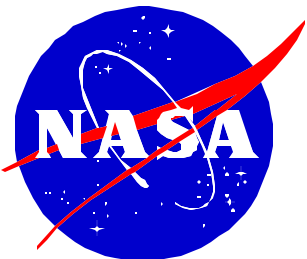


**GAMMA-RAY LARGE AREA
SPACE TELESCOPE
(GLAST)
PROJECT**

**LARGE AREA TELESCOPE (LAT)
INSTRUMENT – SPACECRAFT
INTERFACE REQUIREMENTS DOCUMENT**

JANUARY 29, 2001



**GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND**

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GAMMA-RAY LARGE AREA SPACE TELESCOPE
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NASA Goddard Space Flight Center
Greenbelt, Maryland

433-IRD-0001

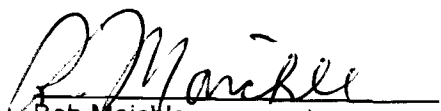
GLAST PROJECT LAT INSTRUMENT – SPACECRAFT IRD

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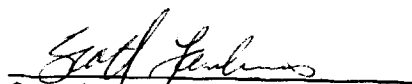
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ACRONYM LIST

APID	Application Identifier
ACD	Anticoincidence Detector
ACS	Attitude Control Subsystem
bps	bits per second
C&DH	Command and Data Handling
CCSDS	Consultative Committee for Space Data Systems
CG	Center of Gravity
CTDB	Command, Telemetry and Data Bus
Dec	Declination
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FDIR	fault detection isolation and recovery
g	gravity
GBM	GLAST Burst Monitor
GEVS-SE	General Environmental Verification Specification for SDTS and ELV Payloads, Subsystems and Components
GLAST	Gamma-ray Large Area Space Telescope
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Hz	Hertz
IGES	International Graphics Exchange Specification
IR	Infrared
IRD	Interface Requirements Document
k	kilo
kg	kilogram
LAT	Large Area Telescope
m	meter
mm	millimeter
M	Mega
MECO	Main Engine Cut Off
Mil Std	Military Standard
PDR	Preliminary Design Review
PMT	Photomultiplier tubes
PPS	Pulse Per Second
RA	Right Ascension
SC	Spacecraft
SI	Science Instrument
sr	Steradian
TBD	To Be Determined
TBR	To Be Resolved
TDRSS	Tracking and Data Relay Satellite System
TSS	Thermal Synthesizer System
UTC	Universal Coordinated Time
UV	Ultra Violet
V	Volt
W	Watt

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1 INTRODUCTION

1.1 PURPOSE

The primary purpose of this Interface Requirements Document (IRD) is to describe and specify the interfaces between the LAT instrument and the spacecraft. However, it also provides the launch vehicle constraints on these system elements, provides design guidelines in certain areas. In addition, it assigns certain interface responsibilities.

The current version of this document is the means by which instrument accommodation requirements are communicated to a number of spacecraft study contractors. At the same time it serves to identify the interface standards to which the instrument is designed and to obtain confirmation of them from the spacecraft study contractors.

1.2 RELATION TO OTHER DOCUMENTS

The requirements in this document normally flow down directly to instrument and spacecraft systems from either the Science Requirements Document or the Mission System Specification. In addition, either the Instrument Performance Specification or the Spacecraft Specification may levy peer requirements.

Since the IRD was written before most of the above documents came into being, the IRD presently contains some requirements that properly belong in some of these other documents. At the present time, those requirements are only in this document, and therefore this document must be used as a companion document. As other requirements documents are established and mature, those requirements can be expected to migrate from this document to those documents where they properly belong.

2 APPLICABLE DOCUMENTS

Requirements in this Specification are traceable to the following documents:

GLAST Science Requirements Document

GLAST Mission System Specification

GLAST Spacecraft Performance Specification

GLAST Mission Concept Review Presentation Package, September 28, 1998

Delta II Payload Planners Guide <http://www.boeing.com/defense-space/space/delta/delta2/guide/index.htm>

GEVS-SE Rev A General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components <http://arioch.gsfc.nasa.gov/302/gevs-se/toc.htm>

CCSDS 102.0-B-4 Recommendation for Space Data Systems Standards. Packet Telemetry <http://www.ccsds.org/publications.html> - telemetry

CCSDS 202.0-B-2 Recommendation for Space Data Systems Standards. Telecommand, Part 2: Data Routing Service <http://www.ccsds.org/publications.html> - telecommand

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CCSDS 701.0–B–2, “Recommendation for Space Data Systems Standards. Telecommand, Part 3: Data Management Service.” CCSDS Recommendation, Blue Book.

CCSDS 101.0–B–3, “Recommendation for Space Data Systems Standards. Telemetry Channel Coding.” CCSDS Recommendation, Blue Book

CCSDS 201.0–B–2, “Recommendation for Space Data Systems Standards. Telecommand, Part 1: Channel Service.” CCSDS Recommendation, Blue Book.

CCSDS 202.1–B–1, “Recommendation for Space Data Systems Standards. Telecommand, Part 2.1: Command Operation Procedures.” CCSDS Recommendation, Blue Book.

LAT Data Format Document (TBS)

Mil-STD-1553B, Aircraft Internal Time Division Command/Response Multiplex Data Bus, 21 September, 1978

Mil-STD 461E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

Electromagnetic Interference (EMI) Requirements Document for the GLAST Satellite, Draft

NASA HDBK 4001. Electrical Grounding Architecture for Unmanned Spacecraft, February 17, 1998
<http://starbase.msfc.nasa.gov/TSL/dispsearch.htm?agency=NASA&disp=E>

3 REQUIREMENTS

3.1 DEFINITION OF FLIGHT SYSTEM

3.1.1 SYSTEM MODULES

There are three major system modules in the GLAST flight system, a spacecraft module a Large Area Telescope module, and a GLAST Burst Monitor (GBM) module, as shown in Figure 3-1. These modules will be built separately, by different contractors. When integrated, these modules form the GLAST observatory. The large area telescope module is referred to as the primary science instrument in this document. Also shown in this figure, is the coordinate system for the observatory.

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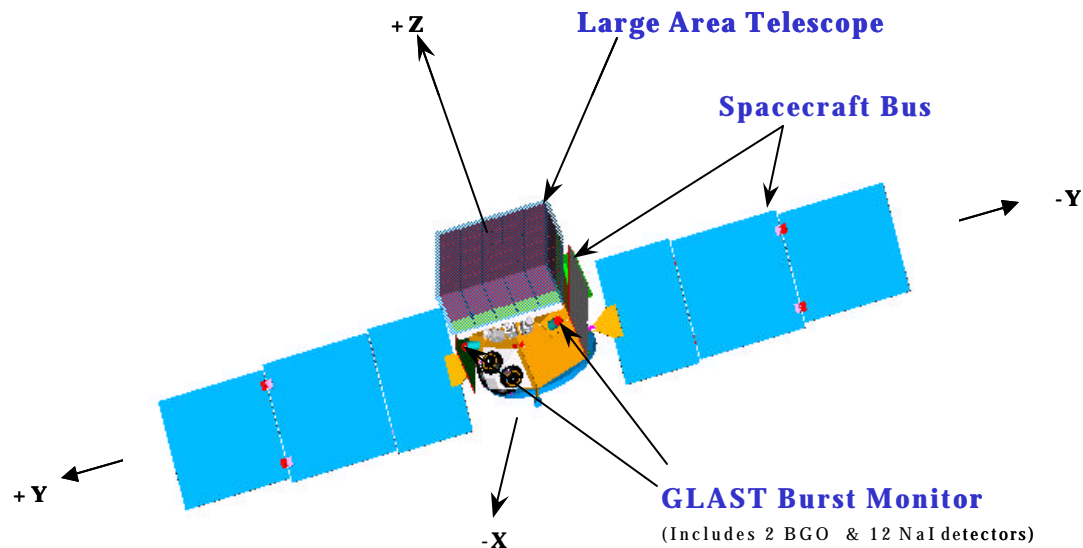


Figure 3-1. Flight System Modules

3.1.2 FLIGHT SYSTEM INTERFACES

The flight system is defined as “everything that flies”, instruments, spacecraft, and launch vehicle. Figure 3-2 shows these components of the flight system and the interfaces between them. It also shows that the flight system has in-flight interfaces with the TDRSS communications satellite system, with direct ground stations, and with the constellation of GPS satellites. Arrows are used in the figure to indicate generally an accommodation requirement. The spacecraft must directly accommodate the launch vibration environment, fairing envelope, and mounting configuration of the payload attach fitting. While on the launch pad, it receives umbilical power and communicates through the umbilical for command and telemetry.

The instruments also have direct interfaces with the launch vehicle as they must accommodate the radiatively coupled launch environment (acoustics, pressure, and temperature) and the fairing envelope. The spacecraft must accommodate the instruments’ mechanical mounting, field of view requirements, and their thermal interface requirements. Additionally, the spacecraft provides power services and command and telemetry services to the instruments. This document addresses the spacecraft-to-LAT science instrument interfaces.

The interfaces between the LAT and GBM instruments are TBD. The spacecraft interfaces with direct ground stations for the downlink of high rate telemetry data. It interfaces with TDRSS when communications are needed at unscheduled times or when coverage is needed over a greater portion of the orbit than the direct downlink provides. The demand access service of TDRSS is used for unscheduled alert transmissions, both safe mode and transient events, and for unscheduled target-of-opportunity commanding.

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Extended coverage is needed during launch and early orbit operations, during any safe mode contingency operations, and for servicing the primary instrument (diagnostics, software uploads).

Finally, the spacecraft receives time and position services continuously throughout the mission from the GPS. The spacecraft distributes a pulse-per-second signal via hardware to provide an accurate time mark.

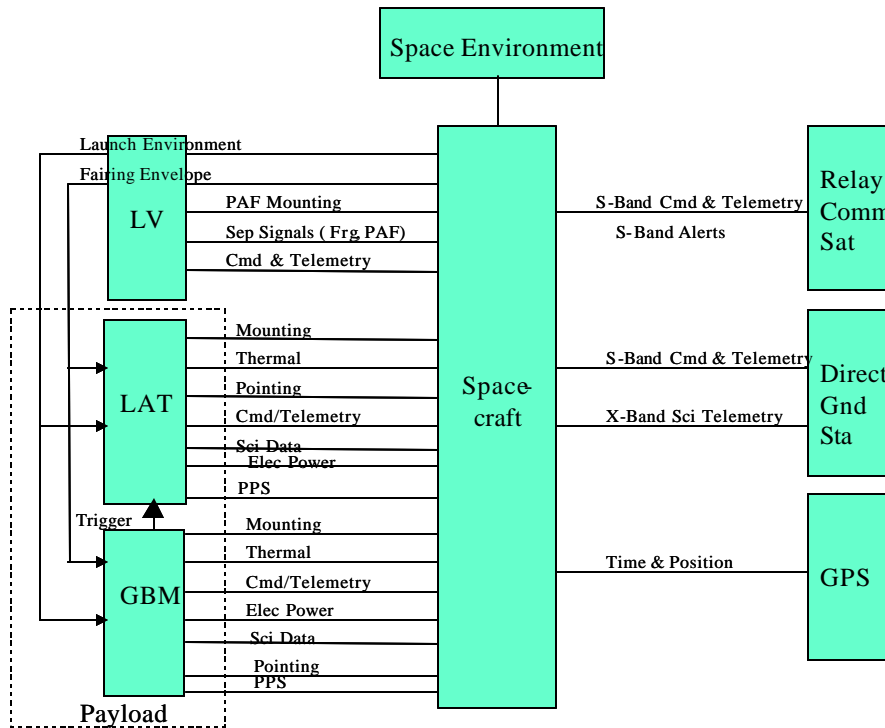


Figure 3-2. Flight System Interfaces

3.2 INTERFACE REQUIREMENTS AND CONSTRAINTS

3.2.1 GENERAL INTERFACE REQUIREMENTS

3.2.1.1 Axes Definitions

The LAT and SC shall use a common definition of right-handed orthogonal axes as shown previously in Figure 3-1. The Z-axis passes through the geometric center of LAT and SC. This axis is defined as the boresite axis of the observatory. The Y-axis is perpendicular to the Z-axis and is aligned with the axis of solar array rotation. The X-axis is orthogonal to the Y and Z-axes. The observatory shall maintain the sun line in the X-Z plane on the +X axis in the normal operating modes.

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3.2.1.2 Celestial Coordinates

The observatory shall use celestial coordinates relative to the J2000 coordinate frame. Pointing commands to the observatory and pointing directions reported by the observatory shall be by Right Ascension (RA) and Declination (Dec) in J2000 coordinates.

3.2.1.3 Pointing Knowledge

The knowledge of the observatory pointing at any time, including during slew, shall be such that the total error is < 10 arcseconds [1σ radial]. This error budget includes:

The intrinsic resolution of the star tracker system; and

The relative alignment of the star tracker system with the LAT reference surface.

The relative alignment of the star tracker system and the LAT reference surface shall be calibrated on orbit using celestial sources as part of the early operations checkout and on a periodic basis throughout the mission.

The stability of the relative alignment between the star tracker system and the LAT reference surface, including all thermal-mechanical effects, shall be < 5 arcseconds [1σ diameter] throughout the mission, and allocated as specified in the Mission System Specification.

The observatory's pointing knowledge budget shall be allocated as specified in the Mission System Specification.

3.2.1.3.1 Jitter

Over periods less than 200 milliseconds, the jitter shall be less than 1 arcsec (TBR), 1σ radial. Jitter is defined as the high-frequency motion of the instrument line of sight caused by any of the spacecrafts moving components (i.e. – solar arrays, high gain antenna, reaction wheels, etc.).

3.2.1.3.2 Slew Rate

The slew rate shall be as defined in the Spacecraft Performance Specification.

3.2.1.4 Math Models

Mathematical models shall be readily exchanged electronically between the LAT and SC contractors and the GSFC. This requires the use of common design tools and versions for file format compatibility. Alternate formats are acceptable only when approved by the Project Office. Exchange of mechanical design information shall primarily use the IGES neutral file format (bounded surface models). Other formats, such as the STEP file format, may also be required.

3.2.2 MECHANICAL

3.2.2.1 Fairing Envelope Constraint

The fairing envelope constraints shall be followed as shown in the reference document, Delta II Payload Planners Guide for the 3-meter fairing.

The maximum lateral, X-Y, dimensions of the LAT shall be constrained to 1.8 m, as shown in millimeters in Figures 3-3 and 3-5. Note that the clearance between the LAT and fairing is reserved for solar arrays or other spacecraft components. The maximum Z dimension of the LAT shall be constrained to 3.15 m. The Z dimension is based on an overall maximum height of 4.55 m for the observatory in the 3-m fairing of the Delta II, and an allocation of 1.4 m for the SC.

3.2.2.2 Envelope of Primary LAT

Figures 3-3, 3-4 and 3-5 show the stay-clear dimensions of the LAT, around which the SC and the instrument interface structure must fit. Note that figure 3-3 shows regions for access to the instrument for electrical integration and test with the spacecraft. These access regions shall not be occluded by any permanent SC structures. LAT-provided, removable thermal and micrometeorite shields will cover this region after all testing is complete.

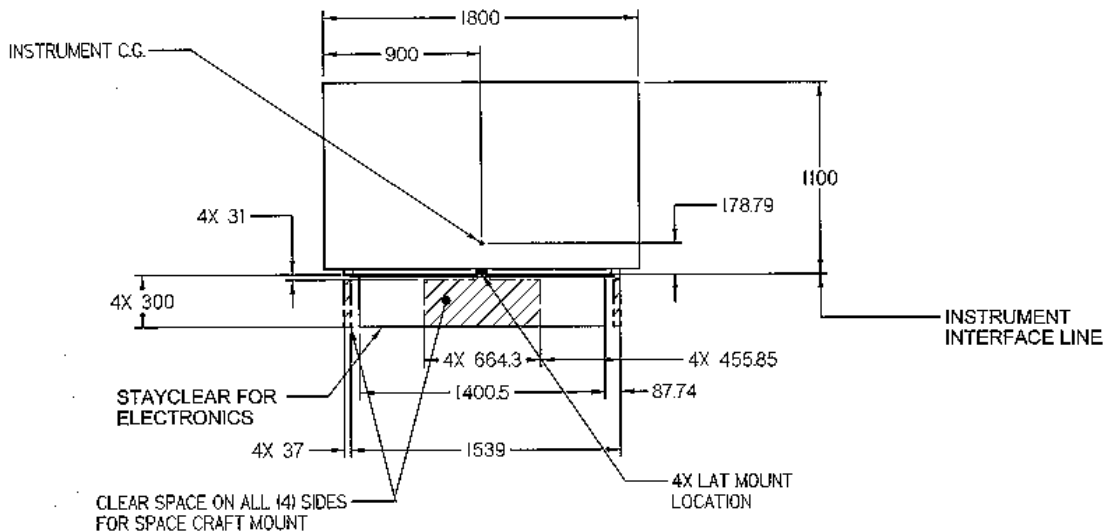
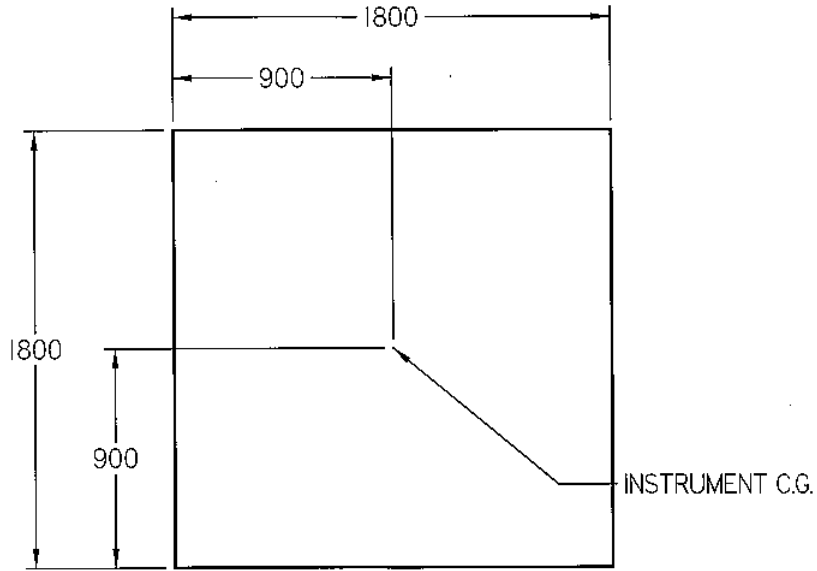


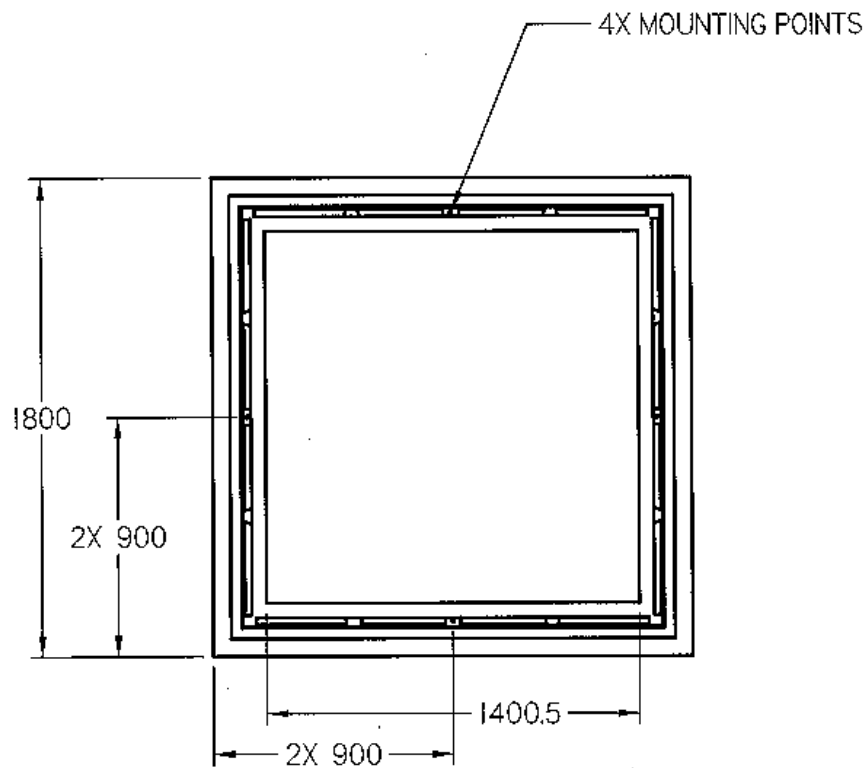
Figure 3-3. Elevation View of LAT (dimensions in mm)

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TOP VIEW

Figure 3-4. Top View of LAT (dimensions in mm)



BOTTOM VIEW

Figure 3-5. Bottom View of LAT (dimensions in mm)

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3.2.2.3 LAT Instrument Interface Structure

An interface structure shall adapt the structural configuration of the LAT to that of the SC and provide mounting support for the LAT. Mounting locations for the LAT are shown in Figures 3-3 and 3-5. The interface structure shall accommodate the routing of electrical cables and dedicated thermal links between the SC and LAT as well as provide access to such components for integration. The SC contractor shall provide the instrument interface structure.

3.2.2.4 LAT Mass Constraint

The maximum launch mass of the LAT shall be constrained to 3000 kg. This does not include the instrument interface structure, but does include any LAT hardware mounted on the SC bus, such as thermal radiators and electronics boxes.

3.2.2.5 CG Constraints

The observatory shall meet the payload requirements of the Delta II 2920-10 launch vehicle with the 6915 PAF and 3-meter fairing. The center of gravity (CG) requirements shall be adhered to as described in the Delta II Payload Planners Guide.

Note the instrument interface plane as shown in Figure 3-3 is the plane of attachment of the Instrument Interface Structure, but does not constitute the mass boundary of the LAT.

The Z-axis location of the center of gravity of the LAT instrument as shown in Figures 3-3 and 3-4 shall not exceed the value from the Delta II Payload Planners Guide for the 2920-10 launch vehicle from its interface plane.

While meeting the observatory constraint, the spacecraft shall accommodate the LAT's center of gravity location.

3.2.2.6 Clear Field of View

In the deployed configuration on orbit, the LAT shall have a minimum clear field of view of 2π sr (TBR) centered on the Z-axis above the instrument mounting plane. The spacecraft shall not introduce any fixed material above this plane, such as solar array restraint mechanisms. The rotation envelope of the solar arrays shall be kept below the instrument-mounting plane.

3.2.2.7 Alignment

The relative alignment of the star tracker system and the LAT reference surface shall be surveyed on the ground and maintained to < 30 (TBR) arcminutes [1σ diameter] during environmental testing and launch to orbit.

3.2.2.8 Structural Design Requirements

3.2.2.8.1 Stiffness

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3.2.2.8.1.1 Observatory

The fixed base stiffness of the SI-SC system shall produce a first mode frequency greater than 35 Hz, axial, and greater than 12 Hz, lateral.

3.2.2.8.1.2 LAT

The fixed base stiffness of the LAT shall produce a first mode frequency greater than 50 Hz.

3.2.2.8.1.3 SC

The fixed base stiffness of the SC shall produce a first mode frequency greater than 50 Hz.

3.2.2.8.2 Static Load Design

The design of the LAT primary structure shall use the quasi-static limit load factors in Table 3-1 applied at the center of gravity of the LAT. Loads are given in units of gravitational acceleration, $g = 9.81 \text{ m/s}^2$.

Table 3-1. **Design Limit Loads**

Event	Liftoff/Transonic	MECO
Axis		
Thrust	+3.25/-0.8	+6.0 ± 0.6
Lateral	± 4.0	± 0.1

Thrust and lateral loads shall be applied simultaneously in all combinations. In the thrust axis “+” indicates compression and “-” indicates tension.

The design of secondary instrument structure and components shall use a limit load factor of ± 12.0 g applied to each axis independently.

The LAT primary structures include the LAT support Grid, ACD, radiators, and Thermal/Micrometeorite Shield. Secondary structures include subsystem structures and components.

3.2.2.8.3 Factors of Safety

Factors of safety are multiplicative factors that are applied to limit loads to evaluate the yield and ultimate strength levels of the structural design. Guidelines for the appropriate use of factors of safety are given in the referenced GEVS-SE Rev A document.

3.2.2.8.4 Component Evaluation Random Vibration

The evaluation of components shall use the generalized random vibration power spectral density in GEVS-SE.

3.2.2.8.5 Acoustics

The acoustic spectrum is given in GEVS-SE for the Delta II launch vehicle.

3.2.2.8.6 Pyroshock

The pyroshock spectrum is given in GEVS-SE for the Delta II launch vehicle.

3.2.2.8.7 Finite Element Model

A finite element model of the LAT in a TBD file format shall be delivered electronically by February 26, 2001 (TBR), to the GLAST Project Office at GSFC. This model is required so that the SC contractor may combine a finite element model of the SC and perform a preliminary coupled loads analysis.

3.2.2.8.8 Observatory Level Integration and Testing

For appropriate operation of the LAT radiators during Observatory Level Integration and Testing, the observatory's +Z-axis shall be oriented towards the earth (i.e.- the observatory shall be oriented upside down). The LAT's handling procedures during observatory integration and testing are TBD.

3.2.3 THERMAL

3.2.3.1 LAT Thermal Design

The design and performance of the LAT thermal system shall be the responsibility of the LAT engineering team. The LAT thermal system is defined to include all LAT surfaces and thermal links that affect the LAT heat balance. The LAT thermal system includes all dedicated LAT radiating surfaces that may be located on the SC module as well as all thermal interfaces and links that transport heat from these surfaces to the LAT. The radiators shall be sized to allow for heat backloading from the solar arrays, Earth IR, and UV albedo energy.

The LAT and SC shall be thermally isolated via SC support structures. A maximum of +5 watts (TBR) heat flow shall be permitted to conductively flow from the SC to the LAT at the worst-case operational temperature range limits of the LAT and SC. The total conductive heat exchange between the SC and LAT, including cables and the interface support structure, shall not exceed +5 watts; assuming LAT interface temperatures

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ranging from +50C to -20C. The +5 watt maximum does not include the heat exchange between the LAT radiator and the SC.

The worst case heat “backloading” from the solar arrays shall not exceed TBD.

The SC module shall provide the thermal isolation hardware. Preliminary thermal design shall use the environmental parameters of Table. 3-2.

Table 3-2 **Thermal Design Parameters**

Thermal Flux Source	Hot Case	Cold Case
Solar Constant	1419 W/m ²	1286 W/m ²
Albedo Factor	0.40	0.25
Earth IR	265 W/m ²	208 W/m ²

3.2.3.1.1 Math Models

A TSS geometry model and SINDA thermal model of the LAT shall be delivered electronically, by January 30, 2001 (TBR), to the GLAST Project Office at GSFC. This model is required so that the SC contractor may combine the instrument thermal model with the SC model so that an integrated thermal analyses may be performed.

3.2.3.2 LAT Radiator Accommodations

The SC shall accommodate the LAT’s thermal radiators.

3.2.3.2.1 Size and Configuration

The LAT radiators’ total radiating surface area shall be 5.4 m² (TBR). This area shall be configured as 2 separate radiators.

3.2.3.2.2 Location

Radiating surfaces shall be parallel to the sides of the LAT. The radiators shall be mounted on the spacecraft bus. The LAT radiators will be located in the X-Z planes (normal to the Y-axes) of the observatory. (Note that the observatory will maintain the sun line in the X-Z plane on the +X-side in the normal operating modes, sky survey mode and pointed observation mode.)

3.2.3.2.3 Mounting

The SC shall provide mounting brackets and mounting thermal isolation as required for the LAT radiators and their thermal links. Mounts shall be designed to permit less than 5 watts heat flow to the instrument radiator assuming that the spacecraft temperature is maximum and the instrument radiator temperature is -40 degrees C. Mount point locations on the radiators are TBD. The solar arrays shall be configured to minimize the

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view factor to the LAT radiators. The view factor to the solar arrays to each radiator panel shall not exceed 0.10.

3.2.3.2.3.1 *Field of View*

The SC shall provide the LAT radiators with a clear field of view of 2π sr (as specified in the Science Requirements Document), except for solar arrays, centered on each radiator normal. Mounting hardware shall be part of the spacecraft budget.

3.2.3.3 Thermal Verification Requirements

Thermal/vacuum test environments for LAT and SC verification testing, as well as LAT/SC combined verification tests shall be according to GEVS-SE Rev A.

During Observatory-level thermal vacuum testing, the LAT +Z-axis shall be aligned with the gravity force vector, ie. +Z-axis pointed towards the earth.

3.2.3.4 Ground Environments

3.2.3.4.1 Ground Storage Temperature

During observatory-level integration, storage, and pre-launch activities, the spacecraft provider shall maintain the LAT's ground storage temperature between 0 degrees C and +40 degrees C (TBR).

3.2.3.4.2 Humidity

The minimum relative humidity shall be no less than 20% (TBR). The maximum relative humidity shall not exceed 60% (TBR).

3.2.3.4.3 Normal Operating Temperature

The LAT's normal operating temperature range shall be between -10 degrees C and $+25$ degrees C (TBR).

3.2.3.4.4 Survivability Temperature

The LAT's survival temperature range shall be between -20 degrees C and $+40$ degrees C (TBR).

3.2.3.5 Thermal Model

A TSS geometry model and SINDA thermal model of the LAT shall be delivered electronically, by February 26, 2001 (TBR), to the GLAST Project Office at GSFC. This model is required so that the SC contractor may combine the instrument thermal model with the SC model and an integrated thermal analyses may be performed.

3.2.4 ELECTRICAL

3.2.4.1 Bus Voltage

The bus voltage supplied to the LAT shall be $28\text{ V} \pm 6\text{ V}$ as seen at the input terminals of the LAT. The LAT shall perform when subjected to voltage transients per CS116 requirements specified in TBD. Under abnormal conditions the LAT shall survive, without permanent degradation, steady-state voltages in the range: $0 < V < 38$ (TBR) VDC.

3.2.4.2 Bus Current

3.2.4.2.1 Overcurrent Protection

The spacecraft shall provide protection of the spacecraft power system by providing overcurrent protection devices on each LAT power connection. The sizes and characteristics of the overcurrent protection devices shall be TBD.

3.2.4.2.2 LAT Current Transients

The following LAT requirements shall be measured when supplied by a voltage source having the impedance characteristics of the spacecraft power source:

LAT current peaks associated with both turn-on inrush current and non-repetitive operational current transients shall not exceed TBD.

During normal operations the LAT shall limit current transient rate of change to TBD.

The LAT shall limit turn-on inrush current transient rate of change to TBD.

The LAT shall limit turn-off current transient rate of change to TBD.

3.2.4.3 Impedances

3.2.4.3.1 Power Source Impedance

The PSE output impedance shall be less than 70 milli-ohms to 3kHz (TBR).

3.2.4.3.2 LAT Power Input Impedance

The LAT power input filter shall present a symmetrical common mode and differential mode impedance to the power bus, as represented by the AC impedance of the differential mode and common mode input filters.

3.2.4.3.3 LAT Common Mode Impedance

TBD

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3.2.4.3.4 LAT Differential Mode Impedance

TBD

3.2.4.4 Power Constraints

3.2.4.4.1 Peak Power

The peak power of the LAT shall not exceed 1000 W (TBR).

3.2.4.4.2 Peak Power Duration

The maximum duration for the peak power dissipation of the LAT shall not exceed 10 minutes (TBR) for each orbit.

3.2.4.4.3 Average Power

The average power dissipation of the SI shall not exceed 650 W (TBR) per orbit.

3.2.4.5 Primary Power Distribution

The SC shall provide one prime and one redundant switched service to the LAT. These services are mutually exclusive in that only one is active at a time. Fault propagation shall not proceed beyond the failure interface. The design of the LAT shall preclude damage to the LAT if both services are active at the same time. The design of the LAT shall also preclude damage to the LAT if power is removed instantaneously without warning.

3.2.4.6 Survival Heater Power Bus

The SC shall provide a separate, redundant Survival Heater Power Bus to the LAT. Survival power is used only for heaters and associated passive control circuitry that maintain the LAT at a minimum turn-on temperature.

Each side of the Survival Heater Power Buses shall be continuously powered during flight.

Survival heaters shall be redundant. Survival heaters shall be electrically isolated from each other and from chassis. Survival heaters shall have independent power returns.

The LAT's survival heater power shall not exceed 150 W (TBR).

The SC shall provide flight software and ground-commandable interfaces which power the survival heaters on and off.

3.2.4.7 Isolation

The LAT shall provide secondary power converters that isolate secondary from primary power returns. Secondary returns shall be isolated from primary returns by $> 1 \text{ M}\Omega$ (TBR) at dc.

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3.2.4.8 Grounding

The observatory shall employ a “hard-grounded” primary ground system with multiple connections in the secondary systems. Figure 3-6 shows the configuration of the ground system. Observatory structure or an electrically conductive ground plane, known as chassis ground, shall provide the ground reference. The primary power system shall be connected to chassis ground at a single point at dc by $< 10 \text{ m}\Omega$ resistance(s) and at ac by an impedance of TBD $\text{k}\Omega$ (TBR frequency). Secondary loads shall each be referenced to chassis ground by a single connection. The chassis ground system shall not be used to conduct load current. The maximum ungrounded surface area, e.g., for MLI, shall be $< 10 \text{ cm}^2$ (TBR).

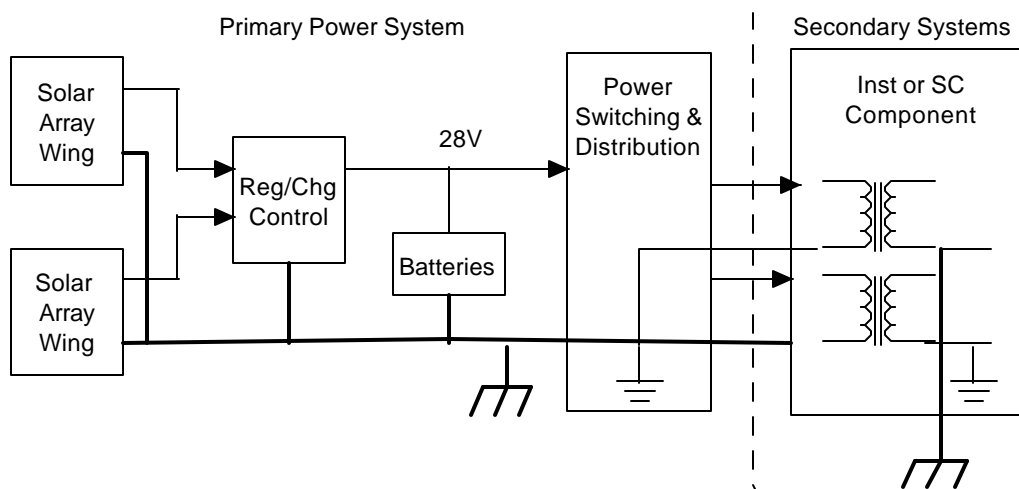


Figure 3-6 Single Reference Ground System with Multiple Connections (TBD)

3.2.4.9 EMC

The SC shall be consistent with the Electromagnetic Compatibility (EMC) guidelines defined in the General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components (GEVS-SE) and the Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment (MIL-STD-461E). Detailed requirements shall be documented in the Electromagnetic Interference (EMI) Requirements Document for the GLAST Satellite.

The spacecraft shall not generate a magnetic field larger than 1 gauss (TBR) at the location of the photomultiplier tubes (PMTs) in the AntiCoincidence Detector (ACD) of the LAT instrument. The PMTs are currently envisioned to be located in a structure which wraps around the perimeter of the LAT's grid.

3.2.4.10 LAT Harness

The spacecraft shall provide fully assembled LAT interface cables with mating connectors. The mass of the LAT interface cables shall be part of the spacecraft mass budget.

3.2.4.11 C&DH Interfaces

This section describes the physical interface requirements for the C&DH services, which include the science data, command and telemetry, time mark and frequency and any discrete interfaces.

3.2.4.11.1 Interface Conductors

Signal conductors shall use paired conductors. Paired conductors may include twisted pair, coaxial, twin axial, and dual coaxial types.

3.2.4.11.2 Interface Circuitry Isolation

TBD

3.2.4.11.3 Physical Characteristics of Interface Signals

TBD

3.2.4.12 Test Point Interfaces

The SC or LAT may elect to use test points to provide external access to internal circuitry via GSE. Use of test points shall meet the following requirements.

3.2.4.12.1 Spacecraft Integration and Test Use

Test points shall not be used during spacecraft integration and test, except as expressly approved and documented in formal procedures.

3.2.4.12.2 Performance Verification Limit

Data collected to verify acceptance or qualification of performance requirements shall be acquired through flight interfaces and not through test point interfaces.

3.2.4.12.3 Keyed Connectors

All test points shall be brought out to a separated, keyed connector(s), which shall be easily accessible.

When the LAT is integrated to the SC, any LAT to SC connector on the LAT side shall be mated and de-mated without requiring any other LAT to SC connector to be de-mated. Any exceptions to the prior statement must first be presented to the Project Office on a case-by-case basis and then receive authorization.

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Separate test connectors shall be used to segregate classes of signals. When not in use and prior to launch, the connectors shall be protected with flight qualified covers.

3.2.4.12.4 Internal Cable Access

The LAT shall be mated and de-mated to the SC without de-mating cables which are internal to the LAT.

3.2.4.12.5 Ground Test Connector Access

The LAT ground test connector shall be easily accessible with the LAT mounted to the SC.

3.2.4.12.6 Power and Load Isolation

The observatory shall not be powered through, nor significantly loaded, by test point interface circuitry, including connection to external GSE.

3.2.4.12.7 Failure Propagation

Test point interface circuitry shall not propagate failures to flight circuitry. This includes credible failures in GSE connected externally to the test point interface connectors.

3.2.4.12.8 Short-Circuit Isolation

Test point short-circuit isolation shall also be provided. The observatory shall operate within specification in the event any test point is shorted to the power bus, ground, or another test point, and upon removal of the short.

3.2.4.12.9 Grounding Integrity

Test point interface circuitry shall not compromise grounding requirements, either by design or use.

3.2.4.12.10 Flight Standards

Test points shall be designed and implemented in accordance with all applicable flight standards and component ratings.

3.2.4.12.11 Test Point Documentation

Test point interfaces, functions and GSE interconnection shall be documented in TBD.

3.2.5 LAT AND C&DH DATA SERVICES

3.2.5.1 Command, Telemetry, and Data Bus

Commands, telemetry, time message, and ancillary data shall be transferred between the LAT and the C&DH via a serial command, telemetry, and data bus (CTDB) as defined by MIL-STD-1553B. The CTDB shall be single fault tolerant, as specified in the Mission System Specification.

3.2.5.1.1 Command, Telemetry, and Data Bus Protocol

The command, telemetry, and data bus (CTDB) shall utilize the communications protocol at the physical layer as defined by MIL-STD-1553B.

3.2.5.1.1.1 *Command Data*

Commands transferred over the CTDB shall be formatted per CCSDS 203.0-B-1, "Recommendation for Space Data Systems Standards. Telecommand, Part 3: Data Management Service" CCSDS Recommendation, Blue Book.

3.2.5.1.1.2 *Telemetry Packets*

Telemetry packets transferred over the CTDB shall be formatted per CCSDS 102.0-B-4 (Packet Telemetry Blue Book).

3.2.5.2 LAT Housekeeping Data

The LAT shall provide the C&DH, upon request, a housekeeping data set as defined in the LAT Data Format Document (TBR).

3.2.5.3 LAT Science Data Subset

The LAT shall provide an instrument defined subset of science data to be included with the housekeeping data set. LAT science data shall be formatted as defined in the LAT Data Format Document (TBS).

3.2.5.4 Pulse per Second Bus

The C&DH shall provide the LAT a pulse-per-second (PPS) signal accurate to ± 0.5 μ sec (TBR) referenced to the on-board GPS receiver.

3.2.5.5 Time Distribution to LAT

The SC C&DH shall issue a time message that gives Universal Time Coordinated (UTC) and GPS time code.

3.2.5.6 GPS Receiver Time Dropout

The PPS signal shall be provided, without interruption, to the LAT in the event of a loss of the time signal provided by the GPS receiver.

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3.2.5.7 PPS Signal Drift

The PPS signal shall drift no more than ± 1 μ sec over a period of 100 seconds when a GPS time signal loss occurs.

3.2.5.8 GPS Signal Loss Indication

The C&DH shall provide a message to the LAT when a GPS time signal loss has occurred.

3.2.5.9 Time Message Distribution

The Time Mark Message shall be issued no more than 100 ms (TBR) after the transition of the 1 PPS time mark signal.

3.2.5.10 Ancillary Data

The C&DH shall provide an ancillary data packet to the LAT at the attitude control loop rate of 5 Hz (TBR).

3.2.5.10.1 Ancillary Data Packet Format and Contents

The ancillary data packet shall contain the time-tagged attitude vector, time-tagged orbit position vector, and attitude and position vector rates, based on GPS data processed by the ACS as well as other data specified in the LAT Data Format Document (TBD).

3.2.5.11 Real-Time Pointing Commands

Execution status of ground-issued pointing commands shall be provided to the LAT in the ancillary data packet.

Note: This capability will be used in early-orbit checkout and in contingency operations in which continuous communications are maintained with the observatory through TDRSS. It will also be used in normal operations via the TDRSS demand access service for coordinated observations with other observatories.

3.2.5.12 LAT-SC Software: Operation modes

3.2.5.12.1 Sky Survey Mode

Status of SC sky survey mode autonomous pointing shall be provided to the LAT in the ancillary data packet.

3.2.5.12.2 Pointed Observation Mode

Status of time-tagged stored pointed-observation mode commands shall be provided to the LAT in the ancillary data packet.

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3.2.5.12.3 Transient Event Repointing

The requirements in this subsection are based on the following system concept. Transient event repointings may interrupt the normal observation modes, viz., sky survey and pointed observations. These interruptions are under the control of an enable. They are inhibited if a telemetry contact is scheduled within the allowed duration of the repointing command. Secondary targets during earth occultation are not used during transient event repointings.

Currently, there are four possible sources of repointing commands, 1) target of opportunity commands via the Science Operations Center, 2) detection of high energy gamma-ray burst by the LAT science instrument, 3) detection of low energy gamma-ray bursts by the GBM instrument, and 4) detection of active galactic nuclei by the LAT science instrument. The direction of repointing is determined by the source of the command. All command sources need to use the same coordinate reference frame. The duration of repointing is presently the same for all sources and is set by ground command. However, it could be different for each type of transient, and it could be set by the source of the command. Finally, a go-no go decision needs to be made based on current pointing direction, proposed repointing direction, time to slew, and viewing solid angle. Where this decision is made is currently TBD.

3.2.5.12.4 Repointing Control Enable

When enabled, the SC shall issue a repointing command to the ACS that supercedes the last SC-generated pointing command. The SC C&DH shall report status to the LAT in the ancillary data packet.

3.2.5.12.5 Repointing Control Enable Window

The time duration of transient event repointings shall be controlled by a ground-issued command.

3.2.5.12.6 Transient Alerts to Ground

Upon receipt of a transient alert message from the LAT, the SC C&DH shall send the message to the ground within 1 second, as specified in the Spacecraft Performance Specification.

3.2.5.12.7 Pointing Coordinates

The transient alert message shall contain the pointing direction coordinates per section 3.2.1.2.

3.2.5.12.8 Transient Event Pointing Commands

The C&DH shall issue a transient event repointing command, derived from the alert message, to the SC ACS that contains the direction and duration of the transient event.

3.2.5.13 Analog Signals

The C&DH shall provide 64 primary and 64 redundant analog for monitoring LAT health and safety.

3.2.5.14 Analog Signal Sample Rate

The sampling rate for the analog signals shall be from 0.01 to 0.1 Hz at a resolution of 12 bits.

3.2.5.15 Discrete Control Signals

The C&DH shall provide 16 primary and 16 redundant discrete pulse signals for configuration and power control of the LAT.

3.2.5.16 Discrete Monitor Ports

The C&DH shall provide 16 primary and 16 redundant discrete monitor ports for monitoring configuration status of the LAT.

3.2.5.17 LAT Command Storage

The C&DH shall provide 256 kbytes of stored command memory dedicated only to LAT utilization.

3.2.5.18 LAT Configuration Commands

The LAT shall be configured by commands issued by the C&DH.

3.2.5.19 LAT Table Loads

The LAT shall load internal tables from commands issued by the C&DH.

3.2.5.20 LAT Memory Loads

The LAT software shall be re-programmable via software load commands.

3.2.5.20.1 Memory Load Rate

Memory loads shall be provided to the LAT at 4 kbps for TDRSS contacts and 2 kbps for ground station contacts (TBR).

3.2.5.20.2 LAT Memory Dumps

Commands shall allow dumps from LAT program memory, data memory, or both.

3.2.5.21 GBM Trigger Signal to LAT

The LAT shall accept an RS-422 trigger signal from the GBM at a rate not to exceed 1 pulse per second (TBR).

3.2.6 SCIENCE DATA INTERFACE

3.2.6.1 Science and Housekeeping Data

The LAT shall output science and housekeeping data, via separate data bus interfaces. The LAT telemetry data bus shall be MIL-STD-1553.

3.2.6.1.1 LAT-SC Science Data Rate

The LAT-SC data rate on the dedicated, science data interface shall accommodate data transfer rates of at least 32 Mbps with a goal of 64 Mbps.

Note: The high rate interface shall be implemented in a flight proven technology. For example, RS-422, or TAXI are candidate technologies.

3.2.6.1.2 Packet Format

All LAT science data transferred shall be formatted per CCSDS 701.0-B-2 Advanced Orbiting Systems Networks and Data Links Blue Book.

3.2.6.1.3 Packet Size

The LAT shall utilize variable length CCSDS source packets up to a maximum length of 65536 octets.

Note: Consideration is being given to having the instrument provide science data as CCSDS CADUs (TBR) in lieu of source packets.

3.2.6.1.4 APID Allocation

The LAT shall utilize APIDs as defined in the GLAST Mission System Specification document.

3.2.7 FAULT PROTECTION

3.2.7.1 Fault Tolerance

SC and LAT systems and interfaces shall be singlefault tolerant, as specified in the Mission System Specification.

3.2.7.2 Fault Detection and Correction

For all critical single faults, the LAT and SC shall have on-board fault detection isolation and recovery (FDIR) hardware and software.

3.2.7.3 Safe Mode

The SC shall enter safe mode when a mission critical fault is detected and cannot be corrected by on-board processes.

3.2.7.4 Safe Mode Notification

The C&DH shall send the LAT a message indicating transfer into safe mode except when the mission critical fault is loss of the C&DH.

3.2.7.5 Load Shedding

LAT power shall be disconnected when ground-based or on-board fault analysis determines load shedding is required.

3.2.7.6 Load Shedding Notification

The C&DH shall provide a message to the LAT 15 seconds (TBR) prior to issuing a command to disconnect LAT power.