GLAST LAT SYSTEM SPECIFICATION	Document # **LAT-SS-00240-D2**	Date Effective 29 Dec. 2001
	Prepared by Gilles Bogaert	supersedes Draft June 23, 2001
	Subsystem/office Calorimeter Subsystem	
Document tilte **CAL Pre Electronics Module (PEM) Specification**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

CAL Pre Electronics Module (PEM) Specification

CHANGE HISTORY LOG

Revision	**Effective date**	**Description of Changes**	**DCN#**
1	**23 June 2001**	Initial Release Draft	
2	29 Dec 2001	Initial release	

1 INTRODUCTION

1.1 Purpose

This document describes the requirements for the Pre Electronic Module (PEM) part of the Calorimeter (CAL) of the LAT.

1.2 Scope

This document specifies requirements for the French delivery, the PEM, ie Mechanical Structure and CDE's, and interface. This specification captures the CAL requirements for the PEM. The present document is one level below the LAT-CAL Specification level IV, LAT-SS-00210-D2 for the GLAST Large Area Telescope (LAT) Calorimeter (CAL).The level IV specification is identified in the tree of following figure. The PEM specification and requirement tree is shown on figure after.
In addition, PEM CDE and parts are also subject to applicable documents for Assurance Product which are out of the scope of this document.

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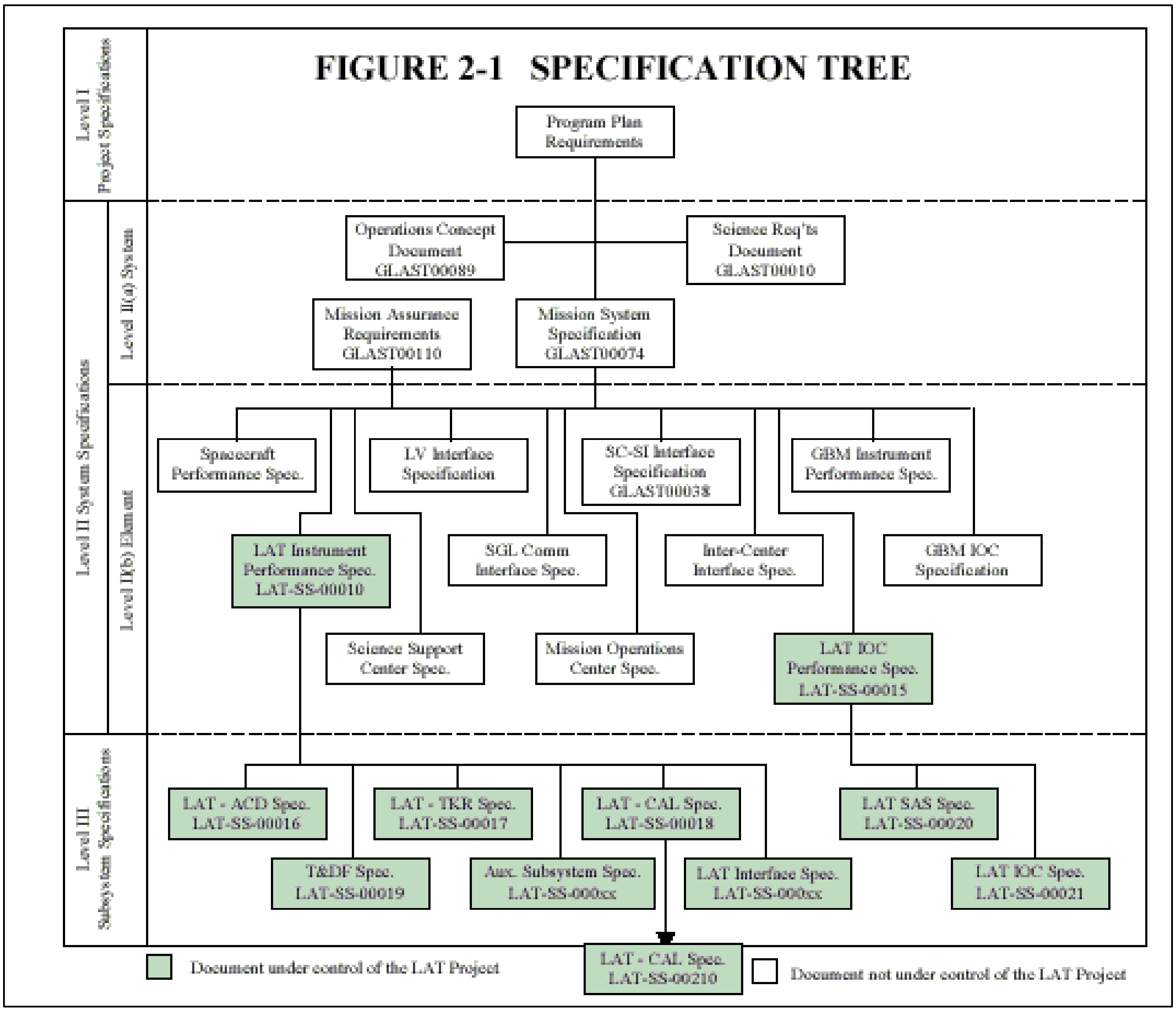
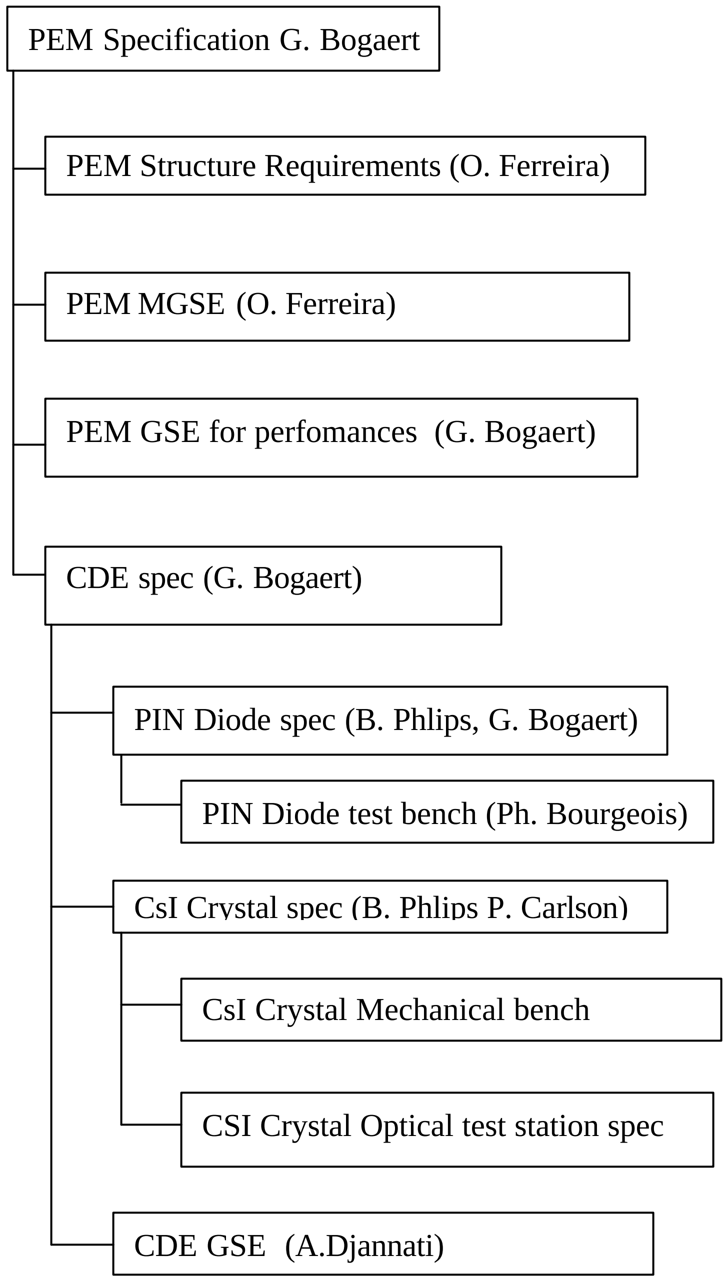


Documentation tree for requirements



1.3 Applicable documents

Documents that are relevant to the development of the GLAST LAT PEM and its requirements include the following:

LAT-SS-00010	'GLAST LAT Instrument Performance Specification'
GSFC433-MAR-0001	'Mission Assurance Requirements (MAR) for Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)' , NASA Goddard Space Flight Center
NPD 8010.2B	' NASA Policy Directive, Use of Metric System of Measurement in NASA Programs'
LAT-MD-00044	'Memorandum of Agreement- French participation to Glast'
LAT-MD-00098	'LAT Calorimeter Program Implementation Plan'
LAT-SS-00018-D4	'LAT CAL Subsystem Specification - Level III Specification'
LAT-SS-00210	'LAT CAL Subsystem Specification - Level IV Specification'
LAT-DS-00072-03	'Specification for the Calorimeter PIN Photodiode Assembly'
LAT-DS-00095-03	'LAT Calorimeter CsI Crystal Specification', 5 April 2001'
LAT-SS-273	'LAT Subsystem Mechanical Interface Control Document'
LAT	'Conceptual Design of the Glast Calorimeter Front-End Electronics (GCFE) ASIC'
GEVS	
LAT-SS-00241	'CAL Structure Requirements'
LAT	'CAL Module Mechanical and Thermal Concept'
LAT	'LAT CAL Part List'
LAT	'LAT CAL Mechanical Structure Mass'
LAT	'LAT CAL Container'
LAT-SS-00239	'Calorimeter CsI Detector Element Specification'
LAT-SS-00211	'Specification for the Calorimeter Photodiode Flexible Cable'
LAT-SS-00258	'PEM Assembly Plan'
LAT-SS-00231-1	'Calorimeter Performance Acceptance Standards and Tests'
LAT-SS-00260	'Calorimeter CsI Detector Element Verification Plan'

LAT-SS-00259	'Calorimeter PEM Verification Plan'
LAT-SS-00257	'Calorimeter Mechanical Structure Verification Plan'
LAT-SS-00256	'Calorimeter PEM Test Bench Specification'
LAT-SS-00307	'Specifications for Calorimeter CsI Detector Element Ground Support Equipment'

1.4 Definitions and acronyms

1.4.1 Acronyms

ACD	Anticoincidence Shield
AFEE	Analog Front End Electronics of the CAL
CAL	the Calorimeter subsystem of the LAT
CDE	Crystal Detector Element of the PEM
CdF	Collège de France
CEA	Comissariat à l'Energie Atomique
CENBG	Centre d'Etudes Nucléaires de Bordeaux Gradignan
CNES	Centre National d'Etudes Spatiales
CNRS	Centre National de la Recherche Scientifique
DAPNIA	Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et de l'Instrumentation Associée
DOE	Department of Energy
DSM	Direction des Sciences de la Matière (CEA)
EGSE	Electric Ground Support Equipment
EP	Ecole polytechnique
FM	Flight Modules
FoV	Field of View
FWHM	Full width at half maximum
GEVS	General Environmental Verification Specification
GLAST	Gamma-Ray Large Area Telescope
GSE	Ground support Equipment
IN2P3	Institut National de Physique Nucléaire et Physique des Particules
IRD	Interface Requirements Document
I&T	Integration and Test
LAT	Large Area Telescope
MC	Monte Carlo
MAR	Mission Assurance Requirements
MECO	Main Engine Cut Off
MGSE	Mechanic Ground Support Equipment
MSS	Mission System Specification
NRL	Naval Research Laboratory
PCC	Physique Corpusculaire et Cosmologie
PEM	Pre electronic module of the CAL
PS	Power Supply

RH	Relative Humidity
RMS	Root Mean Square
SI/SC IRD	Science Instrument - Spacecraft Interface Requirements Document.
SIU	
SLAC	Standford Linear Accelerator Center
TEM	Tower Electronics Module
TBC	To be Confirmed
TBD	To be Determined
TBR	To Be Resolved
TBW	To be Written
TKR	Tracker
T&DF	Trigger and Data flow system

1.4.2 Definitions

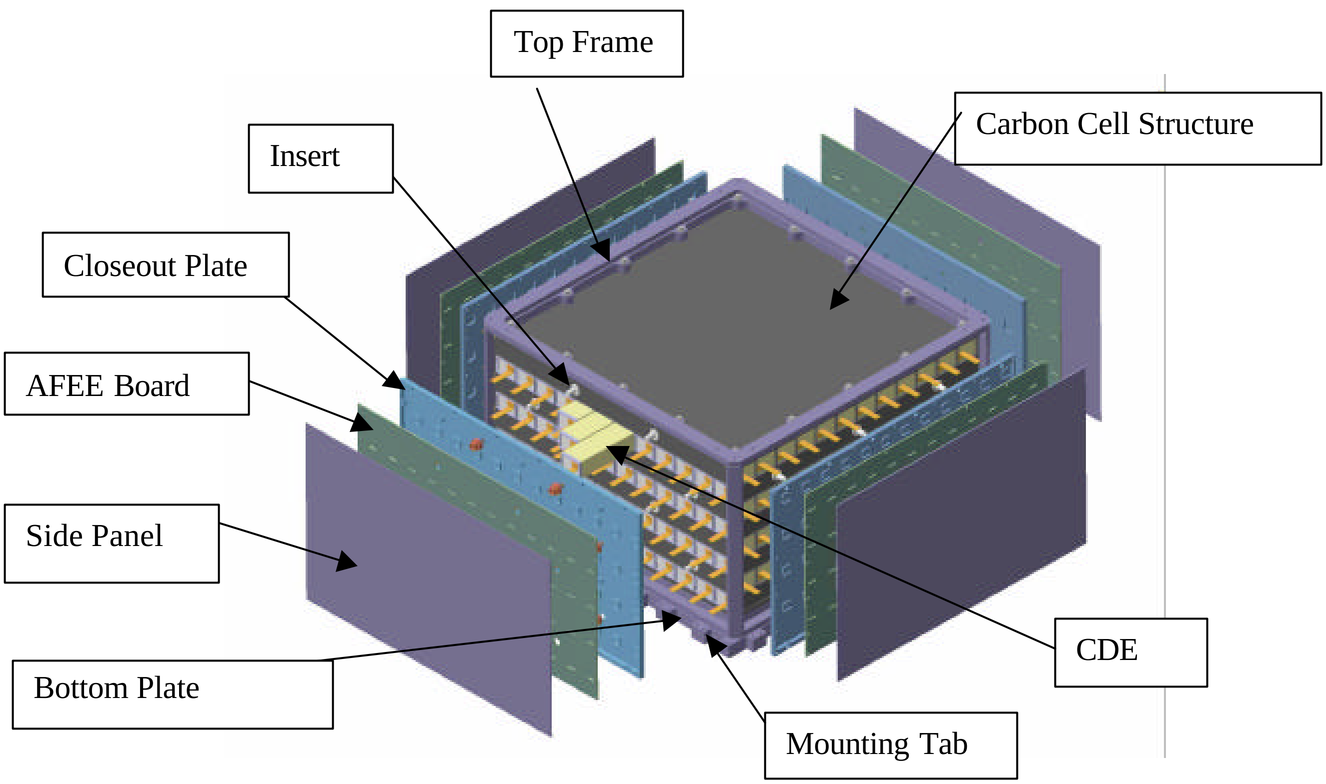
Analysis	A quantitative evaluation of a complete system and/or subsystems by review/analysis of collected data
cm	centimeter
CsI(Tl)	Cesium Iodine, doped with Thallium
dB	Decibel
Demonstration	To prove or show, usually without measurements of instrumentation, that the project/product complies with requirements by observation of the results.
g	gravity acceleration 9.81 m/s2
Inspection	To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
Kg	Kilogram
Light Yield	Amount of light collected by a photodetector connected to a crystal, expressed in electrons per MeV of deposited energy in the crystal by ionizing rays.
m	meter
mm	millimeter
Primary structures	The instrument primary structures include the support Grid, CAL, ACD, Radiators and Thermal/micrometeorite shield
s	second
Simulation	To examine through model analysis or modeling techniques to verify conformance to specified requirements
Stay clear	Nominal stay clear is not to exceed dimensions. Dynamical stay clear includes maximal excursion beyond nominal stay clear.
Testing	A measurement to prove or show, usually with precision measurement 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

2 GLAST LAT CONCEPT

The Lat Sciences Instrument consists of an Anticoincidence Device (ACD), a Silicon strip detector Tracker (TKR), a hodoscopic CsI(Tl) calorimeter (CAL), and a Trigger and Data flow system (T&DF).

2.1 Calorimeter Subsystem

The Cal provides the energy measurement of incident photons and background particles. These measurements, along with the TKR information are used to reconstruct the energy of the incident photons. CAL measurements are also critical to the background particle identification and rejection.
The calorimeter consists of 16 calorimeter identical modules arranged in a four by four array. Each calorimeter module is a hodoscopic array of CsI(Tl) Detectors Elements (wrapped crystal and read out). The hodoscopic properties of the calorimeter are improved by the localization capability of each crystal, thank to their light collection asymmetry.
The CsI(Tl) crystal logs convert the energy from ionizing rays to visible light that is readout at both crystal ends by photodiodes The signals from each photodiode at CsI(Tl) log ends are processed by the AFFE electronics on the CAL electronic boards. The electronic boards respond to the T&DF request by digitizing the energy loss and outputs the data to the data flows system.
Each calorimeter module is inserted in the aluminum Grid and attached to its bottom. Each calorimeter module structure support a Tower Electronic Module (TEM) fixed underside its bottom. SIU boxes are placed for 4 towers underside the TEM boxes. The heat generated in the calorimeter AFEE and in the TEM and SIU Boxes is removed through the Grid to the Radiators.
Following figure shows an expanded view of a single calorimeter module.



2.2 Pre Electronics Module

Each calorimeter module is made of 96 CsI(Tl) Detector Elements (CDE) held in compact geometry by the Mechanical Structure, and connected to the AFEE boards (one by vertical side) attached to the Mechanical Structure, inside the CAL module.

The Calorimeter module without the AFEE boards is called the Pre Electronics Module (PEM). It is made of the Mechanical Structure with cells filled with 96 CDE's in proper position, with cell closing system.

2.2.1 Mechanical structure and CDE interface

The Mechanical Structure of the Calorimeter Module is attached to the Grid and strengths it. It supports the power Supply modules on its bottom. It support the stack of 96 CDE's, holds them in place and provide integrity of them.
It maintains the electronics boards and preserves their integrity. It provides a shielding of the electronics boards from external electric noise.
The Mechanical Structure is made of

- One Base Plate which is attached to the GRID and support the TEM boxes. The Base Plate structural properties are written in LAT CAL Mechanical Interface Control Document. The stiffness of the Base Plate is large enough to prevent damaging stress on the Structure during launch. Cables from AFFE boards to Power Supplies and SIU located under the Calorimeter modules exit the calorimeter at bottom. The cables are attached to the Structure (TBD). The contact areas between GRID,TEM boxes and Mechanical Structure optimize the thermal conductivity.
- One Top Frame which provides carrying attachment points for handling and transportation of the CAL
- Four Al columns, one at each vertical edge of the carbon structure
- One stiff carbon structure with 96 cells for the 96 CDE's, and inserts for mechanical attachments to the metallic parts. It is sandwiched between the Top Frame and Base Plate. The stiffness of the Structure is large enough to prevent any contact with the grid during launch.
- Aluminum Closeout Plate and Side Panels which provide noise shielding and contribute to the structure stiffness. Four Closeout Plates close the cells (one plate per vertical side). Closeout plates provide also attachments to the electronics boards (one per vertical side). Holes in the Closeout plates allow the interconnect of PIN Photodiodes to the AFEE. Closeout Plates are attached to the Base Plate and Top Frame.
- Attachments for the four Electronic boards (one per vertical side). These attachments provide integrity to the electronic boards against environmental conditions, and optimize the thermal conductivity.
- Elastomeric cords at the cell corners allows the CDE to be inserted into and removed from the cells, and hold it in place inside the cells. They provide a protection to the crystals against the shocks to the cell wall in transverse direction and allow the crystal dimension changes with temperature variation in the allowed temperature range.
- Bumpers at CDE ends provide a protection to the CDE against the shocks to the closeout plates in longitudinal direction and allow both the CDE integrity and the CDE dimension changes with temperature variations in the allowed temperature range.

2.2.2 CDE

The CsI(Tl) Detector Element (CDE) is the detection unit of the LAT Calorimeter. Each PEM contains 8 layers of 12 CDE's. Each CDE is made of

- one CsI(Tl) crystal log. Each CsI(Tl) log is tapered such way that the light attenuation allows a precise measurement of the interaction crystal zone
- Two Dual PIN Photodiodes bonded to the crystal end faces, and interconnect. Dual PIN Photodiodes are made of two Silicon PIN Diodes on a single ceramic carrier. Kapton flex are

attached to the PIN Photodiodes and shall be connected to the AFFE connectors across the Closeout Plate at each crystal end.

- A crystal wrap which acts as a guide for the light towards the crystal end read out.

2.3 French Delivrables to NRL

2.3.1 Number and types of deliverable Modules

One PEM Engineering Model
One PEM A and one PEM B for CAL and LAT qualification process and spares
Sixteen Flight PEM's

2.3.2 Deliverable PEM definition

A deliverable PEM is a Mechanical Structure filled with 96 CDE's in proper position. It includes the four Closeout Plates which closes-up the cells, and the complete set of four Side Panels, screws and parts (including spares TBD) to be used in further steeps of integration, i.e., for closing the CAL after electronic mounting, for CAL handling and for TEM box integration (TBD) on the CAL Base Plate.

2.3.3 Acceptance tests

PEM's shall pass acceptance tests according to PEM test plan (xxx) before being delivered to NRL.

2.3.4 Tools

Necessarily tools will be delivered together with the first delivery. Additional tools shall be delivered according to needs for following deliverable tests and Integration at NRL and SLAC (TBD).

2.3.5 Documentation

All documents related to the PEM and parts design, manufacturing process, assembly, integration processes and tested performances are deliverables (TBR). Used formats for data exchanges depend on the data nature and shall be specified in corresponding specification documents.

2.3.6 Schedule

Deliverability dates at NRL are xxx, as defined in document xxx.

2.4 Instrument Responsibilities

[copied from LAT –SS-00210 CAL level 4 specification]
The Calorimeter is being developed by a collaboration led by the Naval Research Laboratory (NRL). NRL is responsible for managing the development of the calorimeter subsystem, including Calorimeter design, fabrications, test, and calibration. NRL is responsible to deliver the Calorimeter Modules to SU-SLAC. The responsibilities of the French parties are listed in section 8.4 of this MoA. The Swedish groups are responsible for the procurement and acceptance testing of the Thallium-doped Cesium Iodide (CsI)
a) The institutions responsible for the research teams taking part in the GLAST LAT instrument and forming *the Collaboration*, hereinafter collectively referred to as *the Collaborating Institutions.* The French institutions involved in the GLAST LAT Calorimeter are Commissariat à l'Energie Atomique / Direction des Sciences de la Matière / Département d'Astrophysique, de Physique des Particules, de Physique Nucléaire et de l'Instrumentation Associée (CEA/DSM/DAPNIA) and Centre National de la Recherche Scientifique / Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) representing the three following laboratories: PCC of Collège de France, LPNHE of Ecole Polytechnique and CENBG of Université de Bordeaux. The U.S. institutions involved in

the GLAST LAT Calorimeter are the Naval Research Laboratory (NRL) and the Stanford Linear Accelerator Center (SU-SLAC).
b) SU-SLAC, operated by Stanford University (hereinafter Stanford), under contract DE-AC03-76SF00515 with the U.S. Department of Energy (DOE), responsible for management and integration of the LAT instrument. SU-SLAC is the responsible party accountable to the U.S. Department of Energy for the program execution. Stanford University is responsible for the appropriate expenditure of U.S. Government funds.

3 Pre Electronics Modules Performances

3.1 Light Yield Large PIN Diode

All 96x2 crystals ends collect at least 5000 electrons per MeV in the Large PIN Photodiode for energy deposited in the middle of the crystal. This measurement will be executed using cosmic ray muons. The center of the crystal is considered to be the central two twelfths of the crystal

3.2 Light Yield small PIN Diode

All the crystal ends collect at least 800 electrons per MeV in the small diode for energy deposited in the middle of the crystal. The center of the crystal is considered to be the central two twelfths of the crystal

3.3 Light tapering

The light tapering of all crystals within a PEM, i.e. the ratio of light collected from the far end over the light collected at the near end of the crystal, is between 0.40 and 0.75. This tapering must be for large and small PIN diodes. This measurement will be executed using cosmic ray muons. The ends of the crystal are considered to be the extreme twelfths of the crystal.

3.4 Light Yield dispersion

The absolute light Yield from all crystals in a module will be plus or minus fifteen percent of the mean.

3.5 Contraints on measurements

These measurements are to be performed with a calibrated laboratory electronics. The amplifier shaping time will be set to match the flight AFEE ASIC designed by SLAC.

4 PEM structural/mechanical

4.1 geometry and mass.

4.1.1 Orientation

Each side of the PEM shall be defined in the coordinate system by a set of marks which shall allow PEM orientation determination during CDE assembly and further steps of integration and test.

4.1.2 PEM Mass

[Derived from LAT –SS-00210 CAL level 4 specification]
The total mass of the PEM shall not exceed the Cal mass (1492 Kg/16 = 93.25 Kg) less the electronic board mass. (TBR)

4.1.3 PEM geometry

The CAL geometry requirements are derived from LAT-Calorimeter Subsystem Mechanical Interface Control Document LAT-SS-00273-1-D3
Following table from LAT –SS-00210 CAL level 4 specification summarizes dimensions.

This is the total height less the height of the mounting tabs on the bottom plate.

CAL Module	Width (mm)	Height (mm)	Length (mm)	Comments
GRID bay nominal dimensions	366.5000			
CAL Module stay clear	364.000	224.300		
CAL Module nominal dimensions	363.000	223.800		Tabs are not included in the width. Height includes the mounting tabs on the bottom plate.
Bottom flange thickness		15.000		
CG of CAL off CAL Bottom Plate		xxx		

Width of the beveled edges of the CAL (TBD)

4.1.4 CsI log size

[Derived from LAT –SS-00210 CAL level 4 specification]
CsI(Tl) maximal dimensions are 333 x 19.9 x 26.7 mm
This corresponds to a projected CsI area of xxx cm2, and a calorimetric depth of xxxx

4.1.5 PEM Passive material

[Derived from LAT –SS-00210 CAL level 4 specification]
Passive material (every thing not CsI) shall represent no more than 16 %(TBR) of the total mass of the calorimeter.

4.1.6 Alignment

CAL module fiducials shall be surveyed to a precision of 0.1 mm (TBR), with respect to the LAT fiducials. (from LAT –SS-00273)

4.2 Mechanical Structure requirements

4.2.1 Motion limits

[from LAT-SS-00273-1-D3]

4.2.1.1 Allowed Lateral Dynamic motions

Maximum of 0.5 (TBR) excursion beyond the static stay clear boundary in any direction. This occurs at the top of the CAL, and the dynamic stay clear tapers down to 0.0 mm at the CAL bottom plate.

4.2.1.2 Allowed Verical Dynamic motions

Maximum of 0.25 (TBR) excursion beyond the static stay clear boundary in either direction. This occurs at the center of the CAL module, and the dynamic stay-clear tapers down to 0.0 mm at the CAL bottom plate.

4.2.2 Stiffness

The PEM fundamental frequency shall be greater than 100 Hz.

4.2.3 Venting

CAL will not be damaged when submitted to the pressure profile defined in xxx-00010.
Air from CAL shall be vented down, past the bottom plate, and not up into the volume between the TKR and CAL. (from LAT –SS-00273)

4.2.4 Purging

4.2.5 electrical conductivity

The electrical reresistance between two points of metallic parts shall be smaller than 0.1 ohm.
The electrical conductivity between two inserts shall be smaller than 10 ohms (TBR)

4.3 PEM Thermal

Upper level thermal requirements for the CAL are specified in LAT CAL Mechanical Interface Control document LAT-SS-00273-1-D3. All the requirements from Interface Control Document applicable to CAL are summanized in 4.4.

4.3.1 Bolted joints

The bolted joint interface with the Grid shall be the primary mechanism for transferring heat into and from the CAL.
At the interface with Grid, the CAL shall have an effective heat capacitance of TBD J/°C.
The Grid CAL Interface shall ensure that the PCBs are not affected by the power dissipated by the TEM-SIU-PS(30 Watts TBR) and vice versa (TBR).

4.3.2 CAL electronics boards

[from LAT-SS-00273-1-D3]
The PEM mechanical structure shall be able to transfer the power dissipated by the electronic boards (1 Watt per board) to the Grid. The thermal conductivity of the board shall be specified. It is assumed equivalent to the one of a 2 mm thick Aluminum plate (TBR).
The temperature gradient of the board from top to bottom shall be lower than 5°C. (TBR)
The temperature gradient between the Grid and any point on the circuit shall be lower than 10°C (TBR).
The change by one watt of the dissipated power of one AFEE board induces a change smaller than 5°C on the three others AFEE boards (TBR).

4.3.3 Heat transfer to the Tracker

[from LAT-SS-00273-1-D3]
The maximum heat transfer from the CAL to the TKR shall be 1 watt per module (TBR), for a temperature difference of 10 °C (TBR)

4.4 PEM Structure External Interface

4.4.1 Mechanical, Thermal, Electrical Interface with the LAT

The CAL module shall provide the mechanical, thermal, electrical interfaces to the LAT as specified in LAT –SS-00273
Table below summarizes the CAL requirement from interface with LAT.

item	Req	Value	comments
8.1	Nominal stay clear	x	from LAT-DS-00233

8.2.1	Stay clear for Dynamic and Thermal Motions Allowed Lateral	0.5(TBR)	
8.2.2	Stay clear for Dynamic and Thermal Motions Allowed vertical	Max 0.25 mm(TBR)	
8.3	Alignment	0.1 mm(TBR)	
9.1.1	Dimensions and Tolerances	according to LAT-DS-00233	
9.1.1	Flatness of mating surface	according to LAT-DS-00233	
9.1.1	Base Plate in plane extensional stiffness	equivalent to 8 mm thick Al plate(TBR)	
9.1.1	Base plate in plane shear stiffness	equivalent to to 8 mm thick Al plate (TBR)	
9.1.1	Base plate effective bending thickness	minimum(TBD)	
9.1.1	Base plate CTE	21-25 10(6)m/m/°C	
9.1.1	Mounting tabs static friction	>0.5 (TBR)	
9.2.1	static loads trust axis	3.25g/-0.8 at liftoff/transonic, 6.0+/-0.6 at MECO	
9.2.1	static load lateral axes	+:-4.0g at liftoff/transonic, +/-0.1 at MECO	
9.2.1	component level random vibration	x	GEVS table 2-4-4
9.2.1	Acoustic levels		GEVS table D-3 (TBR)
9.2.1	external shocks		GEVS table D-8 (TBR)
9.2.1	tab bolt pre-load	4466 N	
9.2.1	Carry load associated with Electronic boxes		no magnification/attenuation expected
9.2.1	Trapped holes for electronic modules load and pre load	TBD	
10.1	bolted join interface with Grid	primary mechanism for transferring heat into and out of the CAL	
10.1	CAL temperature range		see table TBR
10.1	effective heat capacitance at interface	TBD J/°C	
10.1	Range of temperature of Electronic Modules side	TBD	
10.1	Maximum radiation heat transfer from CAL to TKR	1 Watt for 10 °C temperature difference (TBR)	

12.2	CAL modules shall have reference fiducials on the underside of the base Plate.		allows positions to be surveyed after integration
13.1	Venting	Air vented down only	
13.2	Particulates	fracture produced particulates contained inside the CAL stay clear volume	

4.5 PEM Structure Internal interface with AFEE Board

[from LAT –SS-00210 CAL level 4 specification]

4.5.1 Dimensions of the AFEE board

Each AFEE board shall have dimensions of XXX mm by XXX mm.

4.5.2 AFEE board volume (TBR)

The maximal thickness of the board shall be 2 mm. The maximal thickness of the boards and its components shall be 6.4 mm.

4.5.3 Clearances (TBR)

A clearance of 0.8 mm is needed between the Closeout Plate and the nearest component.
A clearance of 0.8 mm is needed between the Side panel and the nearest component.

4.5.4 Attachment of the boards

Each AFEE board shall be supported by the Closeout Plate with screws through holes around its perimeter and 10 holes regularly spaced in the board.
The 10 holes passing through the board are organized in layers of 2 or 3 holes located half way between layers of PIN diode interface holes (for kapton). The diameter of the holes shall be 3 mm +/- 0.5 mm.
All contact surfaces for the AFEE board shall be in the same plan with a 0.2 mm maximal deviation.

4.5.5 AFEE board deformation (TBR)

AFEE boars shall stand the allowed structure deformations under thermal and mechanical loads.

4.5.6 AFEE boards fundamental frequency (TBD)

AFEE board fundamental frequency when attached to the Closeout Plate shall be higher than (TBD)

4.5.7 Thermal interface

The PEM shall dissipate the power from AFEE electronic boards to the Grid through the Bottom Plate, by conduction. AFEE board are in tight contact with the Closeout Plates through the fixation slots and screws. The contact areas have specific surface treatment.

4.5.8 Grounding and electrical connection Structure/AFEE Board

[derived from LAT –SS-00210 CAL level 4 specification]
The AFEE board shall be grounded to the calorimeter structure per LAT document xxx

4.5.9 PIN Diode Shielding against AFEE boards

[derived from LAT –SS-00210 CAL level 4 specification TBD]
Closeout Plates shield the PIN Diodes against the noise from electronics components and wires on the AFEE boards. The aperture in Closeout Plates for interconnect is limited to xxx mm by xxx mm

4.5.10 AFEE shielding

The Side Panels shield the AFEE Board from external noise.

4.6 PEM Structure Internal Interface with CDE's

4.6.1 Interchangeability

CDE can be replaced by any other in the cell structure at any time before AFEE board are integrated. Elastomere parts can be adapted to take into account the CDE size variability.

4.6.2 CDE longitudinal position

CDE longitudinal position inside the cells is determined during the PEM life within one millimeter (TBR)

4.6.3 Interface with Dual PIN Diodes

Dual Pin Diode, and glue on its perimeter or on the crystal if any, shall be inside an area of (W-2.3 TBR mm) x (H –2.3 mm TBR) centered on the middle of the cell (i.e. crystal center), where W and H are the Width and Height of the cell respectively. The so defined area on the crystal perimeter shall be free of glue.

4.6.4 Interface with Capton interconnect

Holes in the Closeout Plate allows the interconnecting kapton passing through. The hole positions corresponds to the middle of each cell. Hole size shall be minimized but allows the kapton to move and adapt its shape to the CDE dimension changes and moves. Aperture surface treatment shall be performed to protect the kaptons against the Closeout Plate metallic edges.

4.6.5 Elastomeric cords

4.6.5.1 CDE integrity

Elastomeric cords along the cell angles hold in place the CDE's and allows their integrity during the PEM life.
This includes ground handling, transportation and storage, environmental testes, launch and on orbit life during 5 years.

4.6.5.2 CDE insertion and removal

Extension of elastomeric cords decreases their diameter and allows insertion and removal of CDE's into the cells without damage.

4.6.6 Elastomeric bumpers

Elastomeric bumpers at CDE ends allow the crystal dimension change and the integrity of CDE's during the PEM life.

4.6.7 CDE bumper interface

CDE bumper interface is designed for assuring CDE integrity during the PEM life. Its optical properties it TBD (color, reflectivity)

4.7 PEM Handling

4.7.1 Attachment points

The top tray of each PEM shall include special attachment points. These points will allow lifting from the top, and must support the mass of the PEM plus the mass of the TEM, SIU and PS boxes.

4.7.2 Protection

PEM fragile parts and surfaces shall be protected against damaging due to shocks or hazards according to their nature.

5 Crystal Detector Elements

5.1 Organisation

[derived from LAT –SS-00210 CAL level 4 specification TBD]
CDE will be composed of the following parts :

- CsI(Tl) crystal – a rectangular parallelepiped with beveled edges and surface polish to control scintillation light yield at the two ends.
- Two Dual PIN Photodiodes bound at both ends of the CsI(Tl) crystal. PIN Photodiodes are bond on CsI using an optical epoxy or silicon glue (TBD)
- PIN Photodiodes are equipped with kapton cable for interconnection.
- Crystals are enveloped in a Wrapping material.

5.2 CDE Performances

Radiation [derived from LAT –SS-00210 CAL level 4 specification TBD]

5.2.1 Absolute Light Yield for large diode (PIN B)

The light yield measured by the large diode shall be greater than 5000 e/MeV for energy deposition in the center of the CsI(Tl) crystal. This value shall be obtained at 20 °C using 3.5 microsecond shaping time.

5.2.2 Absolute Light Yield for small diode (PIN A)

The light yield measured by the small diode shall be greater than 800 e/MeV for energy deposition in the center of the CsI(Tl) crystal. This value shall be obtained at 20 °C using 3.5 microsecond shaping time.

5.2.3 Light Yield dispersion

The light yield shall not vary by more than +- 15 % around the mean value

5.2.4 Light tapering

The ratio of light collected from the far end over the light collected at the near end of the crystal is between 0.4 and 0.75.

5.2.5 damages

Combined damages from accumulated radiation dose over the mission life shall not reduce the light Yields by more than 50 %.

5.2.6 Spatial resolution of energy deposition

The calorimeter shall be capable of positioning a Minimum Ionizing energy deposition to less than 1.5 cm (1sigma) (TBR)

5.3 CDE dimensions

5.3.1 CDE Longitudinal dimension

Crystal maximal length is maximized such a way that no part of the CDE element can be in direct contact with the Closeout Plate during all the PEM life.
CDE length is calculated taking into account the parameters given in following table (dimensions at 20°C).

Parameter	Max value	Min value
Crystal length	333.0 mm	332.4 mm
Bonding thickness	1.1 mm	0.5 mm
DPD carrier thickness	2.0 mm	1.6 mm
DPD pin contact length	1.7 mm	
CDE maximal length	342.6 mm	

Available length for CDE is calculated taking into account the parameters given in following table (dimensions at 20°C).

Parameter	Max dimension	Min dimension
Cal module nominal dimensions		362.6
Side panel thickness	0.8mm	
Side panel to component envelope on internal AFEE side including stay clear	8 mm	
Closeout Plate thickness above the diode connectors	0.3	
Stay clear between diode pin connectors and Closeout Plate		0.9 mm
Min Available length for CDE including stay clear	342.6. mm	

5.3.2 CDE Transverse dimensions (TBR)

CDE (crystal + wrapping material) shall have maximal envelope dimensions:
Width < crystal width + 0.2mm
Height < crystal height + 0.2 mm

When positioned on a flat surface, with wrapping held in close contact with the crystal lateral sides, the height of CDE shall be smaller that cell height but 0.1 mm.

5.3.3 CDE Diagonal (TBR)

CDE diagonal shall be smaller than crystal diagonal (chamfer to chamfer) plus 0.2 mm.

5.4 CDE wrapping

5.4.1 Wrapped crystal aspect

Wrapped crystal shall have no visible scratch, dent or cracks, holes or pleats.

5.4.2 Wrapping crystal attachment

Wrapping shall be firmly joint to the crystal such a way it can be inserted into the cell by pushing the crystal and removed from it without damage for the wrapping.

5.4.3 Wrapping length

Wrapping shall be no longer than the crystal

5.5 CsI(Tl) crystal

CsI crystals requirements are in document xxx, Swedish project No. 2143-4108
Table 4 below summarizes the geometrical and physical properties of the CsI crystals.

Characteristic	value	Tolerance
Crystal shape	parallelepiped	< 0.4 mm
Crystal Length	333.0 mm	+0.0 -0.6 mm

Crystal Height	19,9 mm	+0.0, -0.4 mm
Crystal Width	26,7 mm.	+0.0, -0.4 mm
Envelope Length	333,0 mm	+0.0, -0.6 mm
Envelope Height	19,9 mm	+0.0, -0.4 mm
Envelope width	26,7 mm.	+0.0, -0.4 mm
Flat beveled edges angle	45°	+-5°
Flat beveled edges	0.7 mm	+- 0.2 mm
Surface treatment	Polish finish	
Light yield with Tyvek Wrapping	1.2 MeV line: FWHM <13%	
Light yield uniformity	< 10 % around the mean value	
Light tapering with Tyvek wrapping	Monotonic 60% end to end	+- 10%
Light output reduction due to Radiations (10 kRad)	<50 %	

5.6 PIN Photodiodes

Dual PIN Photodiodes assembly is made of two PIN Diodes on a single ceramic carrier. The two photodiodes are 300 microns thick, and have 25 mm2 and 150 mm2 active areas respectively (ratio= 6). The front face is potted with epoxy by the provider. The back side of the carrier has 4 sticks for connection (diameter xxx) at accurately defined positions.
The PIN diode specification is in document LAT-DS-00072, LAT –DS-00209 (Flight Units).
Following table provides geometrical and electrical properties of the DPD.

Item	value
Carrier Length	22.3 +:-0.2mm
Carrier Width	15.0 +/-0.2 mm
Carrier Thickness	1.8 +/-0.2mm
PINA dimension	10.5 mm x 2.4 mm
PIN A Dark current	<3 nA
PINA capacitance	<15 pF
PIN B dimensions	10.5 mm x 14.5 mm
PIN B Dark current	<10 nA
PIN B Capacitance	<100 pF

5.7 PIN Diode interconnect

Interconnect is made using a Kapton flex with four wires. The flex is soldered to the DPD pins and attached with a adhesive to the DPD carrier back to prevent any stress on the solders. The flex allows CDE testing using a connection in a ZIF connector on Ground support Equipments boards. For flight use the Kapton cable end is removed (cut) at determined distance and is then soldered to wires on the AFEE board.

5.7.1 Geometry /Mechanical

The flex cable length and design shall minimize the stress on the DPD's, and shall fit to CDE dimension changes in the allowed temperature range.

5.7.2 Electrical

The interconnection electrical design minimizes at acceptable level the parasitic capacitance between the cal structure and the wires.

5.7.3 Thermal

The interconnection design shall guarantee the photodiodes are insulated from power dissipated by the AFEE boards.

5.8 PIN bonding

5.8.1 The bonding shall be bubble free

5.8.2 Geometry

5.8.2.1 Bond max thickness

The bond maximal thickness shall be 1.1 mm

5.8.2.2 Bond minimum thickness

The bond thickness shall be greater than 0.5 mm

5.8.2.3 Bonding area on DPD

The bonding overlaps the DPD area.

5.8.2.4 Bonding area on crystal

Bonding area is strictly included in an allowed area (TBD)

5.8.2.5 Parallelism

At least one side of the carrier is parallel to one crystal side within 0.1 mm deviation from DPD edge to edge (TBR)

5.8.2.6 DPD Orientation

The DPD at both ends of the same crystal are oriented with the flex pointing the same direction

5.8.3 Optics

The bonding layer shall be optically clear from 350-400 nm to 700 nm and its index provides an adaptation between the CsI(Tl) crystal and the epoxy window of the diode.

5.8.4 Mechanical properties

5.8.4.1 Thermal cycling

The bonding shall resist to 60 (TBR) vacuum thermal cycling in the temperature range for qualification (-30°C , +50 °C).

5.8.4.2 The temperature change rate is no lower than 5°C /h

5.8.4.3 Manipulations

Bonding shall not damage when applying to the DPD or to the capton a force of 10 N (TBR) in any direction with respect to the crystal.

5.9 CDE Environmental

5.9.1 Thermal

CDE shall be capable of normal operation after being subjected to the environmental conditions given in xxx 00010, section 5.3.12, Environmental.

5.9.2 Mechanical

CDE's inserted in PEM cell structure shall be capable of normal operation after the instrument being subjected to the environmental conditions given in xxx 00010, section 5.3.12, Environmental.

6 Environmental

The environmental conditions described here encompass the normal (or standard) ground and launch conditions that the calorimeter may be subjected to during spacecraft integration and launch. Ground environment covers the conditions the calorimeter could possibly endure once it is delivered for spacecraft integration and test. The calorimeter will be expected to sustain the on-orbit conditions for the duration of its operational life.
The environmental requirements from LAT –SS- 00010 are implemented here below for the PEM.

6.1 Ground Environmental

6.1.1 Ground - Handling Vibration and Shock

The PEM shall be handled per controlled procedures during all phases of ground processing to minimize exposure to structural and mechanical loads.

6.1.2 Ground - Transportation Vibration and Shock

The structural and mechanical loads that the PEM is exposed to during transportation shall be no greater than the launch loads given in 5.8.3 and 5.8.4. The transportation dynamic environment shall be monitored to ensure compliance.

6.1.3 Ground - Temperature and Humidity

The PEM 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.

6.2 Temperature and Humidity

6.2.1 Storage/Transportation Temperature

The range of temperatures to which the PEM may be exposed during storage and transportation is 0 to 40 **(TBR)** °C.

6.2.2 Storage/Transportation Relative Humidity

The relative humidity of the environment surrounding the PEM during storage and transportation shall be in the range 35% **(TBR)** to 55% **(TBR)**.

6.2.3 Assembly and integration Temperature

The range of temperatures to which the PEM may be exposed during assembly and integration activities is 15 **(TBR)** to 25 °C. {Delta II Payload Planner's Guide}

6.2.4 Assembly and Integration Relative Humidity

The relative humidity of the environment surrounding the PEM during assembly and integration activities shall be in the range 35% **(TBR)** to 55% (**TBR**).

6.2.5 Launch Vehicle Temperature

The range of temperatures to which the PEM may be exposed while on the launch vehicle is 13 to 27 °C. {Delta II Payload Planner's Guide}

6.2.6 Launch Vehicle Relative Humidity

The relative humidity of the environment surrounding the instrument while on the launch vehicle shall be in the range 40% **(TBR)** to 55% (**TBR**). {Delta II Payload Planner's Guide}

6.2.7 Ground Processing Rate of Change

The magnitude of the rate of change of temperature to which the PEM may be exposed during all phases of ground processing shall be less than 5..C/hour. {Instrument safety constraint}

6.3 Launch - Static Load {SI/SC IRD 3.2.2.8.2}

6.3.1 Thrust Axis Static Loads

The PEM is a primary structure. It shall be able to withstand the launch static loads in the thrust axis of 3.25/.0.8 g at liftoff/transonic, and 6.0 ±0.6 g at MECO, without violating the dynamic stay clear given in LAT CAL Mechanical Interface Control Document.

6.3.2 Lateral Axis Static Loads

The PEM shall be able to withstand the launch static loads in the lateral axis of ± 4.0 g at liftoff /transonic and ± 0.1 g at MECO, without violating the dynamic stay clear given in LAT CAL Mechanical Interface Control Document.

6.3.3 Combined Static Loads

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

6.4 Launch - Random Vibrations

6.4.1 Instrument Qualification {GEVS Table D-6}

The PEM shall be able to withstand the ASD levels given in LAT-xxx-00010 without violating the dynamic stay clear given in LAT CAL Mechanical Interface Control Document.

6.5 Launch - Acoustic Loads {GEVS Table D-3}

The PEM shall be qualified for the Qualification Noise Levels shown in GEVS Table D-3.

6.6 Launch - Shock {GEVS Tables D-8 and D-9}

The PEM shall be capable of normal operation after the application of the external shock levels applied at the spacecraft separation ring interface, as given in GEVS Tables D-8 or D-9, as applicable.

6.7 Launch - Pressure

The PEM 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.

6.8 On-Orbit - Charged Particle Radiation

6.8.1 Total Radiation Dose

The design of the PEM shall use a multiplicative factor of 5 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 the MSS, Section 3.3.6.1.1, Total Dose.

6.8.2 Single-Event Effects (SEE) Immunity

The PEM shall be capable of normal operation when subjected to the charged particle environment characterized by the LET energy spectrum given in the GLAST MSS Section 3.3.6.1.3, LET Spectrum and shall adhere to the SEE immunity guidelines of MSS Section 3.3.6.1.4.

6.9 Outgassing

All materials used in PEM shall meet the NASA out-gassing requirements

7 Design

7.1 Materials

7.1.1 Qualified materials

Materials shall be qualified for space application by a national space agency. No qualified material shall be qualified according to NASA or CNES dedicated qualification procedure.

7.1.2 Material list

All materials used in the PEM shall be listed in Material List document.

7.2 Mechanical structure

The PEM structure is made of composite and metalic parts assembled together using inserts.The design shall take into account loads induced by mismatch of coefficients of thermal dilatation of the parts, together with the dimension possible change with humidity content of the composite.

A dedicated program shall be developed for the inserts to ensure compliance with functional requirements.

7.3 CDE integrity

The CDE integrity against test and launch loads is performed thanks to elastomere parts along the CDE edges (cords) and at the CDE end (bumpers). The elastomere cords along the CDE chamfers shall allow CDE insertion into the cell when stretched and shall insure the CDE integrity when relaxed.
A dedicated program shall be developed for elastomere parts to ensure compliance with functional requirements.

7.4 Maintainability

It shall be possible to remove and insert any of the 96 CDE of a PEM until the AFEE boards are integrated.

7.5 PEM and part labeling

Each PEM must have identification number. It must be visible from the bottom view and top view.

7.5.1 Cell Identification

[Derived from LAT-TD-00035-01]

The PEM layer 0 (top) has X logs and the layer 7 has Y logs. The four PEM sides of a given CAL module are distinguished by their relative location in X and Y, and are labeled -X, -Y, +X, +Y Following Figures shows the PEM faces with cell labeling system.
I suppose the labeling has already been defined, but I have'nt seen where.

X- face

X+ face

Y- face

Y+ face

0Y+1	0Y+2										0Y+12
2Y+1											

7.5.2 CDE Identification
CDE are labeled according to their crystal identification
CDE labeling allows left right identification.

7.5.3 DPD identification
Each DPD shall have an identification mark visible on its back side
Crystal number is associated to the diode number which is visible before closeout plate are mounted (TBR).

8 LOGISTIC CONSTRAINTS

8.1 Ground environmental
The PEM and CDE and CDE parts shall be housed in environmental controlled and monitored facilities during all phases of ground processing.

8.1.1 Contamination

Contamination is caused by particles generated from materials, machining and assembly procedures. Care will be taken to keep contamination to a minimum.

8.1.2 Cleanliness
The PEM environment shall be free of dust at the level defined by ISO 7 norm.

8.1.3 Environment Temperature
Temperature environment which the CDE's and PEM may be exposed during ground operations is in the range 19°C to 25°C (TBR)

8.1.4 PEM and CDE parts environment Temperature
Temperature environment which the instrument parts may be exposed during ground operations is in the range to be determined according to their nature (TBR)

8.1.5 PEM and CDE environment Humidity
Humidity environment which the instrument may be exposed during ground operations must be higher than 35 % HR (TBR) and lower than 50 %HR (TBR).

8.1.6 Electrostatic discharges
Specific measures shall be taken to ensure that electrostatic discharges susceptible components are handled using antistatic packaging and tools according to standard codes.

8.2 Storage

8.2.1 PEM (TBR)
PEM shall be stored in shipment box defined in xxx (from NRL)

8.2.2 CDE
CsI(Tl) crystals shall change their shape if they are not properly set. Experience shows that accurately machined V block support are the best suited for long term CDE integrity. Both contact surface of CDE on the V block support should be free of bumps due to wrapping system.

8.2.3 Crystals
Crystals shall be stored in V shaped blocks.

8.2.4 DPD

DPD's shall be stored in shipment box

8.3 Transportation

8.3.1 PEM (TBR)

PEM shall be transported in containers to test station and to NRL. Transportation and storage container detailed specifications are written in xxx (from NRL).

8.3.2 CDE

CsI(Tl) crystals shall change their shape if they are not properly constraints. Transportation GSE should be the same as the storagedevice to avoid manipulations.

8.3.3 Crystals

CsI(Tl) crystals shall change their shape if they are not properly constraints. Transportation GSE should be the same as the storage device to avoid manipulations.

9 Test and verification

9.1 PEM Tooling

Mechanical structure is manufactured with dedicated complex tooling. The mechanical properties of the mechanical structures is directly related to this tooling and process. So the qualification of the tooling and process shall require the production of one or a few (TBR) composite structures, that shall be accurately measured and tested.

9.2 PEM acceptance

Verification plan describes the verifications and test the PEM shall pass.
For each Flight PEM, following validations shall be performed :
-Cleanliness inspection of the PEM.
-Mechanical control and measurements
-Electrical controls
-Environmental test to check compliance of mechanical structure for stiffness and strength.
-Performance test to check the Light Yields obtained with 96 CDE's.
-labeling check
-TBD

9.3 CDE acceptance

Verification plans describes the verifications and test the CDE shall pass.
For each Flight CDE, following validations shall be performed :
-Cleanliness inspection of the CDE.
-visual inspection of the wrapping and glue join.
-Mechanical control and measurements
-Perfomance test to check the CDE light yield
-TBD

9.4 Performance Test Equipment

9.4.1 PEM EGSE for performances

PEM performances shall be tested using cosmic muons. EGSE requirements are in doc xxx.

9.4.2 CDE EGSE for performances

CDE performances shall be determined before integration. EGSE requirements are in doc xxx

9.4.3 PIN Diode EGSE

PIN Diode performances shall be determined before assembly. EGSE requirements are in doc xxx

10 Data Exchange

11 Delivery

Delivery shall be done according to delivery plan (TBD)

11.1 Shipment box

The PEM's shall be delivered to NRL in a dedicated shipment box.

11.2 Shipment date

PEM shall be sent using agreed transporter 15 days before delivery date at NRL.

12 Verification strategy

The table 10 indicates the methods of verification employed to verify the PEM Test Bench performances

12.1 Table 10 : verification matrix

Req't #	Title	Summary	Verif. Method