GLAST Large Area Telescope

Pre-Environmental Test Review

Mechanical Test: Plans and Procedures

John Ku
Design Integration and Analysis
Purpose / Contents

• Demonstrate readiness to proceed with environmental testing of the integrated flight instrument
• The LAT…
  – …is heretofore compliant with all mechanical requirements
    • EXCEPTION: Radiator strength test not performed yet
      – Minimum margin is high (low risk)
        » Peak load = 526 lb_f
        » A-Basis Yield Strength = 5352 lb_f
        » MS_{insert} = 9.2
      – Will be performed prior to first required use (Acoustic Test)
  – …has been appropriately tested at lower levels of assembly
  – …passes comprehensive systems test
  – …pre-test analyses are complete
  – …environmental Test plans and procedures are complete
  – …test facilities readiness and certification verified
  – …STE and MGSE are complete, fabricated, and ready for use
  – …test manpower is sufficient to cover all planned activities
All flight system design analyses have been successfully completed and demonstrate adequate margin

- **Mission System Spec → 433-SPEC-0001**
- **LAT-SC Interface Requirements Spec → 433-IRD-0001**
- **Mission Assurance Requirements Spec → 433-MAR-0001**
- **LAT Environmental Requirements Spec → LAT-SS-00778**
- **LAT Performance Verification Plan → LAT-MD-00408-04c**

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* A=Analysis; I=Inspection; ET=To be verified in Dynamics Environmental Test
Requirements compliant: changes since CDR

• Requirements / Design Update, i.e. Changes since CDR (requiring updates to CDR analysis)
  – SC Interface inserts increased from 3/8 → 7/16 and increased spacing
    • Rationale: increased insert size to increase margin of safety
    • Rationale: increased spacing to 1.5D away from pin interface so bearing allowables could be used
    • Approved: Presented at delta-CDR and approved, modifications made to ICD
  – TKR-Grid interface bushings added
    • Rationale: Bearing stress to grid could cause yielding and collateral damage to trackers. Bushings reduce contact stress
    • Approved: Analysis showed bushings reduced stresses, and SS tests passed with no damage to aluminum grid simulator.
  – Finalized Radiator Mount Bracket
    • Rationale: Thermal distortion of radiators could induce high stresses in RMB. Stiffness of RMB reduced in X-direction to minimize thermally induced stress
    • Approved: Documented in LAT-TD-02472-01, Section 5C
  – Radiator Sine vibration tests omitted in favor of tap test and static test
    • Rationale: Tap testing provides adequate dynamic measurement of radiator modes
    • Rationale: Static testing of radiator sufficiently exercises radiator in-plane loads
    • Approved: Series of telecons between SLAC/GSFC/LMCO to reach agreement
Requirements compliant: changes since CDR

- Requirements / Design Update, i.e. Changes since CDR (requiring updates to CDR analysis)
  - Shear Plates added at CAL-Grid interface to address slippage concerns
    - Added mounting bosses to the Grid for Shear Plate mounting
    - Modified EMI Skirt pieces to accommodate Shear Plate mounting to the Grid
    - Removed corner tabs from CAL base plate
    - Rationale: friction alone is not a good way to ensure no slippage. Tight mechanical fit via liquid shims solves this problem
    - Approved: Documented in LAT-TD-02472-01, Section 3 & 5A
  - EBOX attachments fully defined: stand-offs on CAL interface, dry joint on X-LAT interface.
    - Pockets machined in X-LAT to reduce installation stress
    - Detailed stress analysis complete
    - Rationale: X-LAT to EBOX interface was not clearly defined at CDR. This design resulted from a post-CDR tiger team effort.
    - Approved: Peer review held 5 November 2003 and approved.
  - X-LAT test requirement deleted
    - Rationale: Impractical to test and unmeaningful due to impossible boundary conditions. Qualification by analysis route taken
    - Approved: After 5 November 2003 peer review demonstrated high margins, this approach was approved.
    - All margins were reevaluated against ECLA and FDLC2 results
    - ICDs updated and approved
    - Resultant changes to verification matrix incorporated and approved
• Current calculations for system performance are fully compliant with requirements

• Completed analysis of current design demonstrate adequate margin for mechanical loads and stress from handling, test and flight environments (ECLA and FDLC2 used for flight loads)

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**NOTES:**

1/ Shear loads at Calorimeter tabs previously analyzed
2/ Test Required; does not meet GEVS QBA: C=Coupon; X=GSLT; SS=Subsystem
3/ Test Safety factor built into stress calculation
Appropriately tested at lower levels of assembly

- LAT Instrumentation Plan → LAT-TD-00890-03  
  - Flight and ground instrumentation defined
- LAT Dynamics Test Plan → LAT-MD-01196-03  
  - Sine Vibration, Acoustic, and Mass Properties tests described
- All lower level flight system verification activities have been satisfactorily completed and all discrepancies are sufficiently understood to warrant proceeding  
  - Engineering Test Unit testing since CDR are documented and the design reflects the results
  - Coupon Tests  
    - Insert pullout and shear strength (keensert, helicoil, potted inserts, bare threads)  
    - torque to preload ratios  
- Flight-like coupon tests  
  - Grid wing corner  
  - Grid EM1X4 Stiffness Verification Test → Complete → LAT-TD-02417  
- CAL EM Vibration Test → Complete → LAT-TD-01888
- TKR EM Vibration Test → Complete → LAT-TD-04310
- SC Flexure Strength and Stiffness test → Complete → LAT-TD-07813-01
Appropriately tested at lower levels of assembly (cont.)

- Flight Subsystem tests
  - Subsystem EIDP reports provide more detailed subsystem test data
  - The only subsystem test still not performed is the Radiator static test
    - Acoustic Test (Y loads) → Highest loads, Complete
    - Static Test (X & Z loads) → NOT COMPLETE → To be performed at NRL prior to LAT acoustic
      » Test Plan → LAT-TD-08047
      » Test Procedure → LAT-TD-08118
    - High margins = low risk
Appropriately tested at lower levels of assembly (cont.)

- Notable fabrication discrepancies and resolution
  - Subsystem EIDP reports provide more detailed subsystem manufacturing discrepancy information
  - Shear plates are held in place by a captive stud and nut. Substandard nut manufacturing caused galling which could lead to stud failure during attempted nut removal.
    - Resolution: do not remove defective nuts unless necessary. If necessary, split nut to preserve stud.
  - This anomaly affects 8 out of 64 studs and 4 out of 16 Calorimeters
  - Additional information can be obtained from a tech note written by J.Ku: “Use of Substandard Nut,” dated 6 Feb 2006.
Passes comprehensive systems test

- Initial flight system comprehensive performance testing has established a valid performance baseline that complies with requirements
- CPTs will be performed before and after the Vibe and Acoustic tests.
- Between vibration axes, LPT’s will be performed.
  - While vibe data is being reviewed, the LPT’s will be run concurrently
  - LPT duration is estimated to be between 6 and 8 hours
Pre-test analysis

- Analyses used to develop test plans are complete
- Sine Vibration Pre-Test Analysis → LAT-TD-08115
  - Frequency response analysis complete
  - Estimated notching calculations complete
  - Spreadsheets for real-time data reduction complete
  - Sine Vibration TRR completed successfully 24 May 2006
- Acoustic Vibration Pre-Test Analysis → LAT-TD-08116
  - Acoustic analysis in test configuration complete
  - Spreadsheets for real-time data reduction complete
  - Acoustic TRR to be performed no less than 24 hours prior to test
- Mass Properties Pre-Test Analysis → LAT-TD-08117
  - Mass properties spreadsheet with latest measured data complete
  - Spreadsheets for real-time data reduction complete
  - Mass and CG TRR to be performed no less than 24 hours prior to test
Pre-test analysis

- Pre-test analysis sample results (detailed discussion in TRR package)

[Graphs showing peak acceleration response for Response X (ALL) and Response Y (ALL)]
Environmental Test Flow

- The mechanical tests, highlighted in red boxes, are part of the environmental test sequence, shown below (see LAT-MD-02717):

![Environmental Test Flow Diagram]

- Limited Performance Test
- Comprehensive Performance Test
- SVAC Test
- LAT Functional and FSW Test
- TCS Functional Test
- EMI/EMC Emissions/Susceptibility Test
NRL Vibration Facility Layout

VIBRATION FACILITY PLAN VIEW
Sine Vibration Test Configuration

LAT Test Input (base of fixtures): T-axis

VERT. VIBE TEST MOUNTING CONFIGURATION

LAT Test Input (base of fixtures): Z-axis
Environmental Test plans and procedures

• Planning is adequate for all mechanical environmental tests
  – A comprehensive environmental test sequence at appropriate exposure levels is planned that will complete all remaining required verification activities
    • Protoflight Sine Vibration Test Procedure
      – LAT-PS-08112-01
    • Protoflight Acoustic Vibration Test Procedure
      – LAT-PS-08113-01
    • Mass Properties Test Procedure
      – LAT-PS-08114-01
  • Adequate systems performance testing is planned during and between environmental exposures so as to ensure adequate functionality or uncover any deviations
  • Adequate testing for primary and redundant elements is planned
Facilities readiness and certification

- **Unholtz-Dickie Shaker** – ready for test operations
  - Expander Head and Load Frame has successfully completed proof loading
  - Shaker has driven mass simulator in the vertical orientation
  - Horizontal Slip Table Function has been confirmed with mass simulator
- **Ling Shaker/Slip Table** – ready to support test operations
  - Support plate for temporary placement of the LAT instrument available (NOTE: will be installed at the conclusion of test operations for STP-SAT)
- **Handling Pathfinder** has been verified
  - Air Bearing Transport to be verified by May 18
  - Floor is fully supported in this move – no floor support is required
- **Accelerometers** – calibration is current
- **Amplifiers** – calibration is current
- **Crane** – certification is current
- **Hydroset** – certification is current
Facilities readiness and certification (cont.)

- Facility is ready to support LAT Vibration Test Activities
  - NOTE: As of May 22\textsuperscript{nd}, STP-Sat currently testing in Vibration Facility. Scheduled to complete testing by May 24\textsuperscript{th}. Sine vibration testing can start on May 26\textsuperscript{th}.
- All essential test personnel available for scheduled tests
Manpower

• Available resources
  – Technical Team – conduct test, review data, ensure requirements satisfied
    • John Ku (LAT Dynamics Test Director) – Full Time
    • Bob Haynes (Test Conductor) – Full Time
    • Jim Haughton (Test Engineer) – Full Time / As-needed
    • Paul Baird (Test Engineer) – Full Time
    • Chris Fransen (Test Engineer) – As-needed
  – Mechanical Support Team – needed between axes for reconfiguration
    • Eliazar Ortiz (I&T Lead Mechanical Engineer) – See I&T Schedule
    • Mark Molini (I&T Mechanical Engineer) – See I&T Schedule
    • Dave Kiehl (I&T Mechanical Engineer) – See I&T Schedule
    • Tom Nieland (I&T Mechanical Engineer) – See I&T Schedule
    • Leo Manger (I&T Mechanical Engineer) – See I&T Schedule
  – Management – set priorities, enablers
    • Bill Raynor (NRL Facility Manager) – As-needed
    • Paul Dizon (LAT Facilities Test Director) – As-needed
    • Ken Fouts (SLAC I&T Manager) – As-needed
    • Marc Campell (Mechanical Systems Manager) – As-needed
Readiness Statement

• Work to be performed prior to environmental test
  – Sine Vibration Test
    • None → ready to start test on 26 May 2006
  – Acoustic Test
    • Complete Radiator Strength Test Procedure
    • Execute Static Test
    • Hold TRR at least 24 hours prior to test
  – Mass and CG Test
    • Update Dynamics Test plan for mass and CG test
    • Hold TRR at least 24 hours prior to test

• Pending completion of the above items for their respective tests, the integrated LAT will be ready to enter mechanical environmental tests to complete all remaining required verification activities