MIT
Center for Space Research **Chandra X-Ray Center**

MEMORANDUM
November 2, 2004

To:	ACIS/HRC Calibration Teams
From:	Bish K. Ishibashi, D. P. Huenemoerder, and J. E. Davis, MIT/SDS
Subject:	Evaluation on the LETG+ACIS-S rotation issue
Revision:	1.0
URL:	`http://space.mit.edu/CXC/docs/memo_letg_rot_1.0.ps`
File:	`/nfs/cxc/h2/bish/CXC SDS/LETGROT/memo_letg_rot_1.0.tex`

1 LETG+ACIS-S Rotation Issue

This memorandum is to summarize the outcome of our investigation on the LETG+ACIS-S[1] rotation issue addressed by Drake and Ratzlaff (`http://hea-www.harvard.edu/~jdrake/memo/geomn0004/`). Their finding points out that there exists a significant discrepancy ($\approx 0.088^\circ$) between the HRC-S and ACIS-S detector alignments in the CALDB geometry file `telD1999-07-23geomN0004.fits`. The effect of this discrepancy is demonstrated in Figure 2 by Drake & Ratzlaff.

In brief, our analysis shows that the *relative* rotational alignment of the HRC-S and ACIS-S detector arrays in the Spacecraft (SC) coordinate space is not accurate in the current CALDB geometry file (N0004).

In the following sections, this memorandum describes methodology on the examination of ACIS-S/HRC-S detector alignments with LETG grating datasets. Our new quantitative results account for the origin of the 0.088° rotational offset and provide input to adjusting the geometry calibration values.

2 Examination of Detector Alignments

Drake & Ratzlaff have suspected that the relative rotational alignment between the HRC-S and ACIS-S detectors is incorrectly defined in the current CALDB geometry file (`telD1999-07-23geomN0004.fits`). The rotational offset angle between the ACIS-S and HRC-S detectors is specified as $+0.04^\circ$ (in CCW direction in the SC Y-Z plane) in the CALDB file (see Figure 1).

A simple approach to verify the offset angle is to measure clock angles of LEG dispersed events (i.e., LEG arms) projected onto each detectors in the CHIP coordinate system. The difference in the clock angles reflects the true relative value of the rotational offset between these two detectors in the SC Y-Z plane. This stems from the fact that the LEG dispersed arms are projected onto the SC plane at a fixed clocking angle.

We will use two grating datasets to perform this analysis: ObsID 4148 (LETG+ACIS-S) and 4149 (LETG+HRC-S), both of which are available in Chandra public archive.

[1] The similar problems exist with other detector configurations, e.g., LETG+ACIS-I and HRC-I.

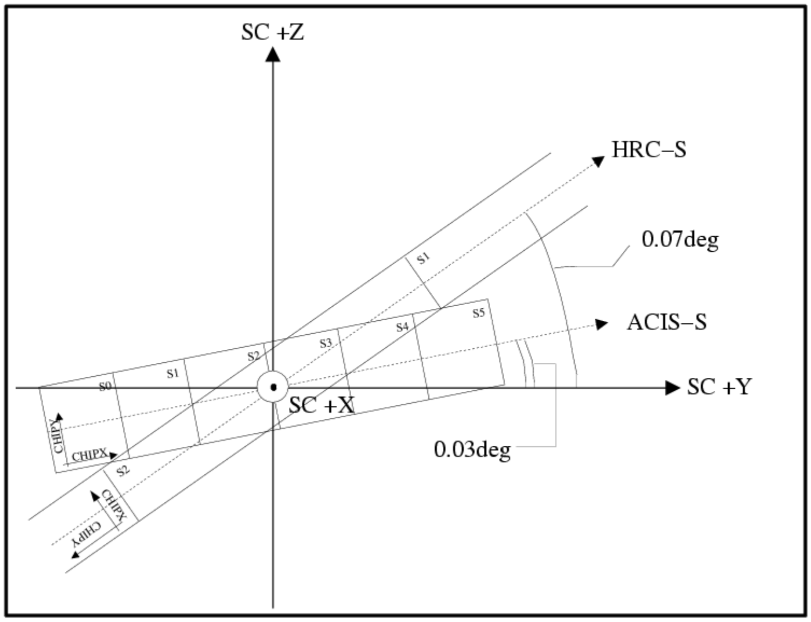

Figure 1: Detector alignments in the spacecraft plane specified in the CALDB geometry file (N0004). The detector layout is drawn as it is viewed from the HRMA down to the SIM plane, i.e., Spacecraft +X axis points out of the plane of SC Y-Z. Right-hand rule applies to all the coordinates referred in the plot. For simplicity, both HRC-S and ACIS-S are moved arbitrarily in the +SC-Z direction so that their layouts are superimposed.

Table 1. Clocking angle measurements

ObsID	Configuration	Clocking Angle (degrees)
4148	LETG + ACIS-S	-0.049 $\pm$ 0.0023
4149	LETG + HRC-S	-0.0048 $\pm$ 0.00030

2.1 Measurements of Clocking Angle

Since photon events in the CHIP coordinate are not corrected for aspect dithering[2], it is not plausible to achieve a measurement in clocking angle (i.e., tilt against a CHIPn axis) with good precision when *all* photon events are used. In order to minimize the effect of dithering, we apply a spatial filtering on the four corners of Lissajous dithering pattern via the *vwhere* S-Lang/SLgtk tool using *ISIS* to pick up relevant GTIs; then we time-filter and use the selected four sets of events to measure their clocking angles against CHIPn axis. Furthermore, in this exercise we used the selected events found in ACIS S3 and HRC S1 chips for comparison. Figures 2 and 3 provides an example of this procedure.

The measured clocking angles of the LEG arms in the CHIP coordinate are tabulated in Table 1. Note that in the HRC-S system, the major axis of the HRC-S detector coincides with the CHIPY axis (not CHIPX like in the ACIS-S detector). Note that the right-hand coordinate rule still applies to the HRC-S system. The sign of the measured angle is defined as negative in clock-wise direction from the major axis of each detector (to remove any ambiguity, that is CHIPX for ACIS-S, and CHIPY for HRC-S again).

Based on these quantities, Figure 4 shows position angles of CHIPn axis (n=X for ACIS-S and Y for HRC-S) with respect to the fixed LEG arm (LEG +1st order arm in this case). The derived relative offset angle is 0.054 deg. The crucial point to note here is that the detector alignments of the HRC-S and ACIS-S is

[2]Aspect dither correction cannot be done without relying on the CALDB geometry file.

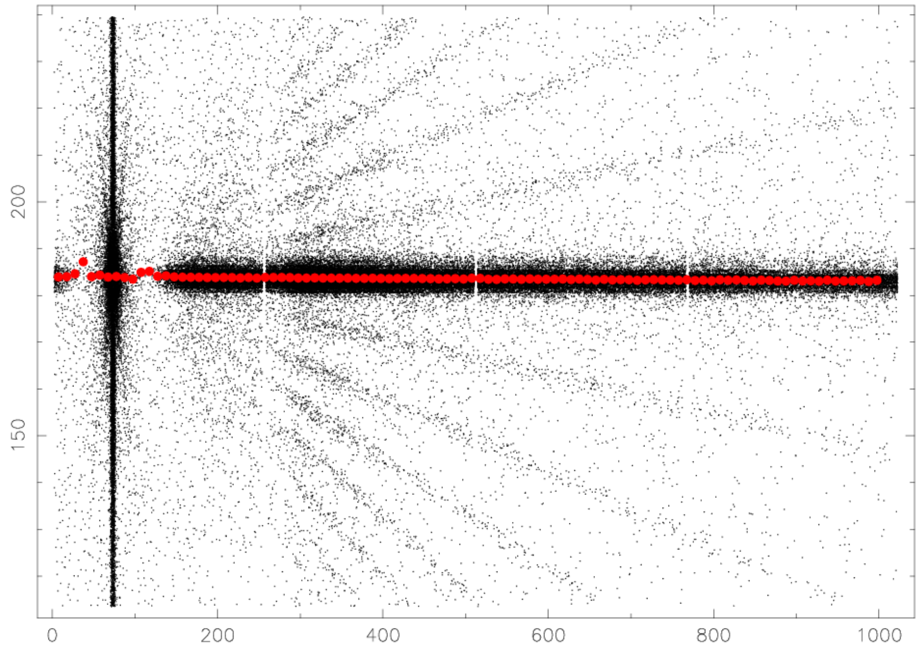

Figure 2: Example of centroid fitting (part I): the case for LETG+ACIS-S. Selected events data are binned with the width of 10 pixels per bin. Then the centroid value in each bin is derived by taking a median of their CHIPY values.

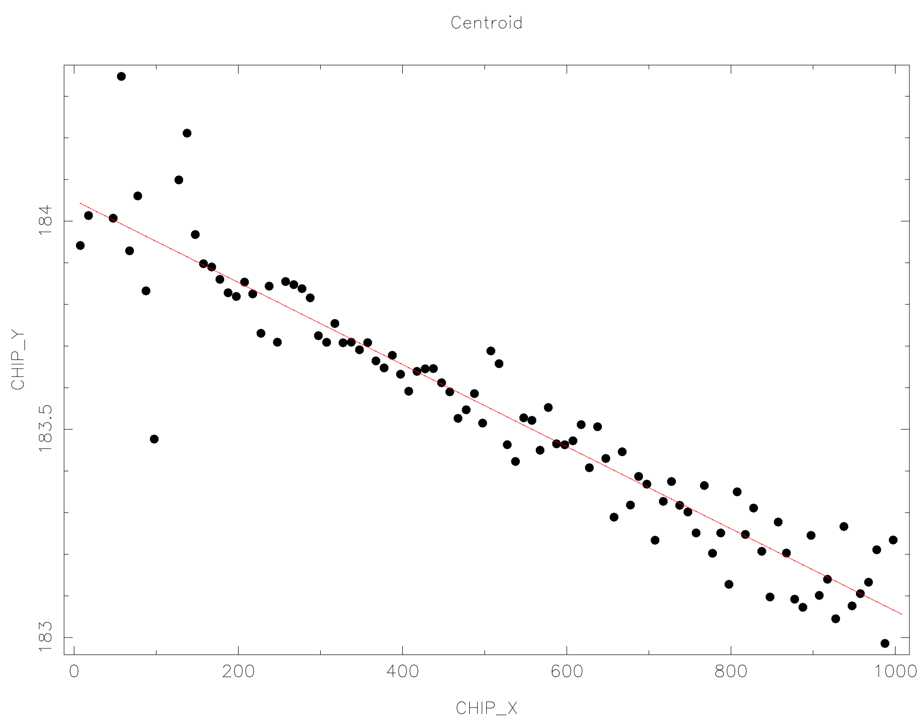

Figure 3: Example of linear fitting (part II). The slope of data points can be measured with fair accuracy ($\approx 0.001°$) in the applied method.

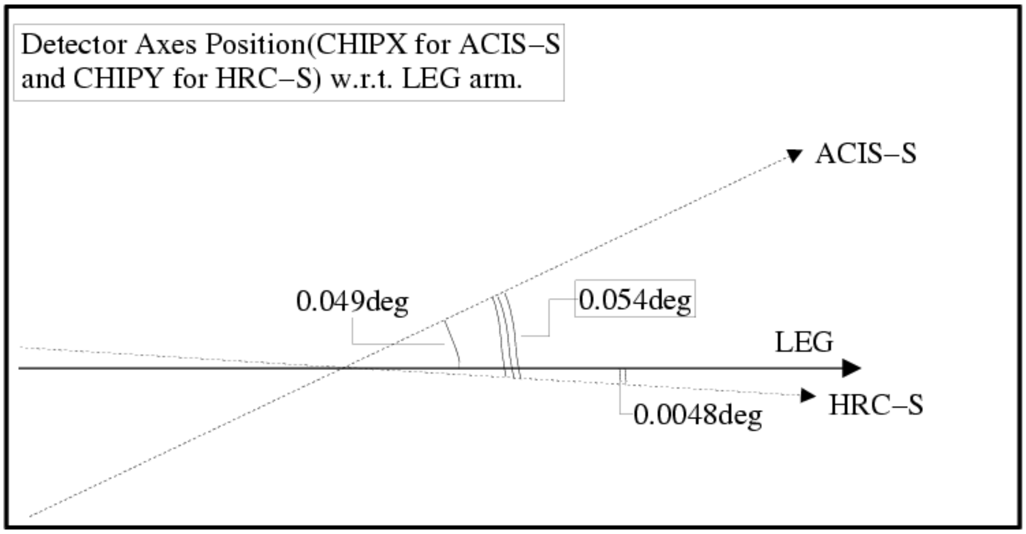

Figure 4: Position angles of the detector axes with respect to LEG +1st order arm. The relative offset angle between the HRC-S and ACIS-S detectors is determined to be ≈0.054°. Note that, while the scale of the offset is close to the value found in the current CALDB geometry file (0.04°), the sign is reversed in this figure (c.f., Figure 1).

reversed, i.e., the ACIS-S array now appears to have a greater position angle than that of the HRC-S array (c.f., Figure 1). Although the absolute scale of the derived offset angle is close to the value (0.04°) found in the current CALDB geometry file, the sign of the values are reversed.

3 Explanation for the 0.088° Rotation Problem

Figure 5 describes how the 0.088° rotation problem arises in the current data processing. Since CIAO relies on the accuracy of the CALDB geometry file, its processing assumes that the HRC-S and ACIS-S detector arrays are aligned as specified in Figure 1. In this case, the HRC-S detector "sees" the LEG arms going more or less horizontally across its CHIPY axis (or tilted by a small angle of -0.0048°). And by definition, the ACIS-S array "expects" the LEG arm to be exactly at the CHIP-Y axis of the HRC-S array. However, in reality the LEG arm is tilted by -0.049°with respect to the CHIPX axis of the ACIS-S detector. Hence the angle between the CHIPY/HRC-S and the LEG arm position angle with respect to the CHIPX/ACIS-S amounts to be 0.089°. This is practically the same value as derived by Drake and Ratzlaff.

4 Summary and Recommended Actions

To summarize, we found that the actual relative detector alignment of the HRC-S and ACIS-S arrays is inconsistent with the detector geometry currently defined in the CALDB geometry file (N0004) and this inaccuracy explains the discrepancy of the LETG dispersion angle between ACIS-S and HRC-S detectors.

The next step is to create a new geometry file with corrected values. Since our analysis provides only the relative detector alignment, it is not certain whether the absolute alignment of either HRC-S or ACIS-S, or both, would need to be adjusted[3].

[3]Note that Drake and Ratzlaff in another document (`http://hea-www.harvard.edu/~jdrake/memo/geomn0004_2/`) find that the geometry alignment of HRC-I are ACIS-I may also be inaccurate (by ≈0.2°). Note that these are the most frequently used detectors for astrometric measurement.

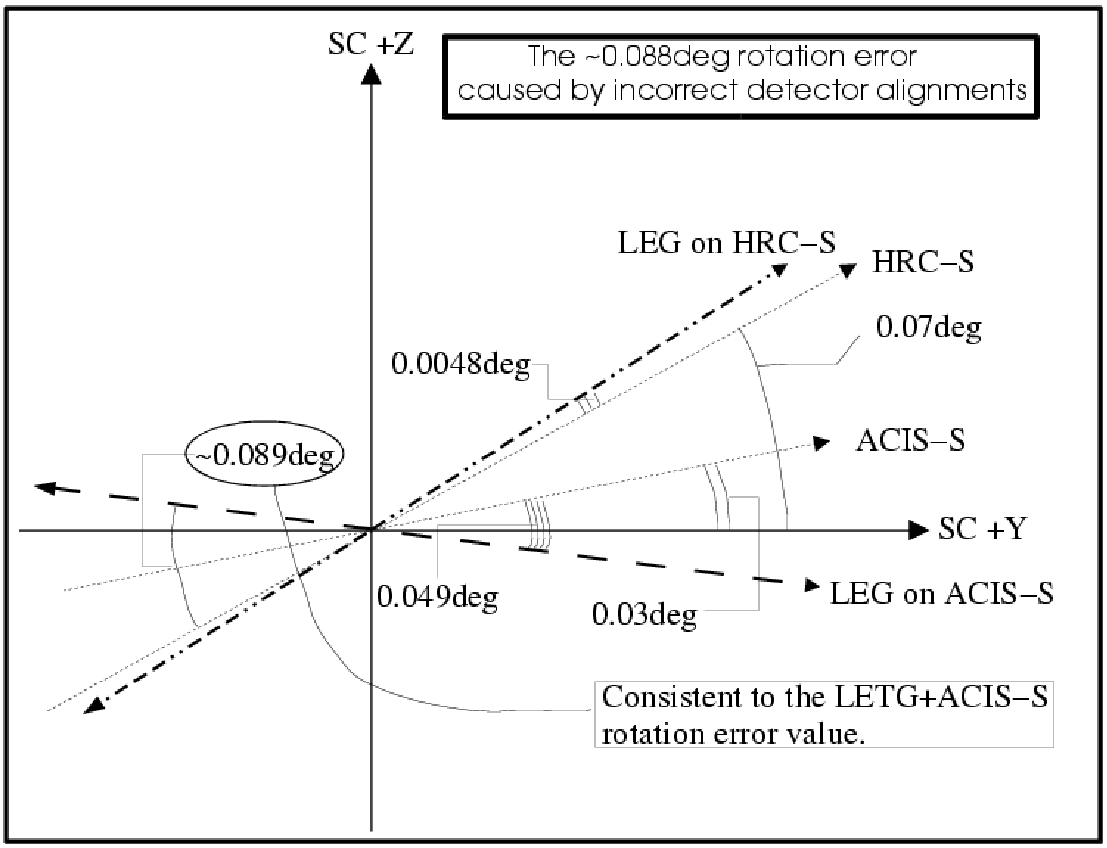

Figure 5: Schematic diagram that accounts for the 0.088° rotation error. The error results from CIAO processing with the inaccurate detector geometry based on the geom N0004 file. Not a software bug.

In order to investigate this geometry issue further, we recommend the following actions to be taken:

- a further review on astrometric property of all detectors by the Cal team (see `http://cxc.harvard.edu/cal/Hrma/optaxis/platescale/geom_public.html` for the type of work needed to be repeated here – if possible – with the accuracy better than $1''$),
- production of a documentation that illustrates clearly how each of astrometric/physical geometry and alignment angle is defined (by the Cal team),
- production of a documentation on Chandra coordinate transformation system (by the SDS team), as there is little useful documentation listed on coordinate transformation at `http://cxc.harvard.edu/ciao/publications.html`.

A review of detector geometry and alignment by the Cal team is the most essential for resolving this issue. In addition, through our analysis we have felt that it would be useful to produce a better documentation on Chandra coordinate transformation system by the SDS team. The existing documents are hard to locate (for e.g., `http://hea-www.harvard.edu/~jcm/asc/docs/ps/ncoords.ps` is found only through `google`, not via CXC search engine) or are too generic to be useful in examining the CALDB geometry data format.