May 1, 2003

LAT Tracker Subsystem Peer Review, 2003 March 24-25

Version 2

REQUESTS FOR ACTION

1. **TKRPR** J. Deily – Predictions vs. Requirements

   REQUEST: Present a summary of predictions vs. requirements. In addition, a form of a "fever chart" relative to the current margins should highlight the appropriate level of concern.

   REASON: The verification presentation had a separate slide for numerous requirements from the tracker performance specification. This needs to be put into a higher level summary and concerns chart to put the situation in perspective. This information could be utilized to trend the instrument performance during design and development.

   ANSWER (RPJ): A summary chart will be presented at the LAT CDR.

   STATUS:

2. **TKRPR** L. Fantano / T. McCarthy – IC Temperature requirements

   REQUEST: Specify a temperature requirement for the heat dissipating IC components located on the tracker trays.

   REASON: It was indicated that the 30°C tracker temperature requirement was applicable to the silicon in the SSDs which are not heat dissipating components. The heat dissipating ICs will likely experience temperatures warmer than the SSDs. Are these components temperature sensitive? If so, what are their temperature requirements?

   ANSWER (HFWS & RPJ): The TKR operates the ICs with extremely low power consumption: the GTFE consumes 10mW on an area of 0.33 cm^2 and a thickness of 0.03 cm, resulting in a temperature difference between MCM and the IC surface of less than a degree, as has been verified by measurements on prototype MCMs. The 30°C requirement does not apply to the ICs—they could easily operate tens of degrees hotter than that with no ill effect. (We specify a derated upper temperature limit for operation of the ICs and MCMs of 85°C.) The ICs connect to the SSDs via wire bonds, but a simple calculation shows that most of the IC heat will flow through the MCM to the tray closeout, not through the wire bonds. Since the power density is

so low that the temperature difference between the IC and tray cannot be more than a fraction of a degree, the SSD temperature limit takes precedence over that of the ICs.

STATUS:

3. **TKRPR** T. McCarthy – Thermal analysis – Maximum temperature

REQUEST: Maximum temperature predicts presented do not reflect the customary 5° analytical uncertainty used to establish these levels. Why not?

For failure case, what temperature limits are used, operating or acceptance? What is system requirement?

REASON: Predictions shown more thermal design margin than you can demonstrate analytically. Design is at limits.

	Presented	With Uncertainty	Limit
Hot Spot	24 °C	29 °C	30 ° C
Failure	28 °C	33 °C	30°C (35 °C AT?)

ANSWER (TB & RPJ): The 30°C requirement is based on end-of-life SSD functionality. Exceeding this temperature will not cause a part or system failure but only a potential science performance degradation. The degradation is very gradual, as it results from an increase in leakage current that produces shot noise, which adds in quadrature with the amplifier noise. The SSD's will not reach a part failure level until well in excess of 60°C. The limiting issue is CTE mismatch between SSDs and the tray mechanical structure. Therefore, if there is a non-recoverable failure of the cooling system, the Tracker would still try to operate at the higher temperature. At the acceptance test limit of 35°C there would most likely be no performance degradation, unless the radiation dose were much higher than expected (the 30°C specification assumes at end-of-life a radiation dose 5 times higher than actually expected—this is one of the margins hiding inside the thermal numbers). At even higher temperatures or with high radiation dose we would have to raise the discriminator thresholds in the hotter, most irradiated regions of the Tracker, resulting in some loss of efficiency in those regions. Another point is that the failure mode presented at the peer review was a complete detachment of a tower from the grid, which is practically impossible. Analysis predicts that failure of a center VCHP heat pipe results at worst in only a 2.1°C increase in Tracker temperature. More of this analysis was provided in the CDR thermal presentation. We will revisit the requirements and margins to clarify this in the requirements documentation and test plans.

STATUS:

4. **TKRPR** L. Fantano / T. McCarthy – Use of conductive paint

REQUEST: Provide rationale that shows that the additional EMI shielding provided by employing a conductive paint (Z-307) on the 2 mil aluminum tracker shields outweighs the contamination risks associated with having electrically conductive paint particles distributed throughout the tracker system. Consider employing the non-conductive version (Z-306) for this application to eliminate this potentially serious contamination risk.

REASON: The contamination risk associated with employing an electrically conductive paint on the 2 mil thick aluminum foil needs to be seriously considered. The added benefit of employing electrically conductive paint on the 2 mil aluminum foil is not obvious considering that the trackers are encapsulated by electrically grounded ACD MLI blankets. Although the plan is to conformal coat, epoxy, etc. all electrical interconnects, the huge number and small sizes associated with the tracker design makes one wonder whether these techniques will be 100% effective. Particles have a funny way of ending up exactly where they do not belong.

ANSWER (TB/SB): We have resolved that the Tracker will use Z-306 nonconductive paint instead of the conductive version. The Z-306 has been added to the materials list and approved.

STATUS: closed (the Tracker is implementing the recommendation)

5. **TKRPR** T. McCarthy – Thermal analysis – Hot spot

REQUEST:

a. What drives the "hot spot" in the thermal analysis? Path length to grid, worst case contact, conductors, or a combination?

b. Would a hot spot in center tower in center tray be hotter than presented if the tray had a poor conduction path?

c. What sensitivity analysis in addition to the failure case was done to investigate hot spot, i.e. range of contact conduction and how they were applied?

REASON: Details and analysis parameters were not discussed fully. Do these analysis results tie into system level predictions? Was the directional nature of the thermal conductivity of the composite material accounted for in the analysis.

ANSWER (MN/LM):

- **The tracker hot spot, located in the center of the towers (Bays 5,6,9,10, about 3 trays down), is a result of a combination of a contact at the interface to the grid, gradient up the tower through the walls, and limited radiation out to the ACD. For a center tower, the increasing path length to the grid drives the temperature higher as one goes up in the tower, but the temperature then starts decreasing again toward the top of the tower, due to radiation of heat from the top of the tower to the ACD.**
- **The conduction path is common to all trays in a tower, namely down the sidewalls on all four sides. If the sidewalls provide a poor conduction path, then the temperature of all trays will increase (see the next point). If a single tray makes poor contact to the sidewall at the MCM thermal boss, then the temperature of only that end of that tray will rise, without affecting other trays significantly. The maximum effect on the given tray in that case is a few degrees—the area is large and each such contact only carries 0.25 Watts of power.**
- **A sensitivity study was completed adjusting all the conductors in the model –10%. Results show that the maximum tracker temperature increased 2.3°C.**

STATUS:

6. **TKRPR** R. Kolecki / S. Seipel / J. Ryan – Locking / Grounding features for fasteners.

REQUEST: Identify the locking feature planned for all tracker fasteners. Pay particular attention to those required to secure a conduction contact for thermal hardware. Also, document use of conductive adhesive on screws used for grounding tray (MCM Ground) to the aluminum core.

REASON: A loss of thermal conduction could have negative impacts on thermal margin. Also, fasteners could be lost during vibration testing. If Urelane is used, it may interfere with grounding.

ANSWER (TB & RPJ): The screws holding the TMCM boards in place are being replaced by a bonded joint. The screws will be replaced by pins for alignment of the MCM during bonding.
The screws between the sidewalls and the trays will have two beads of structural epoxy on the head of each screw. These are small screws of only 2.5 mm diameter. The problem with applying Nusil to the threads is that there is a very large number (about 700) of these screws in the tower that will be inserted and torqued over the course of assembly (perhaps a full day). The pot life and working life of the Nusil would be problematic in this application. The epoxy locking method will be tested on the EM tower.
The screws from the bottom tray to the flexures will have epoxy on the threads, because those flexures are being permanently bonded to the bottom tray. The associated screws will never be removed after bonding.

The screws between the flexures and the grid will use Nusil silicone on the threads. The screws between the thermal strap and the grid will use Nusil silicone on the threads.
The aluminum core will have wires welded to the core and bonded to the closeout with conductive adhesive; screws will no longer be used to make the ground connections (see RFA 12).

STATUS:

7. **TKRPR** J. Ryan – Lateral loads at 45°

REQUEST: Run lateral load cases (quasistatic and random vibration) at 45° to the X & Y axes.

REASON: X & Y axes are aligned with the maximum stiffness of the tracker side walls. The 45° cases will investigate how loads are carried around the corners of the tracker towers.

ANSWER (ES): We will perform FE analysis and determine margins to this load case. If the margins are lower than those calculated for the two load cases parallel to the X & Y axes, proof testing to this load case will be considered.

STATUS: closed by J. Ryan; the analysis was presented at CDR

8. **TKRPR** S. Seipel / J. Ryan – Review EM testing prior to test

REQUEST: EM testing and planning should be reviewed by the GLAST Project Office before test is conducted.

REASON: Testing will likely occur after CDR. Review by GLAST Project Office will facilitate quick closure of RFA at CDR.

ANSWER (ES): The project office will review the EM test plan and bottom tray static proof test plan. This is a normal process required by the GLAST Project office.

STATUS: accepted by J. Ryan

9. **TKRPR** S. Seipel / J. Ryan – Complete test for allowables

REQUEST: Complete testing to define allowable material properties and recomputed margins-of –safety as necessary. If work cannot be completed by CDR show detailed closure plan and associated schedule. Revisit need (thermally) to use K13D sidewall material vs. YS90. Understand and present flow down of thermal margins driving material change.

REASON: Need to establish final design margins.

ANSWER (ES): This action is scheduled. Material & Joint testing will be completed prior to CDR, and new allowables and margins will be available at CDR. Sidewall material (K13D) testing will not be complete by the CDR, according to the current CDR schedule. These tests will be underway, with YS-90A being the fallback position should the allowables come in with unacceptable margins. YS-90A allowables are already in hand.

STATUS: accepted by J. Ryan; work in progress

10. **TKRPR** J. Ryan / H. Spieler – Basis of mass estimates

REQUEST: Provide mass breakdown showing percentages of estimated, calculated, and actual masses. Based on the percentages request additional mass contingency (or lien) on project held mass reserves.

REASON: A less than 1% mass margin was shown. At pre-CDR a 10% margin is not uncommon.

ANSWER (RPJ): A summary mass breakdown will be presented at CDR. The mass details can be found in LAT-TD-00177. The mass reserves are held at the LAT level, not by the subsystem, so the margin is not really 1%. The Tracker allocation was arbitrarily set 5 kg higher than our PDR estimate, with the remaining reserves kept and held by the LAT as a whole.

STATUS: The document 177 was updated and a summary presented at CDR.

11. **TKRPR** S. Seipel / J. Ryan – Verify tower gaps

REQUEST: Verify that the latest gap (2.5 mm) is used in the dead area calculations. Recheck that all structural dimensions used in the calculations (in charts by Bill Atwood) are verified against the latest LAT baseline design (CDR level).

REASON: Chart 13 seems to use 1.5 mm as gap number in calculations.

ANSWER (RPJ): Atwood's slide 13 has a typo relating to the gap (1.5mm was shown, but the gap actually is 2.5mm). However, whether or not he used the incorrect number does not significantly affect his final result on dead area. Numerically the error would be less than the rounding error in the next line.

STATUS: closed by J. Ryan

12. **TKRPR** M. Breidenbach / H. Spieler – Grounding the honeycomb

REQUEST: Ensure that the connection is made in a manner that holds up to vibration and maintains electrical contact over long term.

REASON: The honeycomb core must be maintained at constant high-frequency potential with reference to the silicon strip detectors and front-end electronics. We have concerns about the long-term integrity of the current connection method.

ANSWER (TB & RPJ): The honeycomb core will be electrically connected to all 4 of the closeout sides by bonding with conductive epoxy and compressing metalized cylinders between the core and carbon-carbon. If that fails on a given tray, then after panel assembly the grounding can be accomplished with wires bonded to the honeycomb core and bonded with conductive adhesive to the closeout pieces orthogonal to the MCM sides. The closeouts can be guaranteed to connect electrically to each other by bonding a wire with conductive adhesive in a groove that spans the corner adhesive joint. The various pieces in the core are connected electrically via the face sheets, which are bonded to the sharp core edges under high pressure. The after-assembly method has already been tested and results in less than 1 ohm resistance between any two points on the panel. The tungsten converter foils will connect to the face sheets with conductive adhesive. The MCM ground will connect electrically to the closeout via 3 pins in plated-through holes. The pins will be bonded into the closeout with conductive epoxy. The primary scheme will be tested in full in the EM top and bottom trays.

STATUS: these plans were presented to the CDR review team, which found them to be acceptable

13. **TKRPR** S. Seipel / J. Ryan – FEM to Project Office

REQUEST: Provide both detailed FEM and reduced dynamic FEM to GLAST Project Office.

REASON: Independent verification of proper modeling will reinforce analysis case at CDR, especially since EM testing and subsequent model correlation will not be complete most likely at that time.

ANSWER (ES): The CLA FEM has already been given to the mechanical systems group at SLAC. If they would like to share a copy of that model with GSFC, they can do so for systems level model verification. The detailed TKR model is not a deliverable under the contract with the vendor, nor is it a deliverable from SLAC to GSFC. The cost and schedule implications of

delivering the detailed FEM model can be explored if a formal change request is submitted.

STATUS:

14. **TKRPR** C. Fransen / J. Ryan – Update margin of safety calculations

REQUEST: Please update random vibration margin of safety calculations for bottom tray and sidewall margin of safety to include standard factors-of-safety (i.e. not derated as shown on page 31 Section 2-D). Also, a model uncertainty factor (MUF) of 1.25 should be factored into 3-sigma peak responses (The random vibration margins referred to are on pages 44-51).

REASON: Derating of Factors of Safety is not appropriate, given that rationale provided is not consistent with standard practice (i.e. 3-sigma peaks may well occur during a 60 second test) and that prototype vibration test results show non-linearity of response, suggesting reduced Q of 7 may be unconservative at lower input levels (also, tracker was deteriorating during test possibly causing lower Qs).

ANSWER: Derating the FS to 1.12 and not including a MUF of 1.25 was deemed to be acceptable for the Peer-Review presentation for the following reasons:

1) The GEVS general random vibration levels are known to be overly conservative for the TKR tower structure.

2) The random vibration analysis is by nature conservative because it assumes that a 3s event occurs for all frequencies simultaneously. Phase differences are not accounted for here.

3) A MUF is a recommended practice if the model has not been correlated against test data. Although this exact configuration has not been tested, test data exist to suggest that the assumptions used here are reasonable. Prototype testing of an earlier structure can be used to validate modeling techniques.

Given the new loads now officially provided by the project office, a FS of 1.5 (ultimate) on design levels and MUF of 1.15 will be included for composites in margin calculations and presented at CDR. Similar factors will be used for metals. This will be presented in detail at CDR.

STATUS: the CDR presentation was found to be acceptable by the reviewers

15. **TKRPR** B. Graf / L. Klaisner – MCM Timing analysis

REQUEST: Provide an MCM timing analysis based on the 20MHz signal from the T&DF sub-system which refers to a detailed block diagram (at component level) of the MCM.

REASON: The MCM electronics design was not sufficiently detailed.

ANSWER (HFWS & RPJ): After finishing the timing analysis for the CAL subsystem, the MCM timing analysis is being worked by the SLAC electronics team. It will be available for the CDR, together with a detailed block diagram. Note that the TEM/CAL communication hardware is essentially identical to that of the TEM/TKR (the same LVDS I/O cells are used in the ASICs of both subsystems, and the same LVDS drivers and receivers are used in the TEM). The Peer-Review electronics presentation showed that we have successfully operated the MCM with flight ASICs at the nominal voltage (2.5 V) up to 28 MHz, to be compared with the 20 MHz nominal.

STATUS:

16. **TKRPR** L. Mignosa / J. Ryan – Flexure blade buckling calculation

REQUEST: Look at interaction of lateral displacement of tracker flexure blades with compression buckling of same flexures.

REQSON: Lateral displacement of flexure blades, due to assembly tolerances and thermal temperature changes, will decrease the allowable critical flexure-buckling load.

ANSWER (ES): This was always planned and is scheduled to be completed before Instrument CDR.

STATUS: closed. Hytec completed the analysis, which shows positive margin. A pdf file is posted on the Tracker web page. Accepted by J. Ryan.

17. **TKRPR** L. Mignosa / J. Ryan – Review out-of-plane effects on flexures

REQUEST: Review environments that could cause one flexure mount, at the base of the tracker module, to be out of plane from the seven other flexures at this interface.

REASON: There could be environments or enforced displacements, at this interface, that cause undesirable forces at this redundant interface. These forces should be evaluated.

ANSWER (ES): No action planned. This has been addressed in previous analyses of the flexure and interface.

STATUS:

18. **TKRPR** L. Mignosa / J. Ryan – Annealed Titanium vs. STA Titanium

REQUEST: Consider use of annealed titanium instead of STA titanium for the flexure material. These flexures should also have a non-destructive inspection to screen for flaws, and component level strength / fatigue testing.

REASON: Annealed 6AL-4V titanium has much better ductility and fracture properties than STA 6AL-4V titanium even though material strength allowables are a little lower. Structural and non-destructive testing should be performed on the flexures due to the criticality of this high stress structural element.

ANSWER (ES & RPJ): 6Al-4V Annealed Titanium is the desired flexure material and was considered first in all flexure analysis. However, analysis has shown that annealed titanium does not have the strength to meet the requirements imposed by the GEVS design loads. For that reason STA was used in lieu of annealed titanium. Given the new random-vibration environment provided by the project office, STA titanium is not longer required. Annealed titanium will replace STA titanium as the baseline flexure material. Only a visual inspection of the flexures is planned prior to the bottom-tray static test. The static test will verify the stiffness and strength.

STATUS: the reviewer's recommendation to used annealed titanium was implemented. The inspection and testing requirements are being reviewed.

19. **TKRPR** L. Fantano / T. McCarthy – Thermal design assumptions

REQUEST: Provide detail design assumptions that were incorporated into the tracker design thermal analyses. Include the values and basis for key contact resistances (i.e. contact area, interface medium, and contact pressure) that are incorporated.

REASON: The fifteen minutes that were allocated to discuss tracker thermal issues was not sufficient to understand detailed assumptions that were incorporated into the analyses.

ANSWER (MN/LM):
Radiation: External tower-to-tower included (e=0.88). Internal not included (conservative).
Sources: Q input directly to MCM closeouts, Q per tower=10.2W(hot)
Key conductances:

> **Tray to closeout: through facesheets only.**
> **Closeouts to wall(except bottom tray): through mount bolts, dry joint, 0.4 W/K per tray/closeout interface (adjust based on tray grouping in nodalization)**

Down wall: K13D/YS90 lay-up: 297 W/cm-K (Across wall, 147 W/cm-K)
Interface to grid: Wet RTV joint between bottom of tracker wall and copper strap, 4.4 W/K per interface
Copper strap, 0.8mm effective thickness, 2.2 W/K per strap
Dry joint between copper strap and grid: 12 mount points per interface, totaling 1.2 W/K
Titanium flexures not included (conservative).

STATUS:

20. **TKRPR** H. Spieler – Die Tracking

REQUEST: Track individual dice through MCM testing to allow analysis of possible post wafer-probe yield losses.

ANSWER (HFWS & RPJ): We considered die tracking in the beginning and rejected it because of perceived cost and schedule impact at the MCM assembly vendor. Dice will be tracked at the wafer level in any case. In addition, as presented at the review, we do plan at least to segregate and hold back the dice on the perimeter of the wafers, even though they might pass the wafer-probe tests. The edge dice that pass all wafer probe tests are most likely good and will be retained as spares. Results from wafer testing so far show the bad chips randomly spread across the wafers, except for a few regions where dice exactly at the boundary are always, or nearly always, bad. Specifications for the lapping and dicing are now being prepared, so the cost of tracking dice at the dicing vendor can be requested. In any case, in the second prototype run of MCMs for the Mini-Tower (10 MCMs) we are requesting full traceability of the dice from the dicing vendor and from Teledyne.

STATUS:

21. **TKRPR** H. Spieler – Radiation testing

REQUEST: Justify range of particles used for SEL tests.

REASON: The 130 μm range of Ag ions at TAMU appears excessive.

ANSWER (HFWS): The LAT TKR proposes testing at INFN Legnaro, where the range of ions is about 32um. The GSFC Radiation Branch insists on a much higher range. We have requested justification as early as November 2002 but so far have not received anything rigorous and quantitative. Because the work must progress, we have agreed to do a single SEL test at TAMU. We believe that only the TKR ASICs have to go through this added requirement. If no difference to the Legnaro SEL test is found,

then the remaining LAT ASICs do not have to go to TAMU, given that they using the same process and are laid out with the same rules.

22. **TKRPR** H. Spieler – Failure modes and mitigation

    REQUEST: Review possibility of introducing redundancy of tower power supply / connections.

    REASON: Failure mode with significant science impact.

    ANSWER (HFWS): The power feeds to the TKR TEM modules are redundant. The loss of any TKR power supply will result in the loss of one of the 16 TKR towers, with the probability for the loss of two TKR towers being negligible. The science impact of the loss of one tower is being quantified in the LAT FMEA study. It has to be traded against cost and complexity of a redundant system. On the face of the performance numbers, the LAT "over-design" allows the LAT to achieve the performance goals of the SRD even with loss of one tower. A preliminary analysis indicates that loss of a single tower will still allow LAT to meet the science requirements, though the impact is significant. More details on this will be presented at CDR.

23. **TKRPR** H. Spieler – Design margins

    REQUEST: Check for compounded design margins.

    REASON: Can lead to excessively conservative specifications / requirements and as a consequence, wasted efforts that would be better applied elsewhere.

    ANSWER (HFWS & RPJ): This is a good suggestion, and we are doing this in some areas where we found that requirements had large impacts on needed resources or efforts. One example is the thermal management, where the TKR was able to respond to the need to increase the maximum silicon temperature, because only a few layers were impacted, and because the expected end-of-mission leakage current, which drives this TKR requirement, has a 5x-engineering margin. Another very important area is the overall mechanical design, which has carried a big risk of continual escalation of design cost. We believe that we have finally come to an understanding of and agreement on the needed design margins needed to finalize the design and proceed with the EM assembly and test.

24. **TKRPR** B. Rodini – Fiber volume / void content test

    REQUEST: Require fiber volume / void content test of face sheets for trays?

    REASON: Standard composites fabrication test to assure proper properties (strength, modulus, thermal conductivity). Fiber volume range should be checked against drawing to assure performance void volume is a check on the porosity cured into the face sheet this should be 2% of less.

ANSWER (AB): This is a valid point and has been incorporated into the test matrix as a quality control test of the facesheet laminates: Void Content Test ASTM D2734.

25. **TKRPR** B. Rodini – Composite panel fabrication – peel test

REQUEST: Define peel strength test method. I do not think ASTM D100299 is a test method. Is the test D 1002-99?

REASON: ASTM D1002-99 is a lap shear test not a peel test.

ANSWER (AB): The test matrix presented at the Peer Review was in error. It should have read that we will test all of the used structural adhesives by a lap-shear test ASTM D1002-99.

26. **TKRPR** B. Rodini – Requirements for composite panel fabrication

REQUEST: Define defect acceptance accept/reject criteria for flaws in face sheet and between face sheet and H/C core.

REASON: Unclear on what the requirements is.

ANSWER (AB): The maximum defect acceptance criteria is 3/4" defect diameter (3/8" is the honeycomb cell size; defects smaller than 2 cells are not significant) for the face-sheet to honeycomb adhesion and for the ply-ply adhesion. The closeout joint to the face sheets shall be continuous, without visible interruptions.

27. **TKRPR** B. Rodini – Defect growth during vibration

REQUEST: Investigate nondestructive method to determine if previously found defects in sandwich panel have grown during vibration.

REASON: A defect critical for thermal performance may not change the frequency of the panel.

ANSWER (AB): There are no thermal issues with such defects. A break on the tray surface cannot affect the ladder temperature. At the end of the mission, when the ladder heat dissipation is maximum, the power dissipated per tray face is ~4 milliwatt. This heat flow causes only a very small increase

of the ladder temperature (<0.2^{0}C) assuming that all the heat flow passes through the ladder to the TMCM.
A large break in the TMCM Carbon-Carbon thermal boss could cause a thermal problem. Such a defect would be external and could be directly observed after the vibration test. This is the only location in the tray where a defect could cause thermal issues.

28. **TKRPR** J. Ryan – Tower testing

REQUEST: Strength qualification of the tower assembly must be demonstrated. This can be easily accomplished by incorporating a sine burst test (low frequency) of the Qualification Tower A. Consideration should be given to sine burst testing the flight towers at acceptance levels (because of the composite design and complexity of assembly).

REASON: Strength qualification of tower assembly must be demonstrated by test and / or analysis.

ANSWER (ES): This is a valid point to verify that the TKR tower structure can meet quasi-static load requirements. The test is simple to incorporate and will be included in the test plan.

29. **TKRPR** S. Seipel / J. Ryan – Vibration test instrumentation

REQUEST: Establish the necessary procedures to bond and debond instrumentation to the painted tower sidewalls.

REASON: Care must be taken to avoid damage to the paint both mechanically (peeling, contamination) and thermally (degradation of thermal properties due to use of improper solvents).

ANSWER (TB/SB): This will be specified in the test procedure. The number of accelerometers is small and the accelerometers themselves are small such that they will be bonded to unpainted surfaces. If small amounts of paint are removed to bond the accelerometers the effect on the thermal properties is negligible.

30. **TKRPR** L. Mignosa / J. Ryan – Flexure location

REQUEST: Consider moving the flexure centerline closer to the tracker sidewall.

REASON: The bottom tray of the tracker assembly seems to have much more strain energy, in the first mode, than the other trays above it. Any offset between the flexure centerline and the tracker sidewalls could cause this strain energy.

Movement of the outside flexure blade to be flush with the edge of the mounting flange, at the sidewall interface, would decrease this offset and increase the first mode of the tracker.

ANSWER (ES): No action planned. This has already been considered and optimized for the geometric requirements of the grid interface below.

31. **TKRPR** J. Ryan – Complete test matrix

REQUEST: Provide completed Tracker test matrix.

REASON: Test matrix was not provided. Will need to be presented at LAT CDR.

ANSWER (RPJ): This is available and will be included in the LAT CDR presentation. It has been modified to satisfy RFA 28.

32. **TKRPR** S. Seipel / J. Ryan – Complete conceptual design of MGSE

REQUEST: Complete conceptual design and analysis of all mechanical GSE, including tower vibration / handling fixture, tower lifting fixture and shipping container(s). Margins of safety and proof testing plans should be included, along with a schedule to show successful completion of required items by integrations need dates.

REASON: More development is required to be shown by CDR stage.

ANSWER (RPJ/SB/NM): Detailed design of the lifting fixture has been carried out, and all of the parts for one of these fixtures are in hand. It will be proof tested. The FE model of the full tower will be double checked in the near future to verify margins for lifting the tower by the 8 points in the top tray.
The vibration fixture has also been designed, and it is a small modification of the fixture used in the vibration tests last year. This item has been included in the analysis of the static-test fixture design and its margins have been checked in the course of that work.
Outer candidate shipping containers (commercial items) have been identified and will be procured soon. The inner container needs more design (it will be built around the vibration fixture). Analysis of the shipping containers has not yet been done. Hytec has an example from a previous program that we will review, and then we will plan a program to finalize this item.

33. **TKRPR** S. Seipel / J. Ryan – Pass / fail criteria for testing

REQUEST: Specific pass / fail criteria should be established for testing at all levels of assembly. These criteria shall be clearly captured in the procedures for the execution of each test. Necessary steps to “safe” the flight hardware in the event of anomalous data should also be included in the procedures.

REASON: Necessary to protect flight hardware, properly execute testing, and allow the hardware to proceed to the next level of assembly.

ANSWER (RPJ/SB/TB/NM): We understand the importance of this recommendation and will incorporate clear criteria in all test procedures. This was already done for those flight hardware assemblies already under test: SSD ladders (see LAT-PS-635) and ASIC wafer testing (see LAT-TD-247 and LAT-TD-248).

34. **TKRPR** J. Ryan – Sine sweep test levels

REQUEST: Consider reducing the 0.5 g high frequency sine sweep test to 0.25 g or less.

REASON: Concern is that sweeping through resonant frequency at 0.5 g will cause significant response to the tower.

ANSWER (ES): Agree. Test levels will be reduced to 0.25 g or less.

35. **TKRPR** L. Fantano / T. McCarthy – Thermal balance test

REQUEST: Include a thermal balance test in the test sequence for each flight tower if it is not already included in the baseline test plan

REASON: A thermal balance test for each flight tower would validate key tower heat transfer paths. Thermal vacuum cycle testing will not accomplish this. The added cost associated with performing a thermal balance test could be quite modest considering that plans already exist to perform thermal vacuum cycle test. This activity would greatly mitigate the very significant cost and schedule risk associated with having to de-integrate a tower or towers after instrument level thermal balance tests.

ANSWER (TB, RPJ): Thermal balance is in the plan for the qual-model tower. Implications of a thermal balance test for each of the other towers will be studied. The instrumentation will be available, so it is a question of test time, cost, and schedule. If it is required, then a cost and schedule change request will be submitted to the LAT project office for approval.

36. **TKRPR** T. McCarthy – Mounting of thermisters

REQUEST: Flight thermisters are embedded in cables that run along sides of the tower. They are not mounted directly to hardware, trays, or boards. Why not? Do cable temperatures really reflect hardware temperatures?

REASON: By embedding the thermisters in the cables, temperatures will be dominated by copper and possibly a "thermal short" to bottom of tower, monitoring cable temperatures not tray temperatures.

ANSWER (HFWS & RPJ): The cables connect directly to the MCMs about every 6 cm, and they are sandwiched tightly between tray closeouts and tower walls every 6 cm. Their thermal resistance due to their copper content is about 15 times larger than the thermal resistance of the tower walls, which provide the cooling path for the TKR electronics. Hence we do not believe that the cable makes a thermal short to the tower bottom. Each section of the cable will be in good thermal equilibrium with the tower structure. Mounting the thermistors on the MCMs was initially considered (the BTEM was built that way) but would be more expensive and has no advantage. The thermistors will give accurate measurements of the tower temperature at 16 different points covering all sides and all heights.

37. **TKRPR** T. McCarthy – Subassembly temperature test range

REQUEST: Consider temperature cycle screen test (done in non-vacuum environment) to a wider range than tower will see. Box/tower will see thermal vacuum cycles to –30 °C to +50 °C. Consider temperature cycles of trays to –30 °C to +60 °C. Attribute the additional 10 °C as follows: 5 °C because it is done in air and 5 °C because you want to screen above the box level requirement.

REASON: Typically, lower level assemblies, i.e. tray, would see a more sever temperature screen test beyond the tower level. Testing to –30 °C will be more sever, from a from a part perspective, done in air, so this level is OK.

ANSWER (TB): The tray cycle test will be modified to the range of -30°C to +60°C.

38. **TKRPR** T. McCarthy – Tower thermal test ranges

REQUEST: Consider acceptance test temperature levels at 45 °C vs. 35 °C for tower assembly. Ensure that the acceptance thermal vacuum test of each tower provides a characterization to verify the "thermal character" of each tower.

REASON: Qualification testing is being done to 50 °C. Acceptance test should be qualification minus 5 °C. Acceptance testing to 45 °C provides a more robust level of screening and would provide more design margin going into the system level test. Test level of instrument test will be predicts ± 10 °C, and hence, instrument qualification could be at 49 °C. The "thermal workmanship" of each tower needs to be validated.

ANSWER (TB & RPJ): The qualification and acceptance levels for all the LAT hardware are specified in the LAT environmental requirements document. The Tracker requirements documents reference the LAT document, LAT-SS-00778, which is under the control of the LAT systems engineer. Therefore, any change to these requirements needs the concurrence and approval of the LAT systems engineer. For this particular requirement, the acceptance test is defined in LAT-SS-00778 as "the range over which the unit will operate within specifications at both BOL and EOL." We expect that the tracker *will not* operate within specifications at EOL at a temperature of 45°C, simply because of shot noise from leakage current. (At BOL, with no radiation damage, it *might* be possible to operate the SSDs at that temperature within specifications.) Hence we could not satisfy the given definition of acceptance test if the level were raised to 45°C. A practical solution might be an acceptance test to 35°C and a "thermal workmanship" test to 45°C with the SSD bias turned off. The latter test could operate the electronics at the elevated temperature but not take actual data from the detectors. The Tracker team has no problem with raising the temperature to 50°C if the SSD bias is turned off. We will work on resolving this question.

39. **TKRPR** J. Ryan – Alignment of flexures

REQUEST: Provide plans to address the grid to flexure to bottom tray precision assembly.

REASON: "Tight tolerance" pins and shoulder bolts are used to secure the flexures to the grid / bottom tray interfaces. It will be necessary to document and verify this critical assembly step.

ANSWER (ES): The bottom tray will have the midspan flexures bonded and bolted to the bottom tray using an assembly fixture fabricated from the drill fixture used to drill the grid. The corner flexures will have the bolt hole for the mounting bolt to the grid drilled and reamed to size using the same drill fixture. This process and the fixtures involved have been jointly designed with the Mechanical Subsystem. The process will be tested on the EM tower.

CONCERNS

C1. **TKRPR** J. Ryan – Lateness of testing

CONCERN: Current schedule shows that structural and thermal tower test results will not be available before LAT instrument CDR. This is a particular concern because of two previous tracker tower vibration test failures. Significant analytical work and bottom tray redesign has been conducted and positive margins are now predicted. However, until these tests have been successfully completed, full scale flight tray production should proceed cautiously (if at all).

ANSWER (TB & RPJ): The only tray affected by the previous vibration failures is the bottom tray. The flight bottom trays and the sidewalls will not be fabricated prior to the completion of the EM tests. All other trays have significant design margins. Therefore the risk of beginning fabrication on all trays except the bottom trays is minimal.

C2. **TKRPR** J. Ryan – Document status

REQUEST: Several documentation concerns exist for the tracker subsystem as a pre-CDR peer review.

a. The critical interface definition drawing was shown to be in draft form.

b. Only 50% (40 of 80) of flight drawings were released.

ANSWER (TB & RPJ): The interface drawing will be released prior to CDR. A significant portion of the remaining Tracker flight drawings will be released by CDR. No flight parts will be fabricated prior to release of the drawings.