# DOCUMENT CHANGE NOTICE (DCN)

**ORIGINATOR:** Robert Johnson  
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**DATE:** 3/18/03

**CHANGE TITLE:** DCN for LAT TKR Detailed Subsystem Specification- Level IV Specification

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**CHANGE DESCRIPTION (FROM/TO):**

Initial release

**REASON FOR CHANGE:**

**ACTION TAKEN:**  
☑ Change(s) included in new release  
☐ DCN attached to document(s), changes to be included in next revision  
☐ Other (specify):

**DISPOSITION OF HARDWARE (IDENTIFY SERIAL NUMBERS):**

☑ No hardware affected (record change only)

☐ List S/Ns which comply already:  
☐ List S/Ns to be reworked or scrapped:  
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**SAFETY, COST, SCHEDULE, REQUIREMENTS IMPACT?**  
☐ YES  ☑ NO

If yes, CCB approval is required. Enter change request number:

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**DCC RELEASE:** Natalie Cramar (signature on file)  
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**DCN No.**  
LAT-XR-1832-01  
**SHEET 1 OF 1**

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**FOR** GLAST

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**LAT Project Office – SLAC**
Gamma-ray Large Area Space Telescope

(GLAST)

Large Area Telescope (LAT)

Tracker Detailed Subsystem Specification Level IV
## CHANGE HISTORY LOG

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1 PURPOSE

This document defines level IV detailed system requirements for the GLAST Large Area Telescope (LAT) Tracker (TKR).

2 SCOPE

This specification captures the GLAST LAT requirements for the TKR. This encompasses the subsystem level requirements and the design requirements for the TKR. The verification methods of each requirement are identified.

This specification is one level below the LAT-TKR Specification, LAT-SS-00017.
3 DEFINITIONS

3.1 Acronyms
GEVS – General Environmental Verification Specification
GLAST – Gamma-ray Large Area Space Telescope
LAT – Large Area Telescope
LET – Linear Energy Transfer
MAR – Mission Assurance Requirements
MC – Monte Carlo
MECO – Main Engine Cutoff
MSS – Mission System Specification
SI – Science Instrument
SSD – Silicon Strip Detector
TKR - Tracker

3.2 Definitions
Analysis – A quantitative evaluation of a complete system and/or subsystems by review/analysis of collected data.

cm – centimeter
Demonstration – To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.
Inspection – To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
Primary structures – The instrument primary structures include the support grid, ACD, radiators and thermal/micrometeorite shield.
s, sec – seconds

MPa – 10^6 Pascals (N/m^2) of pressure
Simulation – To examine through model analysis or modeling techniques to verify conformance to specified requirements
Testing – A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements.
Validation – Process used to assure the requirement set is complete and consistent, and that each requirement is achievable.
Verification – Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products.
4 APPLICABLE DOCUMENTS

5 LAT SYSTEM REQUIREMENTS

5.1 Overview of the Tracker Subsystem Conceptual Design

The LAT science instrument (SI) consists of an Anticoincidence Device (ACD), a silicon-
strip detector tracker (TKR), a hodoscopic CsI calorimeter (CAL), and a Trigger and Dataflow
system (T&DF). The principal purpose of the SI is to measure the incidence direction, energy and
time of cosmic gamma rays. The measurements are streamed to the spacecraft for data storage and
subsequent transmittal to ground-based analysis centers.

The TKR converts gamma rays to charged particles and measures with great precision the
path of the charged particles within the TKR. Fast signals from tracks are examined in the T&DF
system for likely gamma ray candidates. Once identified and at the request of the trigger system,
data is read out via dataflow system. The dataflow system uses the data to assemble particle tracks
and, coupled with the ACD and CAL, identify gamma rays.

The Tracker consists of 16 tower modules arranged in a four-by-four square array. Each
tower module (Figure 1) is mounted via flexures to the aluminum Grid, which also supports a
Calorimeter module directly below each Tracker tower module. A Tower Electronics Module
(TEM), which includes the data acquisition and trigger electronics for both Tracker and Calorimeter,
is mounted to the underside of each Calorimeter module. The Tracker towers are enclosed under the
ACD. The heat generated in the towers is removed through the Grid to the radiators.

Each Tracker tower module is made up of 19 trays that support the silicon-strip detectors
(SSD’s). With the exception of the top and bottom trays, each tray supports SSD’s on both the upper
and lower faces. The bottom tray has SSD’s on only the upper face, and the top tray has SSD’s on
only the lower face. The top 16 trays also support tungsten converter foils on their lower faces,
between the panel structure and the SSD’s. The tungsten foils in the top 12 trays are 3.0% of a radiation length. The following four trays have foils that are 18% of a radiation length thick.

Carbon-fiber walls support the stack of 19 trays in a tower module. The walls make the stack rigid, maintain the tray alignment, serve to carry the electronics heat down the tower, and also are coated with aluminum to serve as an EMI shield for the electronics.

A tray is composed of a panel upon which are mounted the converter foils, detectors, and readout electronics. Each panel is composed of an aluminum honeycomb core with carbon-fiber face sheets and carbon-carbon closeouts. The carbon-carbon material is a 3-D structure of fibers that is densified with resin such that it can be readily machined to the detail needed for the interfaces to the panel. The closeouts on the top and bottom trays are special, in order to provide an interface to the Grid on the bottom and lifting points on the top. All other closeouts are identical, but the thick-converter trays use heavier core and thicker face sheets than do the others. Figure 2 shows an exploded view of a single tray panel.

A layer of detectors measures a single coordinate along the trajectory of a charged track, according to which strip, or pair of strips, records a signal. Alternating trays are rotated 90º with respect to each other, such that each converter foil is followed by a pair of detector planes that measures both the $x$ and $y$ coordinates along the particle track. The gap between detector layers in such an $x,y$ pair is only 2 mm. A single detector layer is composed of 16 SSD’s arranged in four “ladders” of four SSD’s each. Within a ladder, the strips of an SSD are wire bonded to the strips of the neighboring SSD’s, to form detector strips that are essentially the length of the tray.

Each layer of detectors is connected to a readout electronics module called the Tracker Multi-Chip Module (TMCM). Each TMCM is located on the side of a tray. A flexible circuit called the “pitch adapter” carries the signals around the tray corner to link the detector strips to the amplifier chips. Two flexible multi-layer cables connect each TMCM to those located immediately above and below and, ultimately, to the TEM located below the Calorimeter.

Figure 2. Exploded view of a tray panel.

Figure 3. View of the bottom trays of a tower module, showing the flexures for mounting the module to the Grid and the thermal straps.
The heat from the electronics flows through the TMCM circuit board, into the tray closeout, and through a boss in the closeout into the tower walls. From the walls the heat flows into the Grid via a set of thermal straps. The bottom tray is mechanically connected to the Grid by means of a set of flexures, with one on each side of the tower and one at each corner, as illustrated in Error! Reference source not found.. The flexures allow the aluminum Grid to expand and contract without imparting stress into the carbon-fiber Tracker structure.

5.2 Tower Configuration

5.2.1 Number of Trays
Each tower shall be comprised of 19 trays (18 x,y detector planes).

5.2.2 Gap Size Between Trays
The distance between trays, surface of SSD to surface of SSD, shall be 2.0 mm ±0.2 mm, and the minimum distance between the tops of encapsulated wire bonds on one tray to the tops of those on the adjacent tray shall be 1.0 mm.

5.2.3 Tower Height
The total height of the tower shall not exceed the number specified in the Tracker-LAT ICD [10] (not including the extension of the flexure mounts below the top surface of the Grid).

5.2.4 Tower Width and Horizontal Stay-Clear Dimension
These dimensions are specified in the Tracker-LAT ICD [10].

5.2.5 Inter-Tower Spacing
The spacing between towers shall be nominally 2.5 mm.

5.2.6 Tower Stiffness
The minimum fundamental frequency of a tower shall be 100 Hz.

5.2.7 Tower Sidewalls

5.2.7.1 Sidewall Material
The tower sidewalls shall be made from GFRP material.

5.2.7.2 Sidewall Fastener Pullout Strength
The pullout strength of the heads of the fasteners holding the sidewalls to the closeouts shall be at least 150 N.

5.2.7.3 Sidewall Fastener Shear-Out Strength
The shear-out strength of fasteners in the plane of the sidewall shall be at least 700 N.
5.2.8 **Tower Handling Fixture**

The top tray in a tower shall include attachment points for a handling fixture that will allow the tower to be lifted from the top without interference from adjacent towers.

5.3 **Tray Configuration**

The tracker tray mechanical structure is a composite honeycomb panel fabricated from carbon-fiber based materials for the closeouts and face sheets and aluminum for the honeycomb core.

5.3.1 **Tray Panel Stiffness Requirements**

Each completed tray shall have a fundamental frequency of at least 500 Hz when supported at the tower wall attachments. For engineering analysis, the silicon-strip detector ladders shall be included only as simple mass.

5.3.2 **Tray Panel Mass**

5.3.2.1 **Thick-converter tray panel mass**

The mass of a panel for a thick-converter tray shall not exceed 650 g, not including the converter foils, detectors, and adhesive for bonding of foils and detectors.

5.3.2.2 **Thin-converter tray panel mass**

The mass of a panel for a thin-converter tray shall not exceed 510 g, not including the converter foils, detectors, and associated adhesive.

5.3.2.3 **Top tray panel mass**

The mass of a top panel shall not exceed 850 g, not including the converter foils, detectors, and associated adhesive.

5.3.2.4 **Bottom tray panel mass**

The mass of a bottom panel with flexures shall not exceed 1000 g, not including the converter foils, detectors, and associated adhesive.

5.3.3 **Tray Panel Transparency**

5.3.3.1 **Thick-converter tray panel transparency**

The average amount of material encountered by a particle traversing a tray panel (not including converter foils, detectors, and associated adhesive) at normal incidence to a face sheet and within the silicon-strip detector active area shall not exceed 0.70% R.L. for thick-converter trays.

5.3.3.2 **Thin-converter tray panel transparency**

Similarly, the corresponding thickness for thin converter tray panels and tray panels for trays with no converter shall not exceed 0.35% R.L.
5.3.4 **Tray Panel Cores**

5.3.4.1 **Tray panel core material**

The panel cores shall be made from ventilated aluminum honeycomb.

5.3.4.2 **Tray panel core grounding**

The core shall make good electrical contact with the screws that attach the TMCM to the closeouts via plated-through holes in the TMCM.

5.3.5 **Tray Panel Face Sheet material**

The tray panel face sheets shall be made from graphite fiber reinforced plastic material (GFRP).

5.3.6 **Tray Panel Closeouts**

5.3.6.1 **Closeout material**

The tray panel closeouts shall be made from carbon-carbon material into which the interfaces for TMCM and tower-sidewall attachment are machined.

5.3.6.2 **Closeout fastener inserts**

Metal inserts shall be used for the fasteners that attach the tower sidewalls to the closeouts.

5.3.6.3 **Closeout fastener pullout strength**

Each fastener for mounting the panel to the tower sidewalls shall have a pullout strength of at least 150 N.

5.3.6.4 **Closeout transparency**

The average thickness of a closeout side shall not exceed 2.0% R.L., including inserts.

5.3.6.5 **Closeout thermal conductivity**

Assuming a maximum of 0.35 W of power dissipation per TMCM, the temperature drop from the TMCM to the contact point with the tower sidewall shall not exceed 0.5°C.

5.3.6.6 **Closeout thermal contact to sidewalls**

The temperature drop in the interface between closeout and tower sidewall shall not exceed 0.25°C.

5.3.7 **Particulates and Contamination Requirements**

5.3.7.1 **Passivation of carbon-carbon surfaces**

All machined carbon-carbon surfaces to which adhesives will not be applied shall be coated to prevent the release of carbon dust.
5.3.7.2 Containment of carbon fibers

The cut edges of face sheets and tower sidewalls shall be filleted with epoxy to prevent the release of carbon fibers.

5.3.8 SSD Specification

The complete SSD specification is given in LAT-DS-00011.

5.3.9 SSD Mounting on Trays

5.3.9.1 SSD Configuration

The SSD configuration shall be a four-by-four grid, with four detectors bonded together as a ladder and four of the ladders bonded to the bias circuit on the tray surface.

5.3.9.2 SSD Bonding

The SSD’s shall be bonded to the bias circuit with compliant silicone-based adhesive of at least 100 µm thick bond-line, to ensure minimal thermally induced stress in the silicon (<7 MPa).

5.3.9.3 Conductive Path for Detector Bias

Part of the adhesive bond shall be conductive, with $R < 3 \Omega$, to bias the backsides of the SSD’s.

5.3.9.4 Parallelism of SSD Layers

The surfaces of the SSD’s from one side of the tray to the other shall be parallel to ±0.200 mm.

5.3.9.5 SSD Ladder Stay Clear

Ladders shall be positioned on a tray within a rectangular stay-clear that is 89.60 mm in width and 358.23 mm in length.

5.3.9.6 SSD Ladder Alignment

The ladders shall be parallel to the tray as defined by the face of the closeouts to ±0.050 mm.

5.3.10 Wire-Bond Encapsulation

All wire bonds, between detectors, from detectors to the pitch adapter, from the pitch adapter to the ASICs, and from the ASICs to the TMCM printed wiring board, shall be encapsulated. Wire bond encapsulation on the TMCM shall be done with a hard-curing epoxy adhesive to protect the wire bonds from damage during cable attachment.

5.3.11 Electrical Insulation

All electrical traces, including TMCM and flex-circuit traces, electrical-component contacts, solder joints, and connector pins shall be coated with insulating material.
5.3.12 Converter Configuration

5.3.12.1 Converter Material
The converter material shall be tungsten, of at least 90% purity.

5.3.12.2 Converter Foil Size
Each converter foil shall match the size of the active area of the detector positioned just above it.

5.3.12.3 Converter Foil Alignment
The position tolerance of the tungsten converter material relative to the SSD below it shall be 0.100 mm.

5.3.12.4 Converter Foil Thickness
The lowest 2 \(x,y\) planes shall have no converter, 4 \(x,y\) planes above them shall have 18% R.L. converters, and the remaining 12 \(x,y\) planes shall have 3.0% R.L. converters.

5.3.12.5 Converter Foil Thickness Tolerance
The thickness of the converter shall be maintained to a tolerance of 0.050 mm for thick converters and 0.025 mm for thin converters.

5.3.12.6 Converter Foil Grounding
Each converter foil shall make electrical contact with the face sheet to which it is bonded.

5.4 Thermal Requirements

5.4.1 Tower Cooling Path
The path for passive cooling of the tower shall be from the TMCM, through the closeout, into the tower sidewalls, and through the bottom tray closeout to the Grid. The five outer surfaces of the Tower shall be painted with a conductive black paint with a minimum infrared emittance of greater than 0.8.

5.4.2 Maximum SSD Temperature
The maximum operational temperature of the SSD’s shall be 30°C.

5.4.3 Maximum Temperature Rise in a Tower
The maximum temperature rise from the Grid to the SSD’s shall be 9.5°C, assuming no more than 0.25 W of power dissipation per TMCM.

5.4.4 Tower Attachment to the Grid and Differential CTE Accommodation
The attachment of the tower to the Grid shall be done such that the aluminum Grid may expand and contract within the qualification temperature test range while imparting minimal stress in
the carbon-fiber Tracker structure and while maintaining the centering of a Tracker tower in a Grid cell to 100 µm.

5.5 EMI Protection

Each Tracker tower shall be covered on all 6 sides by at least 50 µm of aluminum electrically connected to the Grid.

5.6 Electronics Mechanical Interface Requirements

5.6.1 TMCM Mounting

The electronics module (TMCM) for reading out the SSD’s shall be mounted to the closeout on the side of the tray.

5.6.2 TMCM Insulation from the Closeout

At least 50 µm of electrical insulator shall separate the backside trace layer of the TMCM PWB from the closeout wall.

5.6.3 TMCM Alignment for Wire Bonding

The wire-bonding edge of the mounted TMCM shall be parallel to the wire-bond pad row of the SSD’s to a precision of 100 µm over the tray length, and the TMCM wire bonding pad height shall be within 300 µm of the SSD pad height.

5.6.4 Readout Cable Thickness

The Tracker electronics readout cables shall be no more than 800 µm thick.

5.7 Tracker Electronics Requirements

The detailed Tracker electronics requirements are in LAT-SS-00152.

5.8 Environmental Requirements

The environmental conditions described here encompass the normal (or standard) ground and launch conditions that the tracker may be subjected to during spacecraft integration and launch. Ground environment covers the conditions the tracker could possibly endure once it is delivered for spacecraft integration and test. The tracker will be expected to sustain the on-orbit conditions for the duration of its operational life.

For the purpose of environmental testing, a Tracker tower module and a Tracker tray are considered to be “primary structure.”

5.8.1 Ground Environmental

5.8.1.1 Ground - Handling Vibration and Shock

The Tracker shall be handled per controlled procedures during all phases of ground processing to minimize exposure to structural and mechanical loads.
5.8.1.2 **Ground - Transportation Vibration and Shock**

The structural and mechanical loads that the Tracker is exposed to during transportation shall be no greater than the launch loads given LAT-SS-00778. The transportation dynamic environment shall be monitored to ensure compliance.

5.8.1.3 **Ground - Temperature and Humidity**

The Tracker shall be housed in environmentally controlled and monitored facilities during all phases of ground processing. The following sections give the temperature and humidity environments to which the instrument may be exposed during ground operations.

5.8.2 **Temperature and Humidity**

The operating and survival temperatures to which the tracker must be tested are specified in LAT-SS-00778.

5.8.2.1 **Storage/Transportation Temperature**

The range of temperatures to which the Tracker may be exposed during storage and transportation is listed in LAT-SS-00778.

5.8.2.2 **Storage/Transportation Relative Humidity**

The relative humidity of the environment surrounding the Tracker during storage and transportation is listed in LAT-SS-00778.

5.8.2.3 **Assembly and Integration Temperature**

The range of temperatures to which the Tracker may be exposed during assembly and integration activities is listed in LAT-SS-00778.

5.8.2.4 **Assembly and Integration Relative Humidity**

The relative humidity of the environment surrounding the Tracker during assembly and integration activities is listed in LAT-SS-00778.

5.8.2.5 **Launch Vehicle Temperature**

The range of temperatures to which the Tracker may be exposed while on the launch vehicle is 13 to 27 °C.

5.8.2.6 **Launch Vehicle Relative Humidity**

The relative humidity of the environment surrounding the instrument while on the launch vehicle shall be in the range 40% to 55%.

5.8.2.7 **Ground Processing Rate of Change**

The magnitude of the rate of change of temperature to which the instrument may be exposed during all phases of ground processing shall be less than 5°C/hour. *(Instrument safety constraint)*
5.8.3 **Launch - Static Load**
These requirements may be found in LAT-SS-00778.

5.8.4 **Launch - Random Vibrations**
These requirements may be found in LAT-SS-00778.

5.8.5 **Launch - Acoustic Loads**
These requirements may be found in LAT-SS-00778.

5.8.6 **Launch – Shock**
These requirements may be found in LAT-SS-00778.

5.8.7 **Launch – Pressure Variation**
The tracker shall withstand the time rate of change of pressure in the launch vehicle fairing shown in the Delta II Payload Planner's Guide, Section 4.2.1, Figure 4.2.

5.8.8 **On-Orbit - Charged Particle Radiation**

5.8.8.1 **Total Radiation Dose**
The design of the tracker shall use a multiplicative factor of 4, as specified in [1], applied to the total dose estimate to yield the required design margin. The estimated total dose for the anticipated 5-year GLAST mission is given in [1] as a function of shielding thickness. The tracker shall use a conservative estimate of shielding around the silicon-strip detectors to derive a dose level for testing of the detectors (which are by far the tracker items most sensitive to radiation dose).

5.8.8.2 **Single-Event Effects (SEE) Immunity**
The tracker electronics shall be designed and tested to satisfy the SEE immunity requirements specified in [1].

5.8.9 **Outgassing**
All materials used in the Tracker shall meet the NASA outgassing requirements.
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### Table 3. Continuation of Verification Methods

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