GLAST Tracker Tray Dimensional Tolerance Requirements

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Abstract

The GLAST Tracker contains sixteen towers with each tower containing nineteen tracker trays. Alignment of the towers to each other as well as the rest of the instrument is critical for a couple of reasons. Tracking of gamma rays as they are converted in the individual trays depends upon being able to map the silicon strip detectors positions relative to one another throughout the sixteen towers. Tower lean or twist due to tracker tray stacking can also minimize spacing between finished towers increasing the possibility of contact between towers during launch. The tolerances specified for the tracker trays will define the accuracy of the alignment of the silicon strip detectors to each tracker tray, and the tracker trays to one another in each tower stack-up. Ultimately, the tray tolerances will define the alignment of the tracker towers to each other.

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Revision Log

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-	3/14/2001	Steve Ney	Initial release.

Table of Contents

1. Definitions

GLAST	Gamma-ray Large Area Space Telescope
SRSS	Square Root Sum of the Squares
SSD	Silicon Strip Detector

2. Introduction

Determining direction, speed, and distance traveled of an incoming gamma ray is dependent on accurately tracking its conversion in the tracker towers and trays. The accuracy of the tracking depends upon being able to map the SSD positions relative to one another throughout the sixteen towers. Tower lean or twist due to tracker tray tolerances makes mapping of the SSD positions difficult. Tower lean or twist also minimizes the spacing between finished towers; thus, increasing the possibility of contact between towers and damage to the detectors. The tolerances specified for the tracker trays will define the accuracy of the alignment of the SSDs to each tracker tray, the tracker trays to one another in each tower stack-up, and the alignment of the tracker towers to each other.

The tracker tower coordinate system for the alignment requirements is as shown in figure 1. The tower x-direction is orientated parallel to the bottom tray SSDs. The y-direction is in the plane of the trays and orthogonal to the tower x-direction. The tower z-direction is vertical along the stacking direction for the trays. Yaw is the rotation of a tower around the vertical z-axis. Roll is the rotation of a tower around the x-axis. Pitch is the rotation of a tower around the y-axis.

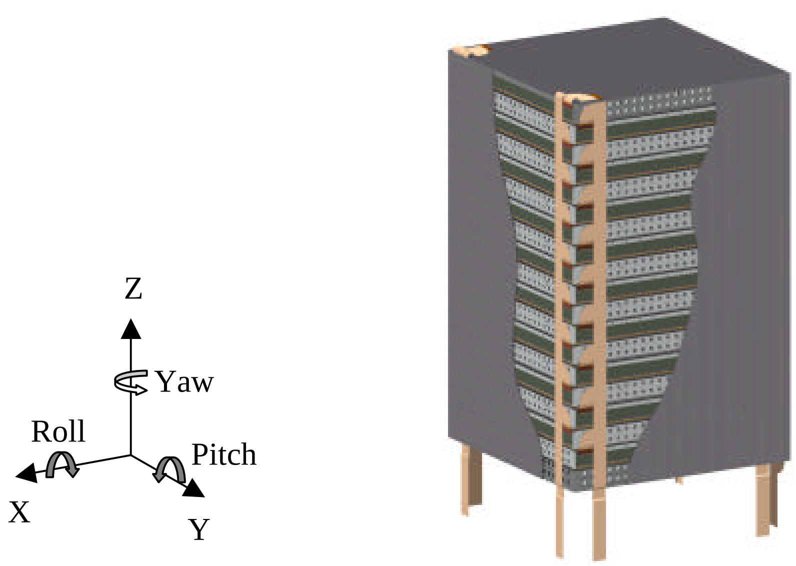

Figure 1. Tracker Tower Coordinate System

The alignment coordinate system for the tracker trays is similar to the tower coordinate system with the x-direction parallel to the SSDs on each tray. The y-direction is in the plane of the tray and orthogonal to the tray x-direction. The z-direction is normal to the tray.

3. Alignment Requirements

Alignment requirements for the GLAST Tracker are broken down into the following three categories: the tower, the tray, and the tray payload. The tolerances on the individual tracker trays control the alignment accuracy of all three categories.

3.1 Tracker Tower Alignment Requirements

The alignment requirements for the tracker tower are based upon the length and the height of the tracker tray as well as the corner post, hole positions.

1. Maximum lean or projection of tower in any lateral direction, (x & y) < or = 150 μm.
2. Maximum height of tower, (z) < or = 626 mm.
    a. Tower height change due to tolerance stack-up, < 1mm.

3.2 Tracker Tray Alignment Requirements

1. The alignment of tray to adjacent tray in the tower stack-up is +/- 25.4 μm.

3.3 Tracker Tray Payload Alignment Requirements

1. The alignment of SSD to tracker tray corner post holes is +/- 25.4 μm.

4. Tolerance Stack-up Analysis

4.1 Tracker Tower Lateral and Vertical Displacements due to Tolerance Stack-up

The analysis for the tolerance stack-up on one tower was done considering a maximum tolerance condition and using Square Root of the Sum of the Squares (SRSS) method to average the tolerance build up. Since not all of the trays in a tower will normally be at a maximum tolerance condition, an average tolerance stack-up was deemed more appropriate.

Three tolerances affect tray-to-tray alignment in a tower and hence the overall tower alignment. They are: projection, profile, and positional. Projection tolerance is the allowable shift in location of a key feature of a part from one side of the part relative to the other. It is used when a mating condition is to be imposed upon a part. For example, drilling holes in the top and bottom of a corner in the closeout frame, the tool may wander slightly during the drilling process. A projection tolerance zone is called out to define how much the hole-feature may vary from top to bottom.

Profile tolerance specifies a uniform boundary along the true profile within which the elements of a part surface must lie. Profile tolerance is used to control the parallelism between two surfaces like the top and bottom edge of the MCM and structural walls. The profile tolerance on the closeout frame walls also controls the overall profile of the closeout frame. Positional tolerance is the total permissible variation in the location of a key feature about its exact true position. The positional tolerance of the corner hole pattern in the closeout frame is critical because it also affects the mating condition between trays.

The affects of these tolerances defined in the previous paragraph are the following:

1. The tray profile tolerance can cause roll or pitch in the tower, thus changing the lateral position of the tower.
2. The tray profile tolerance also affects the vertical height of the tower.
3. Projection and positional tolerances for the tray corner post holes cause lateral shift of each tray relative to its neighboring trays in the tower and thus affects the lateral position of the tower.
4. Projection and positional tolerances also affect yaw rotation around the vertical axis, which can again change the overall lateral position of the tower.

Using SRSS, we see in table 1a that with a profile tolerance of 25.4 μm on the tray profile, a positional tolerance of +/-25.4 μm on the tracker tray corner post holes, and a projection tolerance of +/-12.5 μm on the corner post hole pattern, the tower alignment requirements can be met. The lateral shift in X or Y direction is about 147 μm and the overall vertical height change of a tower due to tolerance build-up is 55 μm. Tables 1b and 1c show the variation in the envelope for selecting positional and profile tolerances for the GLAST tray closeout frame based upon changing the projection tolerance.

Selection of profile, positional, and projection tolerance for individual trays was based on ease of fabrication and cost. As tolerances get smaller, the difficulty in fabrication of a part increases and so does the cost. The largest tray tolerances believed feasible were selected that would meet the alignment requirements for the towers, tray, and the SSDs.

Tracker Tray Tolerances								
Projection (m)			Positional (m)					
1.25e-5			**5.1e-6**	**1.02e-5**	**1.52e-5**	**2.03e-5**	**2.54e-5**	**5.08e-5**
Profile (m)	**1.25e-5**	X	8.56E-5	9.34E-5	1.01E-4	1.10E-4	1.19E-4	1.65E-4
		Y	8.56E-5	9.34E-5	1.01E-4	1.10E-4	1.19E-4	1.65E-4
		Z	2.77E-4	2.77E-4	2.77E-4	2.77E-4	2.77E-4	2.77E-4
	2.54e-5	X	1.22E-5	1.27E-4	1.33E-4	1.40E-4	1.47E-4	1.86E-4
		Y	1.22E-5	1.27E-4	1.33E-4	1.40E-4	1.47E-4	1.86E-4
		Z	5.53E-5	5.53E-5	5.53E-5	5.53E-5	5.53E-5	5.53E-5

	3.81e-5	X	1.65E-4	1.70E-4	1.74E-4	1.79E-4	1.85E-4	2.17E-4
		Y	1.65E-4	1.70E-4	1.74E-4	1.79E-4	1.85E-4	2.17E-4
		Z	8.30E-5	8.30E-5	8.30E-5	8.30E-5	8.30E-5	8.30E-5
	5.08e-5	X	2.12E-4	2.15E-4	2.19E-4	2.23E-4	2.27E-4	2.54E-4
		Y	2.12E-4	2.15E-4	2.19E-4	2.23E-4	2.27E-4	2.54E-4
		Z	1.11E-4	1.11E-4	1.11E-4	1.11E-4	1.11E-4	1.11E-4

Table 1a. Tower Response (X, Y, & Z) Due to Tracker Tray Projection Tolerances of 1.25e-5 m. (Positional & Profile varied)

Tracker Tray Tolerances								
Projection (m)			Positional (m)					
0.0 (Perfect)			**5.1e-6**	**1.02e-5**	**1.52e-5**	**2.03e-5**	**2.54e-5**	**5.08e-5**
Profile (m)	**1.25e-5**	X	5.41E-05	5.69E-05	6.12E-05	6.69E-05	7.35E-05	1.15E-04
		Y	5.41E-05	5.69E-05	6.12E-05	6.69E-05	7.35E-05	1.15E-04
		Z	2.77E-05	2.77E-05	2.77E-05	2.77E-05	2.77E-05	2.77E-05
	2.54e-5	X	1.02E-04	1.04E-04	1.06E-04	1.09E-04	1.14E-04	1.44E-04
		Y	1.02E-04	1.04E-04	1.06E-04	1.09E-04	1.14E-04	1.44E-04
		Z	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05
	3.81e-5	X	1.51E-04	1.52E-04	1.54E-04	1.56E-04	1.59E-04	1.82E-04
		Y	1.51E-04	1.52E-04	1.54E-04	1.56E-04	1.59E-04	1.82E-04
		Z	8.30E-05	8.30E-05	8.30E-05	8.30E-05	8.30E-05	8.30E-05
	5.08e-5	X	2.01E-04	2.02E-04	2.03E-04	2.05E-04	2.07E-04	2.25E-04
		Y	2.01E-04	2.02E-04	2.03E-04	2.05E-04	2.07E-04	2.25E-04
		Z	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04

Table 1b. Tower Response (X, Y, & Z) Due to Tracker Tray Projection Tolerances of 0 m. (Positional & Profile varied)

Tracker Tray Tolerances								
Projection (m)			Positional (m)					
2.54e-5			**5.1e-6**	**1.02e-5**	**1.52e-5**	**2.03e-5**	**2.54e-5**	**5.08e-5**
Profile (m)	**1.25e-5**	X	1.36E-04	1.45E-04	1.54E-04	1.63E-04	1.72E-04	2.20E-04
		Y	1.36E-04	1.45E-04	1.54E-04	1.63E-04	1.72E-04	2.20E-04
		Z	2.77E-05	2.77E-05	2.77E-05	2.77E-05	2.77E-05	2.77E-05
	2.54e-5	X	1.61E-04	1.69E-04	1.77E-04	1.85E-04	1.93E-04	2.37E-04
		Y	1.61E-04	1.69E-04	1.77E-04	1.85E-04	1.93E-04	2.37E-04
		Z	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05	5.53E-05
	3.81e-5	X	1.96E-04	2.03E-04	2.09E-04	2.16E-04	2.23E-04	2.62E-04
		Y	1.96E-04	2.03E-04	2.09E-04	2.16E-04	2.23E-04	2.62E-04
		Z	8.30E-05	8.30E-05	8.30E-05	8.30E-05	8.30E-05	8.30E-05
	5.08e-5	X	2.37E-04	2.42E-04	2.47E-04	2.53E-04	2.59E-04	2.93E-04
		Y	2.37E-04	2.42E-04	2.47E-04	2.53E-04	2.59E-04	2.93E-04
		Z	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04

Table 1c. Tower Response (X, Y, & Z) Due to Tracker Tray Projection Tolerances of 2.54e-5 m. (Positional & Profile varied)

4.2 Tracker Tower Yaw Displacement due to Tolerance Stack-up

The twist or yaw rotation around the tower z-axis for any one tower must be such that no part of the tower extends past the lateral tolerance requirement for the tower of 150 μm. SRSS was used again to determine the maximum average yaw rotation.

Table 2 shows that for a given yaw rotation of 0.0141^{o}, the maximum lateral displacement due to yaw is 22.4 μm. This maximum displacement for yaw was included in the calculation of total lateral displacements for the tower shown in Table 1. The total tower yaw rotation is based upon nineteen trays having the maximum yaw rotation between each tray. This case is only possible if the corner post holes are skewed by some angle from one side of the tray to the other. This skew is controlled by the projection tolerance. If the projection tolerance were zero, the total tower yaw rotation would be equal to the yaw rotation associated with the maximum positional tolerance difference between any two trays in the nineteen-tray tower. The conservative case of assuming a projection tolerance was considered for tolerance analysis continuity.

Tracker Tray Yaw Tolerance		
Total Tray Yaw Rotation (Degrees)	Tray X Displacement (m)	Tray Y Displacement (m)
1.41E-02	2.24E-05	2.24E-05

Table 2. Tracker Tray Yaw Displacement

5. Tracker Tower Component Tolerance Stack-up

Up to this point, only tolerances in the GLAST tray closeout frame have been considered for effecting tower alignment. There are several other components that comprise the assembly of a fully flight ready tower including sidewalls, MCM boards, cabling, and SSD payload. Each of these tower components has a set of tolerances associated with their assembly. Fortunately, most of those tolerances do not have a direct impact on tower alignment. However, the mounting of the sidewalls onto a full 19-tray stack could affect tower alignment, and so the tolerances associated with them must be addressed.

Because of the build up in tolerances in the tray closeout frames, a mismatch of 0.25 mm might occur in the x-z or y-z planes of the tower between the attachment-inserts in the closeout frames and the insert hole pattern in the sidewall. A small aluminum fixture was built to test how much misalignment between the sidewall inset holes and the threaded inserts in the closeout walls could be tolerated without degradations to either one. Figure 5.1 shows the fixture with fasteners inserted.

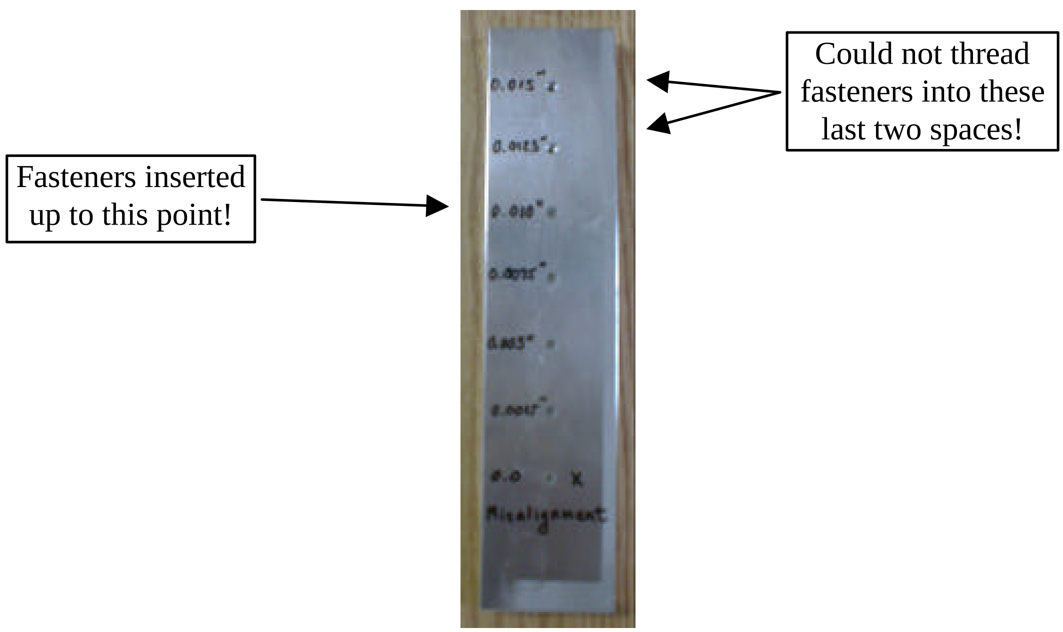

Figure 5.1 Misalignment Test Fixture.

The test showed that the maximum difference that could exist between the two patterns and still be able to install a fastener is 0.010 inches. The torque needed to drive the fastener completely in for the 0.010 inch misalignment however, exceeds the manufacturer's recommended torque specifications, and there was visible thread damage occurring in the fastener. This misalignment was deemed unacceptable. A misalignment of 0.0075 inches was therefore considered the largest acceptable misalignment. When the positional tolerance for the insert hole pattern is added to the stack up tolerances in stacking 19 trays, this misalignment exceeds the acceptable misalignment. Additional clearance of 0.010 inches was added to the diameter of the through hole in the sidewall inserts to insure that damage similar to what was seen in the misalignment test would not occur.

6. Conclusions

Based upon the tolerance stack-up analysis, a tray profile tolerance of 25.4 μm along with a positional tolerance of +/- 25.4 μm and a projection tolerance of 12.5 μm on the tray corner post holes would provide the necessary alignment of the trays in the tracker tower to meet all the alignment requirements for the SSDs, tray, and tower. The largest tolerances for the tray were chosen to keep cost down and make fabrication easier.

7. References

1. Spyrakos, C., *Finite Element Modeling in Engineering Practice*, West Virginia University Press, 1994.