

**LAT-TD-08509-01**

**14 September 2006**

# **LAT Internal Features Survey Report**

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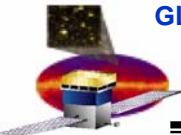


# Revision Information and Supporting Documents

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- **Revision History**
  - **Rev 01:**
    - **25 Aug 2006:** initial revision started by splitting up LAT-TD-07690 “LAT Final Survey Results,” and moving all non-interface and internal risk-mitigation surveying results to this document
  
- **Supporting Documents**
  - LAT-DS-00851, “TKR-LAT Interface Definition Drawing”
  - LAT-MD-00895, “LAT Survey Plan”
  - LAT-MD-03566, “Tracker Tower Assembly and Alignment Plan”
  - LAT-MD-01196, “LAT Dynamics Test Plan”
  - LAT-DS-01221, “Radiator Interface Definition Drawing
  - LAT-DS-00040, “LAT Envelope Drawing”
  
- **Other documents containing survey results**
  - LAT-TD-06368, “Grid Survey Analysis Report”
  - LAT-TD-07690, “LAT Interface Survey Analysis Report”

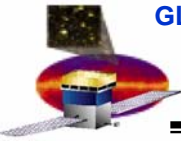
All dimensions in millimeters (mm) unless expressly shown otherwise



# Outline

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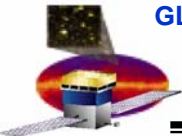
1. Introduction
2. Tracker Tower Locations
  - Tolerance budgeting
  - Grid survey results
  - Tracker inspection results
  - Tracker survey results on the LAT
3. E-Box and EMI Skirt Flatness/Step Height
  - Tolerance budgeting
  - E-Box third layer height
  - Thermal Shunt height and steps to neighboring boxes
  - Step to EMI Shield around perimeter
4. Heat Pipe Alignment
  - Downspout heat pipes (DSHP's)
  - X-LAT heat pipes (XLHP's)
  - Variable-conductance heat pipes (VCHP's)



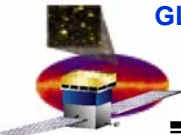
## Introduction

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- This serves to document the results of those parts of the LAT survey program that were used for mitigating risks during LAT integration
  - **Note that these dimensions and features were not for interface compliance purposes**
- For a number of the surveys, a detailed discussion is included to provide the context for the survey, a summary of the analysis that was performed to develop dimensional requirements, and a description of the post-processing analysis
  - **In all cases, the description and discussion is concluded with a concise conclusion statement regarding the disposition of the items surveyed**



## 2. Tracker Tower Locations



## Tolerance Budgeting

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- Ensuring that there are adequate gaps between TKR modules has been a concern for a very long time
- Many things influence the size of the gap and the required minimum, including
  - Nominal dimensions and tolerances of the parts and assemblies
  - Expected relative motions of the sub-assemblies due to a variety of external influences: acoustic, accelerations, and differential expansion
  - Tolerances and precision of the assembly and inspection processes
- To simplify the development process, these factors were parsed out between the TKR and Mechanical subsystems
  - TKR-controlled influences on the TKR-TKR gap
    - Nominal module size—the nominal size increased well after the gap had been set, so tolerances had to be held tighter
    - Tolerances on module dimensions—due to a stack-up of tray and sidewall tolerances
    - Tolerances on placement of the module with respect to its interfaces—eccentric cones were used at the interface to significantly reduce these tolerances
    - Dynamic deflection—a result of the stiffness of the module and the input acoustic loads
    - Static deflection—due to hysteresis of the bolted joint
  - Mechanical Systems-controlled influences on the TKR-TKR gap
    - Grid manufacturing—tolerances of TKR interface holes in the Grid
    - Grid sag—due to launch accelerations, that cause TKR's to tip and the gap to close
    - Grid thermal contraction—due to changes in temperature

# Gap Impingement Allocation

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- The factors affecting the gap were further divided by functional discipline
  - **Motion**
    - The overall dynamic response of the LAT affects the gap closure between TKR modules
    - Part of this response is the response of TKR modules
    - The TKR subsystem structural design and dynamic test response was integrated into the overall LAT structural design
    - Early predictions of relative motions between TKR modules were used to generate the gap-impingement allocation for motion
    - Deflections were handled by specifying minimum natural frequencies
    - These predictions are now being verified by TKR subsystem and LAT static and dynamic testing
    - See LAT-MD-01196, “LAT Dynamics Test Plan” for a description of LAT dynamics testing
  - **Position**
    - Tolerances of size and form both within the TKR subsystem and in the Grid affect the gap closure between TKR modules
    - All these dimensions and tolerances were folded into LAT-DS-00851, the TKR-LAT IDD

# Factors Affecting Impingement on the TKR-TKR Gap

- TKR and Grid fabrication and assembly tolerances were developed with an eye toward how they impacted the gap width

- **TKR stayclear**

- **Top of TKR module: 372.5**
- **Bottom of TKR module: 373.5**

- **Pitch between towers: 374.5**

- **Half-gap allocation**

- **At top: 1.0 mm available**
  - **0.635 position + 0.365 motion**
- **At bottom: 0.5 mm available**
  - **0.288 position + 0.212 motion**

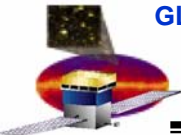
TKR Lateral Fit Inside its Stayclear	Sides	Washers	Top
Nominal tray width	368.500	368.500	368.500
Max Sidewall thickness (incl 0.050 thk alum foil)	1.625	1.625	1.625
Max paint thickness	0.025		
Washer + epoxy thk / single layer EMI tape on top		0.655	0.089
Estimate flatness tolerance of tower side	0.280	0.000	0.280
<b>Tower max width</b>	<b>372.360</b>	<b>373.060</b>	<b>372.488</b>
<b>Tower stayclear width (LAT-DS-00851)</b>	<b>372.500</b>	<b>373.500</b>	<b>372.500</b>
<b>Pitch between TKR towers</b>	<b>374.500</b>	<b>374.500</b>	<b>374.500</b>
<b>Nominal half-gap between stay-clears</b>	<b>1.000</b>	<b>0.500</b>	<b>1.000</b>

Impingement on Gaps Around TKR	Source of Motion		Effect of Source on Impingement (+/- X or +/- Y)					Comments
	+/- Tol's		Lateral at Top		Lateral L/O, MECO		Vertical	
	X/Y	Z	Liftoff	MECO	Bottom	Washers	L/O,MECO	
<b>A. TKR static, acoustic motion wrt nom position</b>			<b>0.266</b>	<b>0.143</b>	<b>0.126</b>	<b>0.126</b>	<b>0.075</b>	
Module acoustic motion (module top, half-peak)	0.123	0.000	0.123	0.000	0.076	0.076	0.000	Predicted from analysis
Static hysteresis based on B.T. static test (half-peak)	0.050	0.025	0.143	0.143	0.050	0.050	0.075	Expected max set of module
<b>B. TKR alignment accuracy and measure precision</b>			<b>0.188</b>	<b>0.188</b>	<b>0.040</b>	<b>0.040</b>	<b>0.120</b>	
Alignment accuracy of eccentrics	0.015	0.015	0.071	0.071	0.015	0.015	0.045	Based on TKR tests
Alignment measurement precision	0.025	0.025	0.118	0.118	0.025	0.025	0.075	CMM precision
<b>C. Grid tolerances</b>			<b>0.366</b>	<b>0.366</b>	<b>0.181</b>	<b>0.181</b>	<b>0.150</b>	
Grid bay datum pins wrt neighboring bay	0.075		0.075	0.075	0.075	0.075		True position to 0.15
Grid stud hole positions wrt bay datum pins	0.075	0.050	0.106	0.106	0.106	0.106	0.150	Mach errors in Grid holes
TKR tipping at top due to Grid hole angle wrt Grid			0.185	0.185				Due to Grid corner hole Z-tol
<b>D. CLA, Thermal dynamic motion wrt nom position</b>			<b>0.019</b>	<b>0.264</b>	<b>0.019</b>	<b>0.019</b>	<b>1.369</b>	
TKR module top swing due to tip from Grid sag				0.245			0.500	
Bay-to-bay motion due to 5 degC dTemp at launch	0.019	0.024	0.019	0.019	0.019	0.019	0.024	Launch vs ass'y temp
ACD vertical drumhead motion relative to base		0.845					0.845	
<b>E. Total impingement on half-gap (simple sum)</b>			<b>0.839</b>	<b>0.961</b>	<b>0.366</b>	<b>0.366</b>	<b>1.714</b>	
<b>F. Nom half-gap between stay-clears</b>			<b>1.000</b>	<b>1.000</b>	<b>1.000</b>	<b>0.500</b>	<b>7.400</b>	
<b>G. Margin on integrated TKR-TKR half-gap</b>			<b>0.161</b>	<b>0.039</b>	<b>0.634</b>	<b>0.134</b>	<b>5.686</b>	

**Max allowed position tolerance of TKR Stayclear on Grid (B+C+margin/2)**

**0.635    0.574    0.538    0.288**

Source: "Tolerances—2005-06-23" spreadsheet



# Verification Strategy

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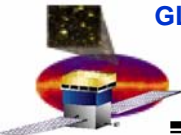
- **Position tolerance verification was done using the TKR stayclear volume as the fundamental interface**
  - **TKR stayclear**
    - As long as a TKR module stays within its stayclear not-to-exceed size, then it is acceptable for use in any Grid bay
  - **Grid tolerances**
    - As long as the TKR interface holes for a given bay can position a TKR stayclear volume within its half-gap position tolerances, then the holes are acceptable, and any TKR module can be integrated into that bay



## Measuring the Hardware to Determine if Factors are Controlled

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- The LAT survey program details the process by which the manufacturing- and interface-related factors are measured to ensure that they are within the allowed limits
- There are three steps to this
  - **Surveying the Grid (LAT-MD-00895, “LAT Survey Plan”)**
    - A Grid Coordinate System (GCS) was established to define the center of the Grid
    - The LAT Coordinate System (LCS) is orthogonal to the GCS, with a simple Z-offset up to the top flange of the Grid
    - All TKR interface holes were inspected
    - These as-built hole locations were used to define 16 Bay Coordinate Systems (BCS)
    - A BCS is nominally located at the center of a bay, orthogonal to the GCS, but errors in hole positioning result in offsets and tilting of the BCS, which in turn impact TKR positioning
  - **Surveying and aligning the TKR tower (LAT-MD-03566, “Tracker Tower Assembly and Alignment Plan”)**
    - The TKR towers are inspected by CMM in Pisa after they are constructed
    - Based on the actual size of the tower, a Tower Coordinate System (TCS) is constructed for each
    - The TCS defines the ideal center/orientation of the actual tower, to minimize its footprint
      - This corrects for any individual feature out-of-tolerance conditions
      - The TCS accommodates and adjusts for any systematic mis-shaping of the tower, including racking, bowing, and twisting
    - Finally, with the ideal center defined, the eccentric cones are used to place the TKR interface holes in their correct location with respect to the tower ideal center (the TCS origin)
  - **Surveying TKR’s on the LAT (LAT-MD-00895, “LAT Survey Plan”)**
    - Finally the TKR’s are surveyed in their final location on the LAT
    - The location of the TKR TCS is established with respect to the LCS
    - The offset of the TCS is then compared to the allowed position tolerance to determine if the module is integrated within tolerance



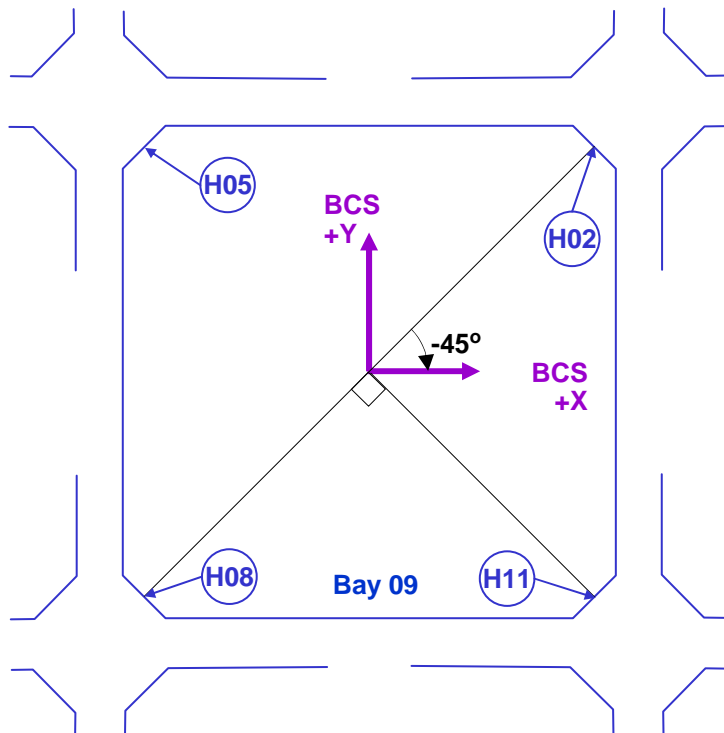
## Grid Survey Results

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- LAT-TD-06368, “Grid Survey Analysis Report” provides a complete description of the surveying and analysis of Grid dimensional inspection data—including TKR interfaces, Spacecraft interfaces, and Grid features
- The following is a precis of the report as related to the TKR interface
  
- TKR interface holes on the Grid
  - Each TKR is mounted at 16 points around a bay of the Grid
  - Of these 16 locations, only 3 of the 4 corner locations are used for positioning the TKR
  - The holes on the Grid were toleranced such that even with a systematic offset of all holes to the maximum of the tolerance, the Grid could still be used
- TKR interface hole inspection results
  - 49 out of 64 corner holes in the Grid are out of tolerance
  - 9 out of 64 corner holes are out of their planarity tolerance
- However, what matters is not the individual hole location, but the location and attitude of the BCS as defined by the 3 corner holes. A few predictions:
  - If the hole errors were random, then the BCS origin should still be close to nominal, even though the individual holes are out of tolerance
  - Given the machining set-up, the holes should all be close to parallel to the Grid LCS, which means that the BCS Z-axis should not be tipped much; if all 3 corner holes in a given bay are parallel to the GCS, their average height is less important
  
- Next step: define the as-built BCS for each bay, using actual hole locations...

# Bay Coordinate System Locations

- **BCS origin**
  - The table shows that all but 2 of the 16 BCS origins are within their allowable tolerance
  - This shows that machining errors were, indeed, random
- **BCS orientation**
  - There is very little tip whatsoever in the BCS Z-axis



**Grid Bay Coordinate System Offsets**

	BCS Ctr Delta off Nom			Angle to Grid Norm	H08-H02 Angle off 45
	dXc (mm)	dYc (mm)	dZc (mm)	dRR (deg)	dRZ (deg)
Bay 00	0.107	0.115	0.026	0.009	-0.001
Bay 01	0.124	0.071	0.002	0.002	0.009
Bay 02	0.024	-0.016	0.042	0.012	0.007
Bay 03	0.016	0.006	-0.005	0.007	0.002
Bay 04	0.037	0.047	0.025	0.011	-0.002
Bay 05	0.008	0.021	-0.032	0.009	-0.002
Bay 06	0.032	0.018	0.002	0.005	0.002
Bay 07	0.040	0.035	-0.021	0.008	0.001
Bay 08	0.108	0.034	0.032	0.026	0.013
Bay 09	0.064	0.023	0.027	0.012	0.007
Bay 10	0.091	0.045	-0.011	0.004	0.008
Bay 11	0.064	0.013	-0.006	0.002	0.009
Bay 12	0.096	0.020	0.009	0.016	0.013
Bay 13	0.085	0.034	0.006	0.018	0.009
Bay 14	0.089	0.033	0.001	0.019	0.010
Bay 15	0.079	0.023	-0.032	0.013	0.010
<b>Max:</b>	0.124	0.115	0.042	0.026	0.013
<b>Tol:</b>	0.114	0.114	0.051	0.603	

Source: "LATSurveyDataR5--2005-04-02Survey.xls"

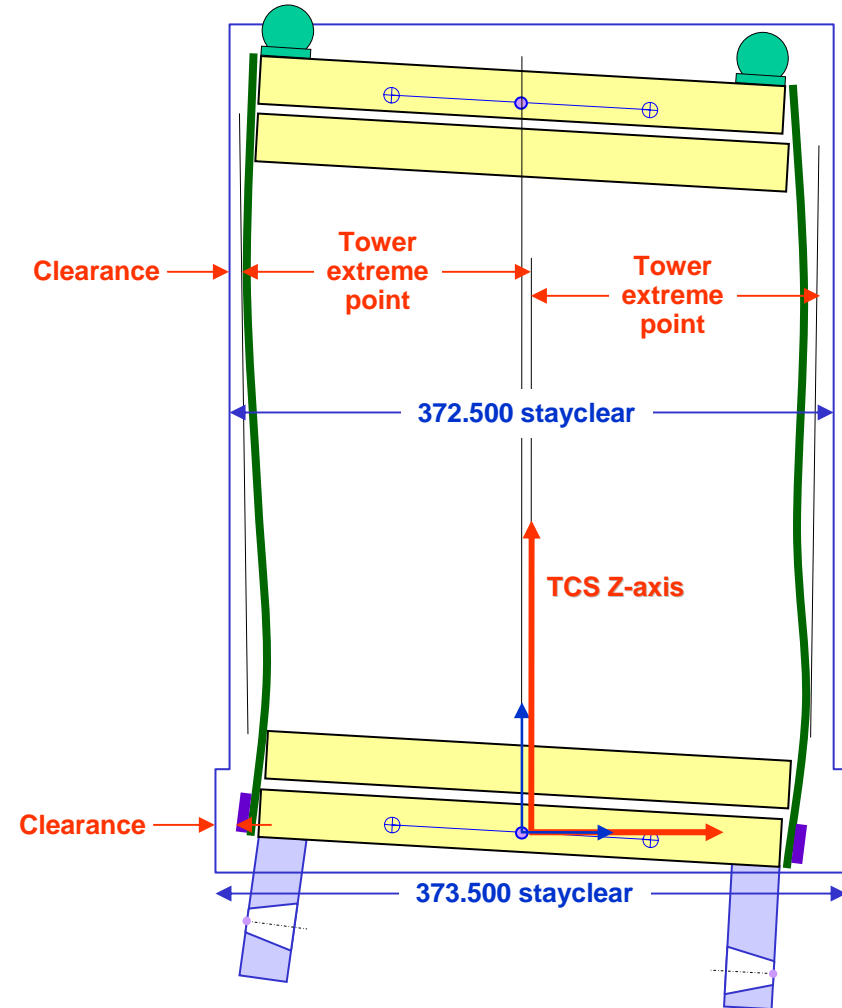
## Grid Inspection Conclusions

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- All Grid bays have BCS origins and orientations that are acceptable
- TKR modules that are within their stayclears may be integrated into any Grid bay, and will stay within their allowed positions
- The TKR-TKR gap allowance will be preserved with the as-built Grid
- **Use the Grid as-is**

# Tracker Inspection Results

- A Tower Coordinate System (TCS) is defined for each TKR tower
  - This is defined to produce the minimum footprint—or shadow—of the tower
  - The clearance is the difference between the footprint as defined by the tower extreme point and the stayclear
  - $\text{Clearance} = \text{half-stayclear} - \text{extreme point}$
  - Any clearance  $> 0$  means that the TKR tower is within its stayclear
- Results of inspection of TKR-A through TKR-15
  - Min clearance on sidewall: 0.146
    - This translates to a min clearance at the EMI tape of 0.07
  - Min clearance at washer: 0.078



# Tracker Tower Inspection Details

- Sidewall inspection data shows that TKR assembly is done to very tight tolerances
- All TKR modules fit within their stayclears and most are coming in only slightly larger than nominal

## TKR Max Tower Dimensions in Tower Coord System

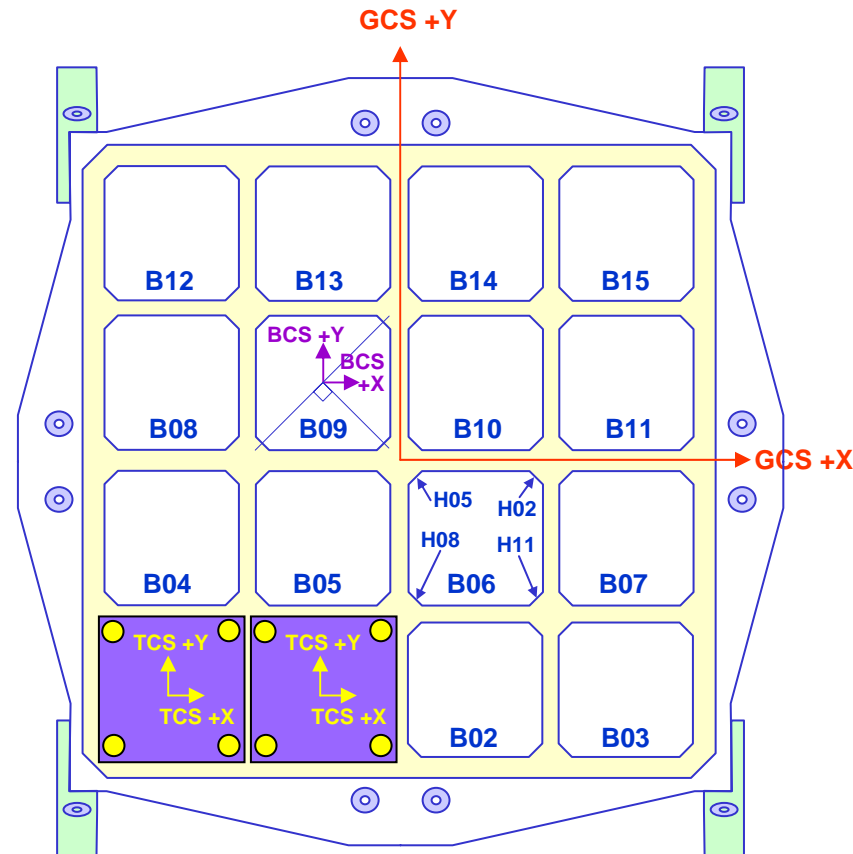
Print Date: 19-Dec-05

Copy of TKR EIDP report data showing location of extreme point on each Sidewall and washer set, in TCS

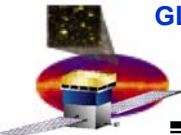
S/N	Sidewall Extreme Point				Bottom Washer Extreme Point			
	+X Wall	+Y Wall	-X Wall	-Y Wall	+X Washer	+Y Washer	-X Washer	-Y Washer
TKR-A	186.028	186.029	-186.041	-185.953	186.583	<b>186.672</b>	-186.568	-186.495
TKR-B	186.000	186.020	<b>-186.094</b>	-186.004	<b>186.641</b>	186.457	-186.531	-186.495
TKR-1	185.963	<b>186.091</b>	-186.001	-185.977	186.453	186.492	-186.408	-186.502
TKR-2	185.923	185.904	-186.008	-185.892	186.456	186.398	-186.430	-186.499
TKR-3	185.939	185.967	-185.937	-185.984	186.443	186.602	-186.356	-186.407
TKR-4	185.962	186.074	-185.955	-185.966	186.465	186.471	-186.419	-186.341
TKR-5	185.910	186.038	-186.076	-185.962	186.398	186.440	-186.446	-186.466
TKR-6	185.994	185.951	-185.929	-185.921	186.489	186.346	-186.319	-186.471
TKR-7	185.897	185.919	-185.997	<b>-186.014</b>	186.400	186.464	-186.430	-186.428
TKR-8	185.935	186.004	-186.000	-185.970	186.439	186.459	-186.381	-186.426
TKR-9	185.998	185.916	-185.964	-185.973	186.383	186.386	-186.507	-186.397
TKR-10	<b>186.104</b>	186.025	-185.918	-185.954	186.417	186.334	-186.334	-186.413
TKR-11	185.950	185.963	-185.968	-185.940	186.434	186.399	-186.410	-186.391
TKR-12	185.933	185.915	-185.978	-185.900	186.482	186.384	-186.356	-186.397
TKR-13	185.914	185.984	-185.975	-185.942	186.386	186.366	-186.379	<b>-186.565</b>
TKR-14	186.002	185.947	-185.940	-185.936	186.381	186.400	<b>-186.580</b>	-186.444
TKR-15	185.879	185.961	-185.915	-185.892	186.350	186.400	-186.282	-186.381
Average	185.961	185.983	-185.982	-185.952	186.447	186.439	-186.420	-186.442
St Dev	0.056	0.057	0.052	0.036	0.074	0.088	0.085	0.057
Extreme	186.104	186.091	-186.094	-186.014	186.641	186.672	-186.580	-186.565
Clearance	<b>0.146</b>	0.159	0.156	0.236	0.109	<b>0.078</b>	0.170	0.185
Nom	185.875	185.875	-185.875	-185.875	186.530	186.530	-186.530	-186.530
Stayclear	186.250	186.250	-186.250	-186.250	186.750	186.750	-186.750	-186.750

# LAT Survey Data Processing

- The third step is to integrate the TKR's on the Grid, and survey the as-installed location
  - Here, we could use shims to check for a minimum gap between neighboring modules
  - However, this provides little insight into the nature of a problem, since the source of a problem would be a combination of multiple tolerances from two towers and Grid bays
- The actual geometry of both the TKR and Grid are complex, so we stay with evaluating the location of the TKR stayclear to simplify the data processing (this is conservative)
- Steps in post-processing TKR survey data on the LAT
  - From TKR EIDP, pull TKR retro-reflector ball locations on the top of the TKR, with respect to the TKR TCS
  - From LAT survey data, pull TKR retro-reflector ball locations with respect to the LAT LCS
  - With these two sets of related information, the Metrology group finds the translational and rotational offsets of the TKR TCS with respect to the LAT LCS



LAT Top View



## LAT Survey Results

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- Any translation or tipping of the TKR TCS from its nominal location means that the half-gap to neighboring modules is closing on one side and opening on the other
  - Translations of the TCS directly impact the half-gap width
  - Rotations of the TCS produce:
    - Tipping: this significantly impacts the half-gap at the top, since the tower is taller than it is wide
    - Twisting: this produces additional translation at the tower corners
- The combination of the effects of translation and tipping of the TCS are then compared with the allowables (from table on page 5)
 

	Allowed	Measured Max
– Motion of TKR stayclear at top of module:	0.635	0.593
– Motion of TKR stayclear at washers near bottom:	0.288	0.226
- Post-processed survey data on the next page shows that the offsets of the installed TCS' produce tower motions that are within their allowables
  - Minimum margin of any TKR module to its as-installed gap-impingement allocation is 0.042

Source: "TKRTowerSurveyDataR3--2005-06-23.xls"

# TCS Location Details

## Tracker Tower Coordinate System (TCS) Offsets

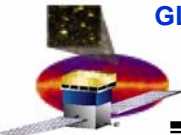
Sheet revised on: 19-Dec-05

Print date: 19-Dec-05

*dimensions in mm and radians*

Bay	TKR S/N	Offset of TCS Origin from Nominal (Actual - Nominal)						Total Offset + Tip + Twist			
								at Top		at Bottom	
		dX	dY	dZ	RX	RY	RZ	dX	dY	dX	dY
B00	TKR-A	-0.067	-0.053	0.049	-0.000365	<b>-0.000702</b>	0.000401	<b>0.593</b>	0.256	0.142	0.128
B01	TKR-2	-0.038	0.020	<b>-0.271</b>	0.000183	-0.000044	0.000262	0.115	0.147	0.086	0.069
B02	TKR-14	-0.118	-0.087	-0.126	-0.000114	0.000229	0.000078	0.044	0.029	0.132	0.102
B03	TKR-15	-0.040	-0.154	-0.022	-0.000096	0.000285	0.000102	0.162	0.111	0.059	0.173
B04	TKR-B	0.023	0.033	-0.143	0.000010	-0.000407	0.000318	0.298	0.086	0.082	0.092
B05	TKR-1	-0.111	-0.083	-0.227	0.000060	-0.000209	-0.000065	0.258	0.134	0.124	0.095
B06	TKR-12	-0.027	-0.064	-0.140	-0.000386	-0.000098	0.000366	0.158	0.253	0.095	0.132
B07	TKR-13	-0.095	0.000	-0.208	0.000016	0.000312	0.000036	0.113	0.017	0.101	0.007
B08	TKR-5	-0.146	-0.057	-0.077	-0.000315	-0.000678	-0.000008	0.583	0.147	0.148	0.058
B09	TKR-3	<b>-0.187</b>	<b>-0.192</b>	-0.136	0.000153	0.000130	0.000180	0.137	0.325	<b>0.221</b>	<b>0.226</b>
B10	TKR-7	-0.018	0.069	-0.095	<b>-0.000669</b>	-0.000253	0.000236	0.225	<b>0.543</b>	0.062	0.113
B11	TKR-9	-0.158	-0.003	-0.071	-0.000336	-0.000145	0.000271	0.302	0.263	0.209	0.054
B12	TKR-6	0.031	0.049	-0.023	-0.000360	-0.000589	0.000342	0.412	0.344	0.094	0.112
B13	TKR-4	0.048	-0.055	-0.047	-0.000411	-0.000395	<b>0.000411</b>	0.282	0.286	0.125	0.131
B14	TKR-10	-0.135	-0.052	-0.170	-0.000645	-0.000469	-0.000088	0.452	0.379	0.151	0.068
B15	TKR-11	-0.041	-0.001	-0.140	-0.000576	-0.000263	0.000367	0.279	0.437	0.110	0.070
<b>Max:</b>		0.048	0.069	0.049	0.000183	0.000312	0.000411	0.593	0.543	0.221	0.226
<b>Min:</b>		-0.187	-0.192	-0.271	-0.000669	-0.000702	-0.000088				
<b>Max allowed total offset:</b>		0.635	0.635	0.288	0.288						
<b>Margin (allowed - actual):</b>		<b>0.042</b>	0.093	0.067	0.062						

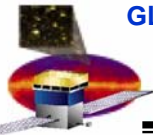
Source: "TKRTowerSurveyDataR3--2005-06-23.xls"



## LAT Survey Details

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- **This analysis is simplified and conservative**
  - **Evaluations are based on the TKR stayclears, not the actual hardware**
    - The degree to which the hardware is within the stayclear constitutes added margin
    - Page 12 shows that the minimum margin of the TKR module extreme dimension within its stayclear is 0.146, which directly adds to the clearance
  - **Evaluations were to the half-gap, meaning that each TKR module TCS must be placed within its allowed location on the Grid, independent of the neighboring modules**
    - Any systematic pattern of Grid hole location errors constitutes added margin
    - If neighboring modules are offset away from a module, the gap will be larger than this worst-case estimate
    - For perimeter bays, any TKR tipping out towards the ACD has 5 mm of added margin, guaranteed, since ACD inside stayclear is 10 mm beyond the TKR stayclear
- **Conclusions:**
  - **TKR modules are all positioned accurately and within their allowed tolerances**
  - **The residual TKR-TKR gap is large enough to ensure no collision during testing and launch**



### **3. E-Box and EMI Skirt Flatness/Step Height**

## Tolerance Budgeting

- The table below shows all tolerances that contribute to the step between neighboring E-Boxes and between an E-Box and the neighboring piece of EMI Shield
  - Tolerances are assumed to stack-up linearly with no statistical averaging
  - Allowable steps:
    - E-Box to E-Box:  $\pm 0.683 \text{ mm} \leftarrow (\pm 0.278 \text{ box ht}) \times (2 \text{ boxes}) + (\pm 0.127 \text{ Grid sag})$
    - E-Box to EMI Shield:  $\pm 0.532 \text{ mm} \leftarrow (\pm 0.278 \text{ box ht}) + (\pm 0.127 \text{ EMI Shield}) + (\pm 0.127 \text{ Grid sag})$
  - Part tolerance allowables came from part and assembly drawings
- The X-LAT Plate and X-LAT Heat Pipes (XLHP's) are designed to accommodate up to a 0.7 mm step at either of these transitions
  - On the  $-Y$  and  $+Y$  sides of the LAT the XLHP's must bend to accommodate this mismatch
  - The heat pipes and their mounts to the X-LAT Plate have been designed and analyzed to handle this bending with no resultant negative stress margins and no impact on the heat transfer across the bolted joint to the E-Boxes

Tolerances from Interface Definition Drawings that Impact X-LAT Position and Interface Fits		
Tolerance Stack-Up Across Key Interfaces	Ht (mm)	Comments
Max E-Box to E-Box step height	0.683	Compared with 0.7 mm allowable
Max EMI Shield to E-Box step height	0.532	Compared with 0.7 mm allowable
<b>EMI Skirt</b>		
Flatness/height tolerance of bottom surface wrt Grid datums	0.127	contributes to step ht to E-Boxes
<b>CAL</b>		
CAL plate thk wrt CAL datum on Grid bay (1/2 of parallel tol)	0.1	contributes to step ht to E-Boxes
Effect of Grid bowing on bay-to-bay height difference	0.127	contributes to step ht to E-Boxes, EMI Shield
<i>EPU/SIU/HIB/GASU/PDU box height tolerance</i>	<i>0.127</i>	
<i>Ht tol of shimmed TPS/TEM/Stand-off wrt CAL base plate</i>	<i>0.051</i>	<i>tolerance on shimming process</i>

## E-Box Third Layer Height and Box-to-Box Steps

- The bottom faces of the special third-layer E-boxes was surveyed and a best-fit plane found
  - Since the PDU and GASU span more than one bay, a best-fit surface was established separately for each bay in which it resides
  - Max (less negative coordinates, or closer to the Grid), and Min (more negative, or farther from the Grid) values were found for each extreme point on each box
    - “max” is equivalent to the least material condition (LMC) of the box
    - “min” is equivalent to the maximum material condition (MMC) of the box
  - The max and min points were compared with the allowables
- **Conclusions:**
  - **All E-box bottom faces and box-to-box steps are within their allowable height ranges**

### Special Box Flatness/Height Measurement

Coordinates with respect to the Grid Coordinate System; dimensions in mm

Rev Date: 13-Apr-06

Print Date: 14-Apr-06

Bay #	Box	Best-Fit Plane Z-Coordinate			Offset from Avg		Tol (+/-)	Not-to-Exceed Z-Coord's			Min Margin	P/F
		Min	Avg	Max	Min	Max		Min	Nom	Max		
Bay00	EPU	-229.250	-229.160	-229.064	-0.090	0.096	0.278	-229.284	-229.006	-228.728	0.034	PASS
Bay01	HIB	-229.171	-229.060	-228.942	-0.111	0.118	0.278	-229.284	-229.006	-228.728	0.113	PASS
Bay02	HIB	-229.090	-229.021	-228.964	-0.069	0.057	0.278	-229.284	-229.006	-228.728	0.194	PASS
Bay03	EPU	-229.058	-229.004	-228.944	-0.054	0.060	0.278	-229.284	-229.006	-228.728	0.216	PASS
Bay04	PDU	-229.201	-229.101	-228.937	-0.100	0.164	0.278	-229.284	-229.006	-228.728	0.083	PASS
Bay05	GASU	-229.020	-228.914	-228.804	-0.106	0.110	0.278	-229.284	-229.006	-228.728	0.076	PASS
Bay06	GASU	-229.107	-229.005	-228.85	-0.102	0.155	0.278	-229.284	-229.006	-228.728	0.122	PASS
Bay07	SIU	-229.098	-229.020	-228.946	-0.078	0.074	0.278	-229.284	-229.006	-228.728	0.186	PASS
Bay08	PDU	-229.171	-229.065	-228.948	-0.106	0.117	0.278	-229.284	-229.006	-228.728	0.113	PASS
Bay09	GASU	-229.074	-228.954	-228.801	-0.120	0.153	0.278	-229.284	-229.006	-228.728	0.073	PASS
Bay10	GASU	-229.094	-228.966	-228.872	-0.128	0.094	0.278	-229.284	-229.006	-228.728	0.144	PASS
Bay11	SIU	-229.090	-229.025	-228.941	-0.065	0.084	0.278	-229.284	-229.006	-228.728	0.194	PASS
Bay12	EPU	-229.120	-228.986	-228.878	-0.134	0.108	0.278	-229.284	-229.006	-228.728	0.150	PASS
Bay13	HIB	-229.102	-228.990	-228.897	-0.112	0.093	0.278	-229.284	-229.006	-228.728	0.169	PASS
Bay14	HIB	-229.142	-229.065	-228.988	-0.077	0.077	0.278	-229.284	-229.006	-228.728	0.142	PASS
Bay15	HIB	-229.146	-229.034	-228.953	-0.112	0.081	0.278	-229.284	-229.006	-228.728	0.138	PASS

## Thermal Shunt Height and Steps to Neighboring Boxes

- The Thermal Shunts were supposed to be fabricated so their covers stick proud of the bottom surface of the E-Boxes. The as-built profile of the E-Boxes would be measured and the Shunt covers machined to match the heights of the neighboring boxes
- It is clear from the survey data that the Thermal Shunts were not made intentionally over-height, with both Shunt heights coming within 0.050 mm of the nominal box height
- Allowable step height
  - The distance to neighboring boxes is larger than the distance from a perimeter box to the EMI Shield, so we will be able to handle at least as large a step to the Thermal Shunt
  - Set the allowable step height at 0.532 mm
- The table below shows maximum step of 0.3 mm, corresponding to a min margin of 0.233 mm
- Conclusion: **Use as-is**

### Special Box Flatness/Height Measurement

Coordinates with respect to the Grid Coordinate System; dimensions in mm

Rev Date: 13-Apr-06

Print Date: 14-Apr-06

Bay #	Box	E-Box Z-Coordinate			Step from Box to Thermal Shunt								
		Min	Avg	Max	Thermal Shunt Z-Coord		Measured Step		Max Step (+/-)	Min Margin	Pass/Fail		
					Min	Avg	Max	Down				Up	
Bay00	EPU	-229.250	-229.160	-229.064	HIB to Bay05/06 -Y Thermal Shunt								
Bay01	HIB	-229.171	-229.060	-228.942	Bay05 -Y Therm Shunt	-229.034	-229.011	-228.987	-0.092	0.184	0.532	0.348	PASS
Bay02	HIB	-229.090	-229.021	-228.964	Bay06 -Y Therm Shunt	-229.094	-229.050	-229.002	-0.130	0.088	0.532	0.402	PASS
Bay03	EPU	-229.058	-229.004	-228.944	GASU to Bay05/06 -Y Thermal Shunt								
Bay04	PDU	-229.201	-229.101	-228.937	Bay05 -Y Therm Shunt	-229.034	-229.011	-228.987	-0.230	0.033	0.532	0.302	PASS
Bay05	GASU	-229.020	-228.914	-228.804	Bay06 -Y Therm Shunt	-229.094	-229.050	-229.002	-0.244	0.105	0.532	0.288	PASS
Bay06	GASU	-229.107	-229.005	-228.85	GASU to Bay09/10 +Y Thermal Shunt								
Bay07	SIU	-229.098	-229.020	-228.946	Bay09 +Y Therm Shunt	-229.100	-229.016	-228.969	-0.299	0.105	0.532	0.233	PASS
Bay08	PDU	-229.171	-229.065	-228.948	Bay10 +Y Therm Shunt	-228.976	-228.956	-228.918	-0.104	0.176	0.532	0.356	PASS
Bay09	GASU	-229.074	-228.954	-228.801	HIB to Bay 09/10 +Y Thermal Shunt								
Bay10	GASU	-229.094	-228.966	-228.872	Bay09 +Y Therm Shunt	-229.100	-229.016	-228.969	-0.203	0.133	0.532	0.329	PASS
Bay11	SIU	-229.090	-229.025	-228.941	Bay10 +Y Therm Shunt	-228.976	-228.956	-228.918	0.012	0.224	0.532	0.308	PASS
Bay12	EPU	-229.120	-228.986	-228.878									
Bay13	HIB	-229.102	-228.990	-228.897									
Bay14	HIB	-229.142	-229.065	-228.988									
Bay15	HIB	-229.146	-229.034	-228.953									

## EMI Shield Height Around Perimeter of LAT

- The bottom face of the EMI Shield was surveyed all around the perimeter of the LAT
- The height of the Shield was calculated for 4 segments on each edge, corresponding to the 4 neighboring bays of the Grid
  - The average, “max”, and “min” heights were calculated for each section
  - Heights were compared with the -229.006 +/- 0.127 dimension off the Grid
- In 14 of 16 segments, the EMI Shield violated its maximum material condition (MMC) limit
  - This is consistent with the integration experience, where the O-rings on the Shield-Grid mount face were difficult to install, and tended to prevent a good seating of the Shield on the Grid

### EMI Shield Perimeter Height off Grid

Rev Date: 13-Apr-06

Coordinates with respect to the Grid Coordinate System; dimensions in mm

Print Date: 14-Apr-06

MMC = max material condition    LMC = least material condition

Bay #	EMI Shield Z-Coordinate			Offset from Avg		Tol (+/-)	Not-to-Exceed Z-Coord's			Margin to NTE Bdy		P/F
	Min	Avg	Max	Min	Max		Min	Nom	Max	at MMC	at LMC	
Bay00-X	-229.338	-229.196	-229.123	-0.142	0.073	0.127	-229.133	-229.006	-228.879	-0.205	0.244	FAIL
Bay04-X	-229.460	-229.315	-229.099	-0.145	0.216	0.127	-229.133	-229.006	-228.879	-0.327	0.220	FAIL
Bay08-X	-229.383	-229.316	-229.223	-0.067	0.093	0.127	-229.133	-229.006	-228.879	-0.250	0.344	FAIL
Bay12-X	-229.430	-229.163	-229.007	-0.267	0.156	0.127	-229.133	-229.006	-228.879	-0.297	0.128	FAIL
Bay00-Y	-229.153	-229.135	-229.108	-0.018	0.027	0.127	-229.133	-229.006	-228.879	-0.020	0.229	FAIL
Bay01-Y	-229.194	-229.112	-229.048	-0.082	0.064	0.127	-229.133	-229.006	-228.879	-0.061	0.169	FAIL
Bay02-Y	-229.114	-229.055	-229.015	-0.059	0.040	0.127	-229.133	-229.006	-228.879	0.019	0.136	PASS
Bay03-Y	-229.097	-229.056	-229.026	-0.041	0.030	0.127	-229.133	-229.006	-228.879	0.036	0.147	PASS
Bay12+Y	-229.240	-229.209	-229.167	-0.031	0.042	0.127	-229.133	-229.006	-228.879	-0.107	0.288	FAIL
Bay13+Y	-229.389	-229.318	-229.186	-0.071	0.132	0.127	-229.133	-229.006	-228.879	-0.256	0.307	FAIL
Bay14+Y	-229.281	-229.237	-229.191	-0.044	0.046	0.127	-229.133	-229.006	-228.879	-0.148	0.312	FAIL
Bay15+Y	-229.282	-229.248	-229.227	-0.034	0.021	0.127	-229.133	-229.006	-228.879	-0.149	0.348	FAIL
Bay03+X	-229.261	-229.075	-228.989	-0.186	0.086	0.127	-229.133	-229.006	-228.879	-0.128	0.110	FAIL
Bay07+X	-229.300	-229.203	-229.111	-0.097	0.092	0.127	-229.133	-229.006	-228.879	-0.167	0.232	FAIL
Bay11+X	-229.410	-229.340	-229.293	-0.070	0.047	0.127	-229.133	-229.006	-228.879	-0.277	0.414	FAIL
Bay15+X	-229.267	-229.178	-229.052	-0.089	0.126	0.127	-229.133	-229.006	-228.879	-0.134	0.173	FAIL

## E-Box to EMI Shield Step Height

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- The height limits on the EMI Shield were established to ensure that the step between the Shield and the neighboring E-Box stayed within the allowable limit, to prevent over-stressing of the X-LAT Plate, and particularly the X-LAT Heat Pipes.
  - The max allowed step between an E-Box and its neighboring Shield is +/- 0.532 mm
- Since the EMI Shield exceeded its allowable limits, calculate the step height between E-Box and Shield for all 16 locations to determine if the allowable is exceeded
  - If the step height is within allowable limits, the EMI Shield can be used as-is, even though its height is out of tolerance
  - The table on the previous chart shows that without exception, the Shield exceeded its MMC limit, so the step height need only be calculated using the LMC limit (“max” dimension) of the box, with the MMC limit (“min” dimension) of the Shield

# E-Box to EMI Shield Step Height Evaluation

- The mapping below shows
  - E-Box LMC height in pink (repeated from an earlier chart)
  - EMI Shield MMC height in orange
  - The difference between the two in yellow, which is the maximum possible step
- Results
  - The step is smaller on the two Y-sides, which is where the X-LAT Heat Pipes bridge across and bend. This is a good, since it keeps bending stresses in the XLHP's down
  - The step/gap on the X-sides is larger, but we can handle that since only the relatively thin X-LAT Plate must absorb this step in bending
  - The out-of-tolerance condition in Bay 12, -X side can be accommodated, since only the thin X-LAT sheet metal needs to bend over this step
- Conclusion: **Use as-is**

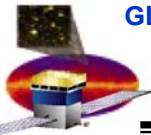
EMI Shield-to-E-Box Step Height										Rev Date: 13-Apr-06					
Coordinates with respect to the Grid Coordinate System; dimensions in mm										Print Date: 14-Apr-06					
Max allowed step from E-Box to EMI Shield =		0.53200													
= E-Box LMC Height															
= EMI Shield MMC Height															
= Difference (max step height)															
<b>+Y</b>															
		Bay15+Y				Bay14+Y				Bay13+Y				Bay12+Y	
		PASS				PASS				PASS				PASS	
		0.329				0.293				0.492				0.362	
		-229.282				-229.281				-229.389				-229.240	
<b>+X</b>	Bay15+X	PASS	0.314	-229.267	-228.953	-228.988	-228.897	-228.878	-229.430	0.552	<b>FAIL</b>	Bay12-X	<b>-X</b>		
	Bay11+X	PASS	0.469	-229.410	-228.941		-228.948	-229.383	0.435	PASS	Bay08-X				
	Bay07+X	PASS	0.354	-229.300	-228.946		-228.937	-229.460	0.523	PASS	Bay04-X				
	Bay03+X	PASS	0.317	-229.261	-228.944	-228.964	-228.942	-229.064	-229.338	0.274	PASS	Bay00-X			
		-229.097				-229.114				-229.194				-229.153	
		0.153				0.150				0.252				0.089	
		PASS				PASS				PASS				PASS	
		Bay03-Y				Bay02-Y				Bay01-Y				Bay00-Y	
<b>-Y</b>															

The logo for the GLAST LAT Project, featuring a stylized satellite or probe with a blue and white body and a red and yellow circular element, set against a dark background with a star.

## E-Box and EMI Shield Height Survey Conclusions

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- **E-Box heights**
  - All heights are within allowable tolerances
  - Conclusion: **OK**
- **Thermal Shunts**
  - Shunts were not machined as required
  - As-built Shunts produce a step to neighboring boxes that is within allowable limits
  - Conclusion: **use as-is**
- **EMI Shield**
  - Shield height was out of tolerance towards the maximum material condition on 14 of 16 segments of shield
  - However, the resulting step height to neighboring E-Boxes was still within allowable limits
  - Conclusion: **use as-is**
- **Conclusions**
  - The X-LAT Plate may be installed, and will perform as required, with no degradation of margin to its structural or thermal performance



## 4. Heat Pipe Alignment

## Motivation for Checking Heat Pipe Alignment

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- The LAT contains 4 sets of heat pipes, all of which must be functional both during ground thermal-vacuum testing and on-orbit
- These heat pipes nominally run in planes that are parallel to the LCS YZ-plane
  - This allows for ground thermal testing with the +X-axis pointed vertically up
  - All heat pipes will function during ground test when the LAT is in this orientation
- The degree to which the heat pipes function normally depends on the slope of any rise in the heat pipe
  - If the LAT is misaligned, or the heat pipes are installed at a small angle, this could impact their performance during ground testing
  - We need to measure and catch any such misalignments before testing, so we have the data needed to diagnose any potential problem with LAT orientation during testing
- For a given heat pipe, the only angle of interest is that which tends to rotate the heat pipe off a horizontal plane during testing
- Heat pipe alignment values requiring surveying
  - F1: DSHP best-fit line YY and XX angles (12 sets of angles)
  - F2: Average DSHP YY and XX angular orientation in YY and XX (2 values)
  - F4: XLHP evaporator section best-fit line ZZ and XX angles (6 sets of angles)
  - F5: Average XLHP evaporator section ZZ and XX angular orientation (2 values)
  - F6: Angular offset of XLHP evaporator sections from their average (6 sets of offsets)
  - F7: XLHP condenser section best-fit line YY and XX angles (12 sets of angles)
  - F8: Average XLHP condenser section best-fit line YY and XX angular orientation (2 values)
  - F9: Angular offset of XLHP condenser section from their average (12 sets of offsets)

# Downspout Heat Pipe Orientations

- Allowed DSHP misalignment angle =  $RX = 0.155$  degrees =  $0.048'' / 17''$  long run
- All heat pipes meet the tolerance
- The average angle of offset for the heat pipes is very small
  - This shows there is no systematic mis-orientation due to assembly methods
  - Given the small average, there is no need to correct for it in the orientation of the LAT
- Conclusion: All DSHP's OK; no need to orient the LAT due to DSHP considerations

<b>LAT Heat Pipe Orientations</b>	Rev Date: 8-May-06
Coordinates with respect to the LAT Coordinate System; dimensions in mm	Print Date: 23-Aug-06

**Downspout Heat Pipes (DSHP's)**

- F1 DSHP best-fit line RY and RX angles (12 sets of angles)
- F2 Average DSHP RY and RX angular orientation (2 values)
- F3 Angular offset of DSHP's from their average (12 sets of angular offsets)

Heat Pipe	Raw Survey Data			RX = j/k		Offset from Avg (Deg)	RY = i/k		Offset from Avg (Deg)
	i	j	k	(Rad)	(Deg)		(Rad)	(Deg)	
DSHPMY0	-0.000444	0.000233	1.000000	0.000233	0.013	0.005	-0.000444	-0.025	-0.035
DSHPMY1	-0.000867	-0.000151	1.000000	-0.000151	-0.009	-0.017	-0.000867	-0.050	-0.059
DSHPMY2	-0.000470	0.000343	1.000000	0.000343	0.020	0.011	-0.000470	-0.027	-0.036
DSHPMY3	0.000174	0.001138	0.999999	0.001138	0.065	0.057	0.000174	0.010	0.001
DSHPMY4	0.001899	0.000977	0.999998	0.000977	0.056	0.048	0.001899	0.109	0.100
DSHPMY5	0.000760	0.000858	0.999999	0.000858	0.049	0.041	0.000760	0.044	0.034
DSHPPY0	0.001502	0.000518	-0.999999	-0.000518	-0.030	-0.038	-0.001502	-0.086	-0.095
DSHPPY1	-0.002381	0.000416	-0.999997	-0.000416	-0.024	-0.032	0.002381	0.136	0.127
DSHPPY2	-0.001605	0.000078	-0.999999	-0.000078	-0.004	-0.013	0.001605	0.092	0.083
DSHPPY3	0.000990	-0.001080	-0.999999	0.001080	0.062	0.053	-0.000990	-0.057	-0.066
DSHPPY4	0.001301	0.000410	-0.999999	-0.000410	-0.023	-0.032	-0.001301	-0.075	-0.084
DSHPPY5	-0.000656	0.001294	-0.999999	-0.001294	-0.074	-0.083	0.000656	0.038	0.029
Survey date: 18-Nov-2005				<b>Min</b>	-0.074	-0.083		-0.086	-0.095
				<b>Avg</b>	0.008			0.009	
				<b>Max</b>	0.065	0.057		0.136	0.127

-Y side of LAT, on -X corner ("left-most" when looking at LAT)

-Y side of LAT, on +X corner ("right-most" when looking at LAT)

+Y side of LAT, on -X corner ("right-most" when looking at LAT)

+Y side of LAT, on +X corner ("left-most" when looking at LAT)

HP Angle Not-to-Exceed		
Rise	Run	
0.048	17.7	inches

<b>NTE Tol</b>	0.155	
<b>Pass/Fail</b>	<b>PASS</b>	
<b>Margin</b>	0.081	0.019

# X-LAT Heat Pipe Condenser Section Orientations

- Allowed XLHP misalignment angle =  $RX = 0.324$  degrees =  $0.1'' / 17''$  long run
- Not all heat pipes could be inspected, given the tight packaging constraints of the center-most pipes on the sides of the EMI Shield → all heat pipes that were inspected met tolerance
- The average angle of offset for the heat pipes is very small
  - There appears to be no systematic mis-orientation
  - Given the small average, there is no need to correct for it in the orientation of the LAT
- **Conclusion: All XLHP's condenser sections OK; no need to orient the LAT**

<b>LAT Heat Pipe Orientations</b>	Rev Date: 8-May-06
Coordinates with respect to the LAT Coordinate System; dimensions in mm	Print Date: 23-Aug-06

## X-LAT Heat Pipes (XLHP's) Condenser Sections at Ends

- F7 XLHP condenser section best-fit line RY and RX angles
- F8 Average XLHP condenser section best-fit line RY and RX angular orientation
- F9 Angular offset of XLHP condenser section from their average

Heat Pipe	Raw Survey Data			RX = j/k		Offset from Avg (Deg)	RY = i/k		Offset from Avg (Deg)		
	i	j	k	(Rad)	(Deg)		(Rad)	(Deg)			
XLHPMY0	0.009771	-0.005237	0.999939	-0.005237	-0.300	-0.261	0.009772	0.560	0.514	-Y side of LAT, on -X corner ("left-most" when looking at LAT)	
XLHPMY1	0.001919	-0.001583	0.999997	-0.001583	-0.091	-0.051	0.001919	0.110	0.064		
XLHPMY2											
XLHPMY3											
XLHPMY4	-0.000373	0.000031	-1.000000	-0.000031	-0.002	0.038	0.000373	0.021	-0.025		
XLHPMY5	-0.000979	0.004871	-0.999988	-0.004871	-0.279	-0.240	0.000979	0.056	0.010	-Y side of LAT, on +X corner ("right-most" when looking at LAT)	
XLHPPY0	0.001360	0.005503	0.999984	0.005503	0.315	0.355	0.001360	0.078	0.032	+Y side of LAT, on -X corner ("right-most" when looking at LAT)	
XLHPPY1	-0.000237	-0.004011	0.999992	-0.004011	-0.230	-0.190	-0.000237	-0.014	-0.060		
XLHPPY2											
XLHPPY3											
XLHPPY4	0.002936	0.000581	-0.999996	-0.000581	-0.033	0.006	-0.002936	-0.168	-0.214		
XLHPPY5	0.004770	-0.005287	-0.999975	0.005287	0.303	0.342	-0.004770	-0.273	-0.320	+Y side of LAT, on +X corner ("left-most" when looking at LAT)	
Survey Data: 3 May 2006				<b>Min</b>	-0.300	-0.261			-0.273	-0.320	
				<b>Avg</b>	-0.040				0.046		
				<b>Max</b>	0.315	0.355			0.560	0.514	

<b>NTE Tol</b>	0.324
<b>Pass/Fail</b>	<b>PASS</b>
<b>Margin</b>	0.008

0.324
-0.236

HP Angle Not-to-Exceed		
Rise	Run	
0.1	17.7	inches

# X-LAT Heat Pipe Evaporator Section Orientations

- Allowed XLHP misalignment angle =  $RZ = 0.155$  degrees =  $0.027'' / 10''$  run
- All heat pipes that were inspected met tolerance—given the long run of the XLHP evaporator sections, standard assembly tolerances were more than adequate to meet requirements
- The average angle of offset for the heat pipes is very small
  - This is a slight systematic angular offset
  - Given the small average, there is no need to correct for it in the orientation of the LAT
- Conclusion: All XLHP's evaporator sections OK; no need to orient the LAT

<b>LAT Heat Pipe Orientations</b>	Rev Date: 8-May-06
Coordinates with respect to the LAT Coordinate System; dimensions in mm	Print Date: 23-Aug-06

**X-LAT Heat Pipes (XLHP's) Evaporator Sections on X-LAT Plate**

- F4 XLHP evaporator section best-fit line RZ and RX angles (6 sets of angles)
- F5 Average XLHP evaporator section RZ and RX angular orientation (2 values)
- F6 Angular offset of XLHP evaporator sections from their average (6 sets of angular offsets)

Heat Pipe	Raw Survey Data			RX = k/j		Offset from Avg (Deg)	RZ = i/j		Offset from Avg (Deg)
	i	j	k	(Rad)	(Deg)		(Rad)	(Deg)	
XLHP-0	0.000032	-1.000000	-0.000209	0.000209	0.012	0.010	-0.000032	-0.002	0.011
XLHP-1	0.000140	-1.000000	-0.000386	0.000386	0.022	0.020	-0.000140	-0.008	0.005
XLHP-2	-0.000341	1.000000	0.000002	0.000002	0.000	-0.002	-0.000341	-0.020	-0.006
XLHP-3	-0.000266	1.000000	-0.000194	-0.000194	-0.011	-0.013	-0.000266	-0.015	-0.002
XLHP-4	-0.000195	1.000000	-0.000037	-0.000037	-0.002	-0.004	-0.000195	-0.011	0.002
XLHP-5	0.000399	-1.000000	0.000187	-0.000187	-0.011	-0.012	-0.000399	-0.023	-0.010
				<b>Min</b>	-0.011	-0.013		-0.023	-0.010
				<b>Avg</b>	0.002			-0.013	
				<b>Max</b>	0.022	0.020		-0.002	0.011

HP on -X side of LAT ("on the bottom" in T-Vac config)

HP on +X side of LAT ("on the top" in T-Vac config)

<b>NTE Tol</b>	0.155		0.155
<b>Pass/Fail</b>			<b>PASS</b>
<b>Margin</b>	0.133		0.132

HP Angle Not-to-Exceed		
Rise	Run	
0.027	10	inches

# Variable Conductance Heat Pipe Condenser Section Orientations

- Allowed VCHP misalignment angle =  $RX = 0.155$  degrees =  $0.027'' / 10''$  run
- VCHP's were mounted to the Radiator face sheets using a jig
  - All VCHP's were verified to be parallel to each other and to two alignment holes in the face sheet of the Radiator
  - The VCHP survey consisted of surveying the location of the alignment holes for each Radiator and fitting a line between them—this line is parallel to all VCHP condenser sections for the Radiator
- All VCHP condenser sections are oriented to within a very tight tolerance to planes parallel to the YZ-plane
  - This includes any misorientation due to heat pipe installation, and misalignment of the Radiators and Radiator Mount Brackets on the Grid
- **Conclusion: All VCHP condenser sections OK; no need to orient the LAT**

## LAT Radiator Survey on the LAT at NRL

Rev Date: 24-Jul-06

Coordinates with respect to the LAT Coordinate System; dimensions in mm

Print Date: 23-Aug-06

Summary of LAT Radiator Survey of 6/28/06

= raw survey data

### Radiator VCHP Condenser Section Angle

ijk vector of line joining the centers of the two holes in FOSR-side facesheet that established the position of the VCHP condenser section. The ijk vector of the levelling tool minus that of the holes provides the offset information needed for levelling the VCHP condenser sections.

### Variable Conductance Heat Pipe (VCHP) Condenser Sections on Radiators

Heat Pipe	Raw Survey Data			RX = j/k	
	i	j	k	(Rad)	(Deg)
+Y Rad ijk vector	0.000155	-0.000011	1.000000	-0.000011	-0.000630
-Y Rad ijk vector	-0.000371	-0.000023	1.000000	-0.000023	-0.001318
				<b>Min</b>	-0.001318
				<b>Avg</b>	-0.000974
				<b>Max</b>	-0.000630
				<b>NTE Tol</b>	0.155
				<b>Pass/Fail</b>	<b>PASS</b>
				<b>Margin</b>	0.153

HP Angle Not-to-Exceed		
Rise	Run	
0.027	10	inches

## Heat Pipe Orientation Summary

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- All heat pipes were surveyed and shown to be within their allowed tolerance of angular orientation with respect to parallels to the LCS YZ-plane
  - No compensation or other rotation of the LAT is needed to correct for heat pipe out of tolerance conditions
- The average angular mis-orientation of any group of heat pipes was also very small
  - This shows that there was little, if any, systematic error in the placement of the heat pipes during assembly and integration
  - Given that the averages are small, there is no benefit in rotating the LAT to orient to the average heat pipe angle
- Conclusions
  - All heat pipe run are within tolerance
  - No LAT re-orientation is needed during ground thermal-vacuum testing
  - During ground thermal-vacuum testing, the LAT should be aligned such that the LCS +X-axis is aligned with the gravity vector, pointing up, with no compensation or other offsets made