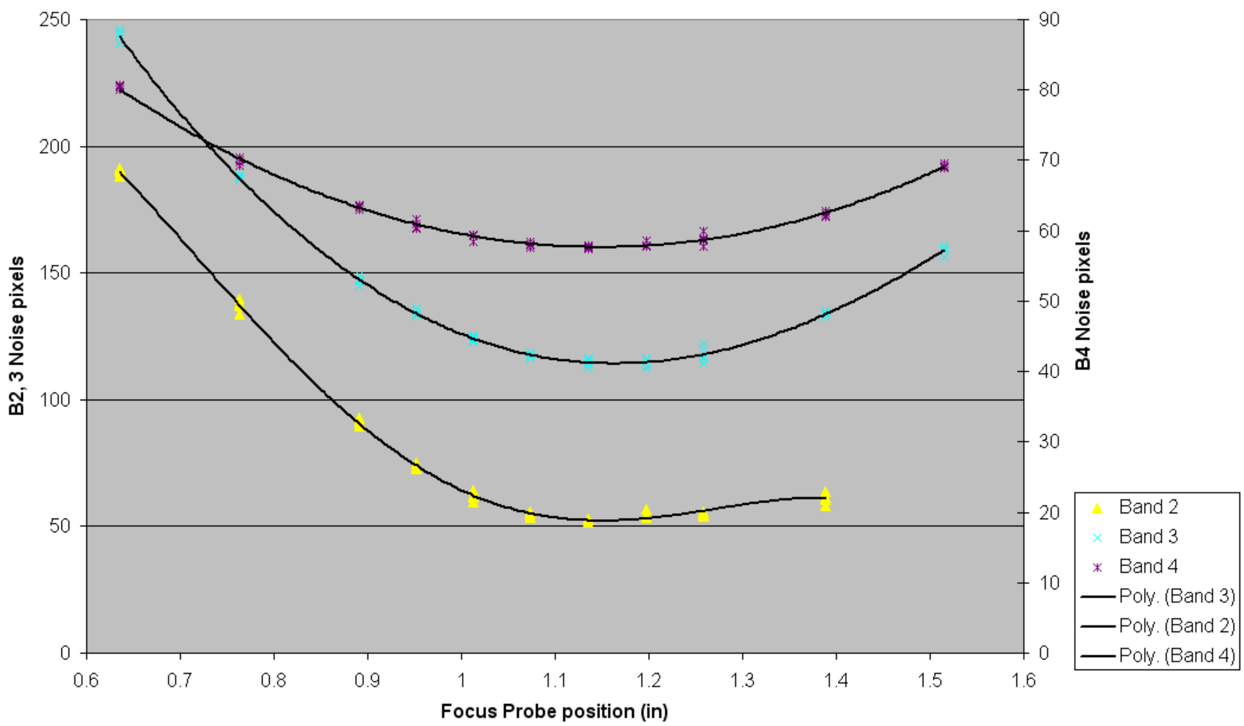

Figure 7: Band 2, 3 and 4 focus curves at the center position. These are used to calculate the relative focus between bands 2 and 3 and 4.

The relative focus of bands 3 and 4 to band 1 is, of course, found by adding the difference between these bands and band 2 to the difference between band 2 and 1. The band 2, 3, and 4 shim increment is calculated by adding the relative shift between these bands and band 1 to the band 1 shim increment measured with the Blue Tube setup.

The improvements in the fitting and noise pixel calculations were applied to the pre-vibe focus data. This affected the band 3 and 4 relative focus (the band 1 to 2 relative focus was unchanged). The updated band 3 and 4 pre-vibe shim increment plots are shown in this document. These improvements also made clear uncertainty in these calculations due to the noise pixel calculation method and from how well the curve fits the data. The estimated uncertainties are indicated in the plots below. The indicated uncertainty is only for the relative focus between the plotted band and band 1, and to get the total shim increment uncertainty this should be added in quadrature with the Band 1 shim increment uncertainty. Uncertainty from the MIC2 test is generally dominant.

The band 2, 3, and 4 post vibe shim increment is shown compared to the pre-vibe results in Figures 8 to 13. As stated in the focus verification report, for the pre-vibe shim increment, the band 1 blue tube data was not collected at exactly the same array positions as the MIC2 data, but the difference is not significant. For the post-vibe shim increment maps, the MIC2 and post-vibe band 1 data were collected within ~10 pixels of the same location.

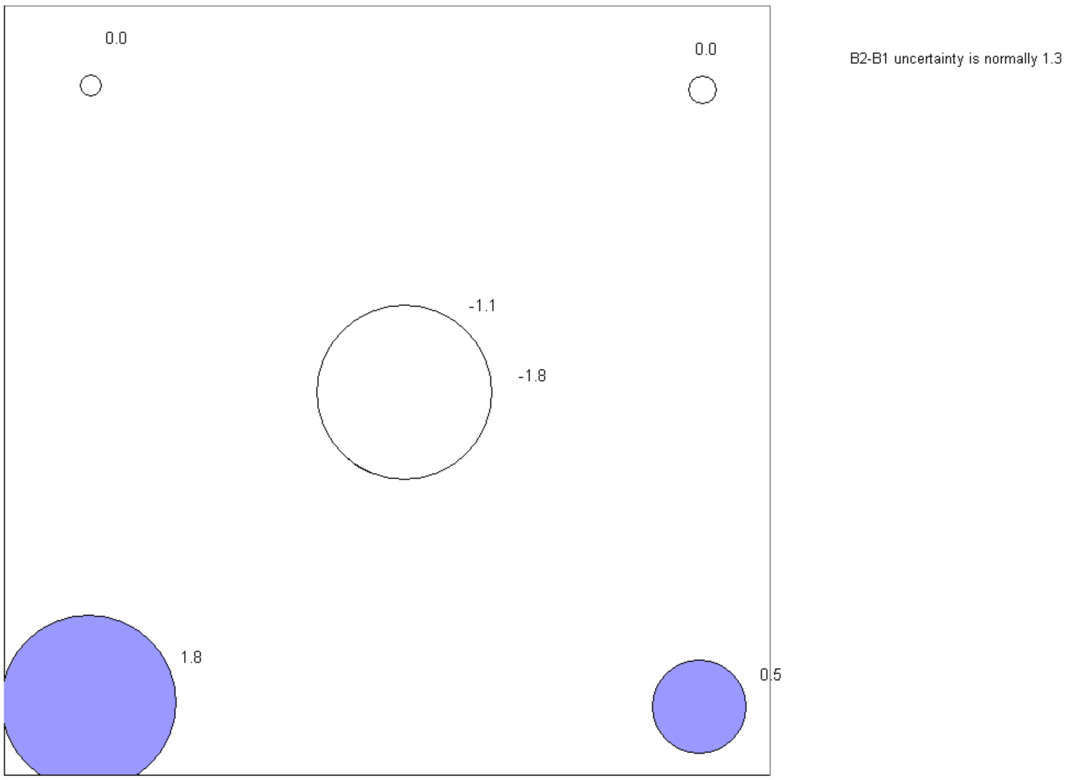

Figure 8: Pre-Vibe band 2 shim increment. This is the same as in the Focus Verification Report.

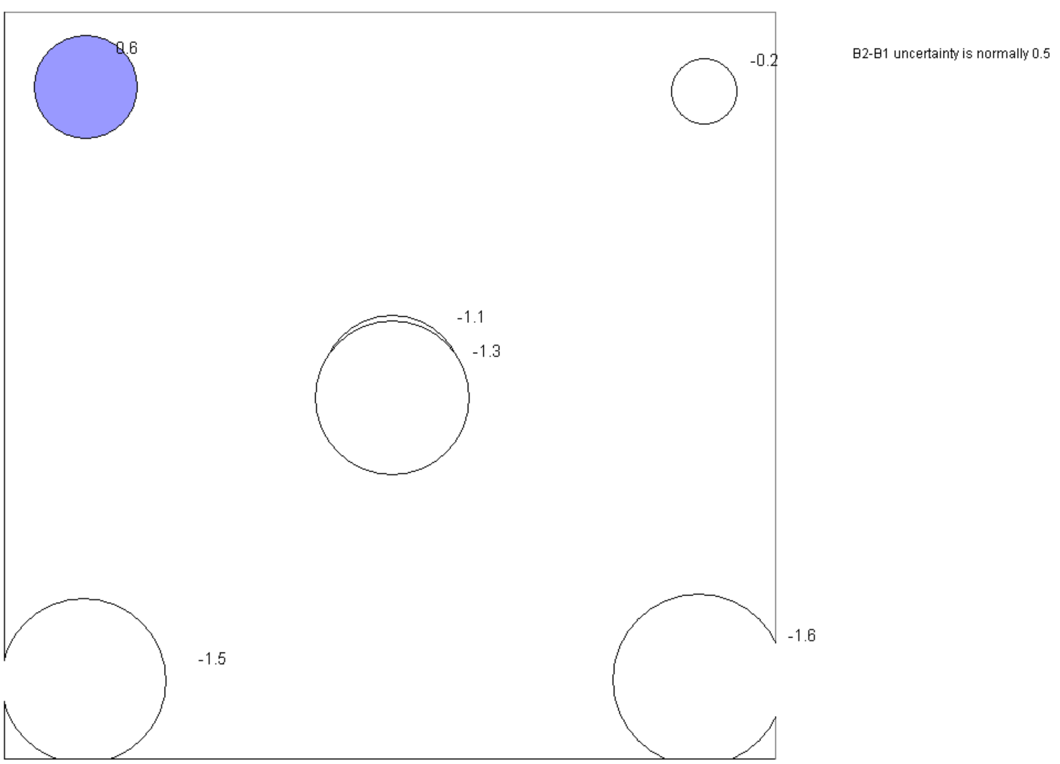

Figure 9: Post-Vibe band 2 shim increment plot.

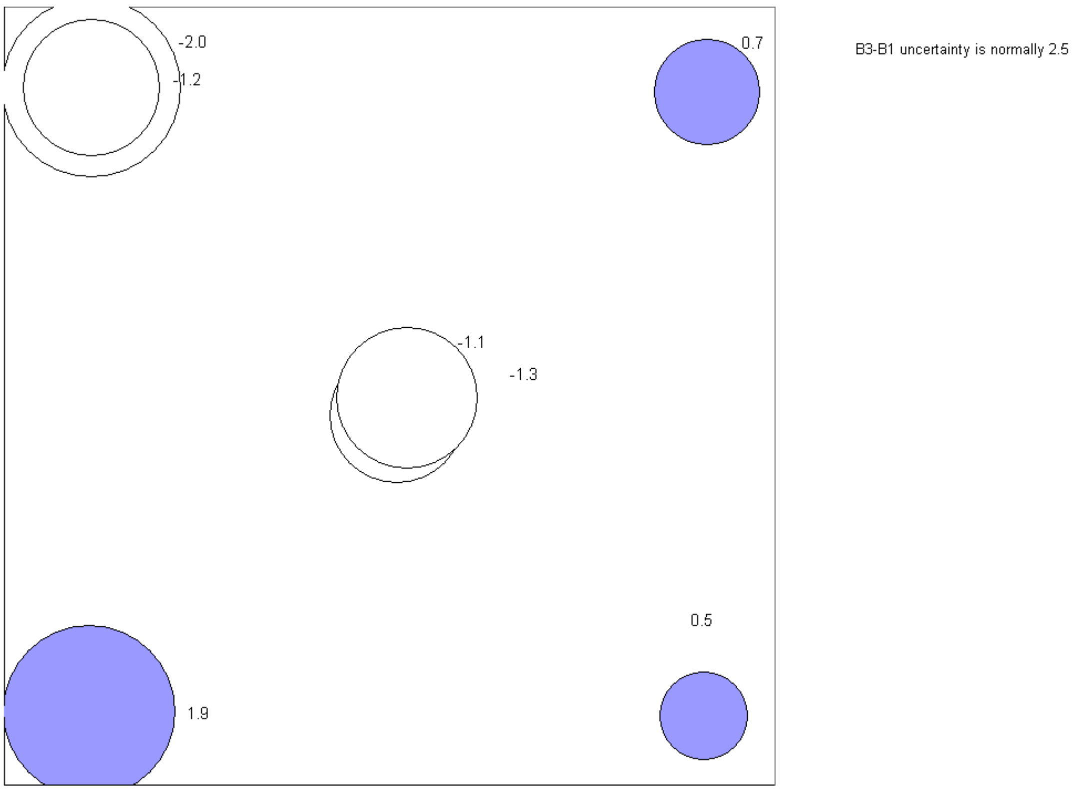

Figure 10: Updated pre-vibe band 3 shim increment plot.

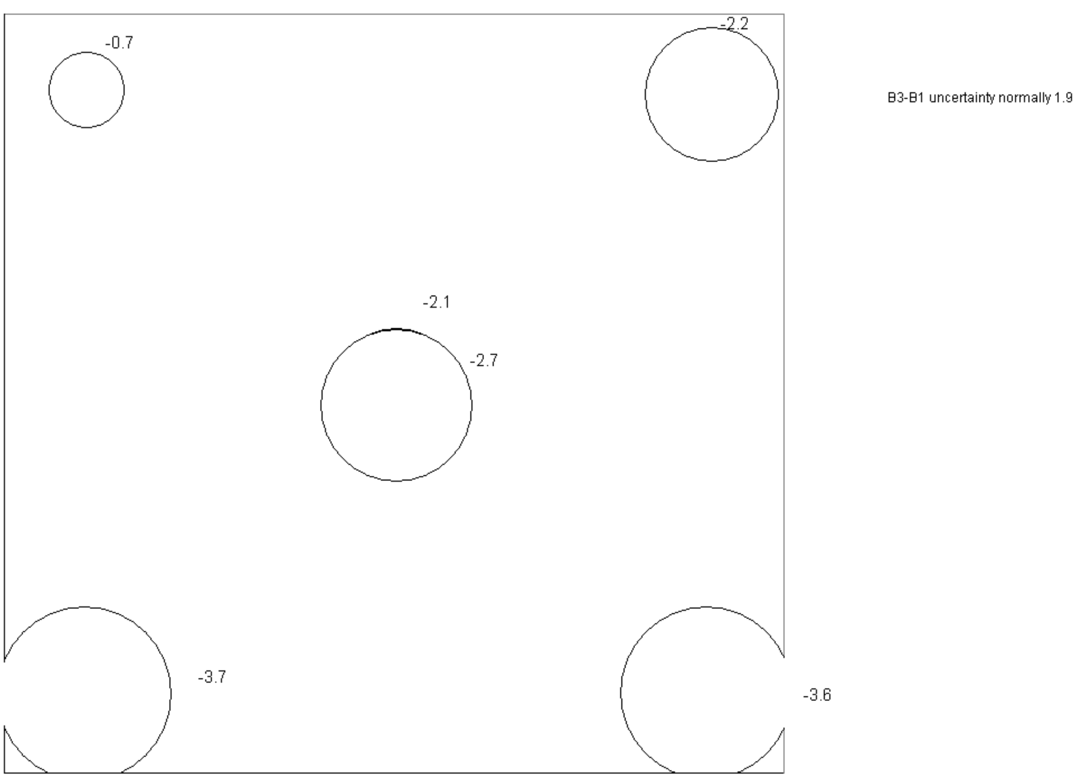

Figure11: Post-vibe band 3 shim increment plot.

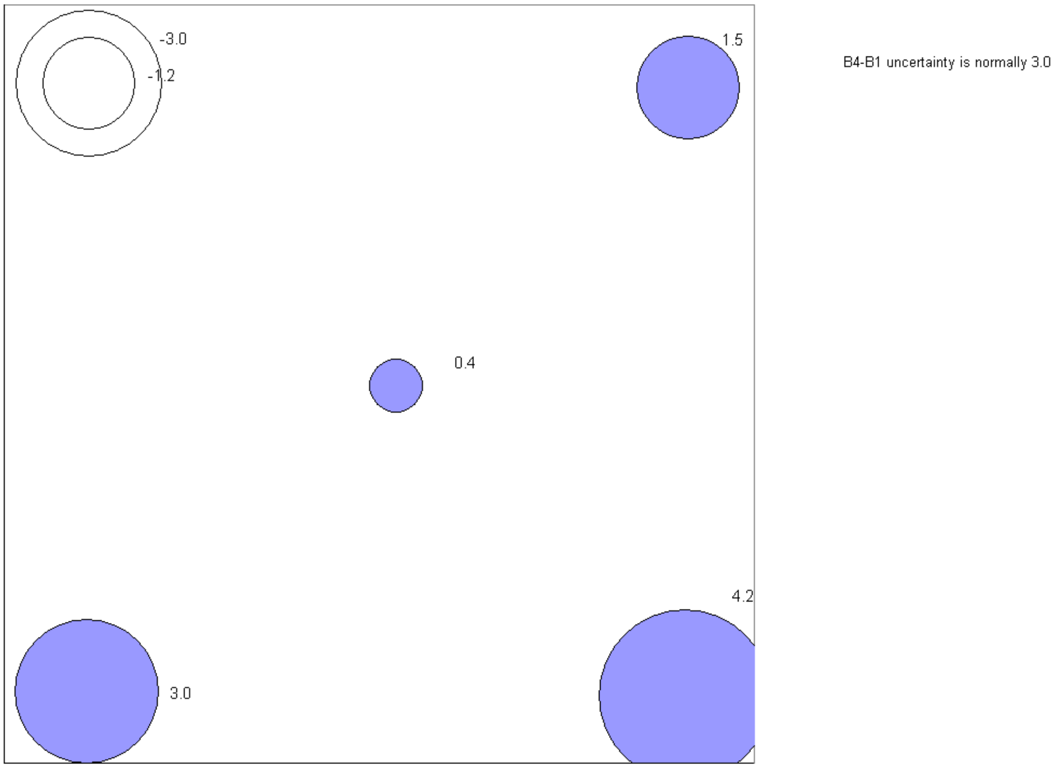

Figure 12: Updated pre-vibe band 4 shim increment map.

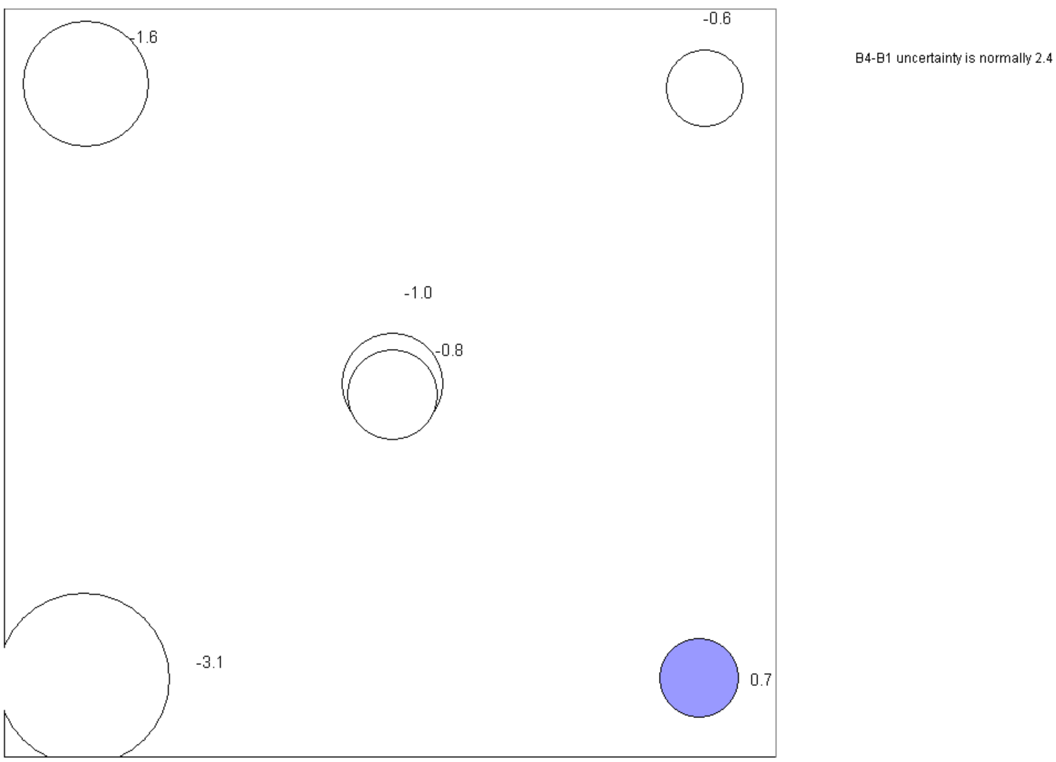

Figure 13: Post-vibe band 4 shim increment plot.

The differences in the band 2 maps are easily explained by the uncertainty. It is mainly the bottom two locations that are different, which is inconsistent with the relative lack of change in the other points. The uncertainty in a difference of pre and post-vibe values at any location is ~1.6 mils for each point (adding 2 MIC and 2 Blue tube test uncertainties), and the difference in the bottom two points are within reasonable multiples of this. The band 2 focus requirement of no more than ±2.4 mils from focus is met post-vibe.

For bands 3 and 4, the uncertainty in the difference of pre and post-vibe results at any point are 3.2 and 4.9 mils, respectively, and no points differ by as much as twice the uncertainty. The average change in shim increment is -2.5 mils for both bands. This could be indicative of a real shift, but since the uncertainty in this average is about 1.5 mils for band three (2.2 for band 4), uncertainty alone can not be ruled out. Band 3 and 4 clearly meet their focus requirements of ±4.3 and ±7.9 mils.

4. CONCLUSIONS

No significant change in focus occurred due to environmental testing. Bands 1 through 4 are predicted to be within their focus budgets when WISE arrives on-orbit. The predicted amount of defocus in each band is 25, 25, 60, and 30 µm for bands 1 through 4 respectively.