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# Gamma-ray Large Area Space Telescope (GLAST)

# Large Area Telescope (LAT)

# Calorimeter Mechanical Structure Specification

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# CHANGE HISTORY LOG

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# Table of Contents

# 1 INTRODUCTION

## 1.1 PURPOSE

This document defines the requirements for the mechanical structure of the calorimeter (CAL) modules of the Gamma-Ray Large Area Telescope.

## 1.2 APPLICABLE DOCUMENTS

Documents that are relevant to the development of the mechanical structure for the GLAST CAL modules and its requirements include the following:

| | |
|---|---|
| GEVS-SE Rev A | 'General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components', revised June 1996. |
| GLAST00110 | 'Mission Assurance Requirements for Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)' , NASA Goddard Space Flight Center, Current Draft Sept 20, 2000 |
| MSFC-SPEC-522 | 'Design Criteria for Controlling Stress Corrosion Cracking', revised 1 July 1987 |
| MIL-HDBK-5H | 'Metallic Materials and Elements for Aerospace Vehicle Structures', revised 1 December 1998. |
| NPD 8010.2B | 'NASA Policy Directive, Use of Metric System of Measurement in NASA Programs' |
| LAT-DS-00072-03 | 'Specification for the Calorimeter PIN Photodiode Assembly', 20 February 2001 |
| LAT-DS-00095-03 | 'LAT Calorimeter CsI Crystal Specification', 5 April 2001 |
| LAT-MD-00404 | 'LAT Contamination Control Plan' |
| LAT-SS-00047 | 'LAT Mechanical Performance Specification' |
| LAT-SS-00010-02 | 'LAT Performance Specification – Level II(b) Specification' |
| LAT-SS-00018-09 | 'LAT CAL Subsystem Specification - Level III Specification', 28 November 2001 |
| LAT-SS-00107-1 D2 | 'LAT Mechanical Parts Plan', 19 March 2001 |
| LAT-SS-00210-D2 | 'LAT CAL Subsystem Specification – Level IV Specification' |
| LAT-DS-00233 | 'LAT Mechanical Systems Drawing: CAL – LAT Interface' |
| LAT-SS-00273 | 'LAT – Calorimeter Subsystem Interface Control Document' |
| LAT-SS-00115 | 'LAT Mechanical Systems – Level III Specification' |
| LAT-TD-00035 | 'LAT Coordinate System' |

## 1.3 DEFINITIONS AND ACRONYMS

### *1.3.1 Acronyms*

| | |
|---|---|
| AFEE | Analog Front End Electronics of the Calorimeter |
| CAD | Computer Aided Design |
| CAL | Calorimeter Subsystem of the LAT |
| CDE | Crystal Detector Element of the PEM |
| CsI | Cesium Iodide |
| CTE | Coefficient of Thermal Expansion |
| GEVS | General Environmental Verification Specification |
| GLAST | Gamma-Ray Large Area Space Telescope |
| LAT | Large Area Telescope |

| | |
|---|---|
| LV | Launch Vehicle |
| MECO | Main Engine Cut-Off |
| MPS | Mechanical Performance Specification for the mission |
| PEM | Pre Electronic Module of the CAL |
| RMS | Root Mean Square |
| T&DF | Trigger and Data Flow Subsystem of LAT |
| TBD | To Be Defined |
| TBR | To Be Resolved |

### *1.3.2 Definitions*

| | |
|---|---|
| Analysis | A quantitative evaluation of a complete system and/or subsystems by review/analysis of collected data |
| 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 | Acceleration of gravity (9.81 $m/s^2$) |
| Inspection | To examine visually or use simple physical measurement techniques to verify conformance to specified requirements. |
| kg | Kilogram |
| mm | Millimeter |
| s | Second |
| 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 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 |
| W | Watt |
| mm | Millimeter |
| Ω | Ohms |

# 2 GENERAL DESCRIPTION

The Calorimeter (CAL) of the GLAST Large Area Telescope is configured in 16 identical modules, in a 4x4 array. Each module contains 96 CsI logs with photodiodes glued at both ends. Analog Front-End Electronic (AFEE) boards, which processes the signals of the photodiodes, are attached to each side of the CAL modules.

The mechanical structure of the CAL modules consists of:

- **Carbon Composite Structure -** provides support for the 96 CsI Detector Elements (CDE)
- **Aluminum Base Plate -** provide the structural interface to the LAT Grid structure
- **Aluminum Top Plate** – Closes out the top of the CAL module
- **Aluminum Cell Close-out Plates** (4) – provides protection to the ends of the CDEs
- **EMI Shields** (4) – provides electromagnetic interference (EMI) protection to the AFEE boards

The composite structure consists of an array of 96 carbon fiber epoxy resin composite cells, arranged into 8 layers of 12 cells. Each layer is rotated by 90° in the relation to the neighbors, to define an X – Y orientation for the CsI logs.

All the aluminum parts are attached to inserts, manufactured inside the composite structure.

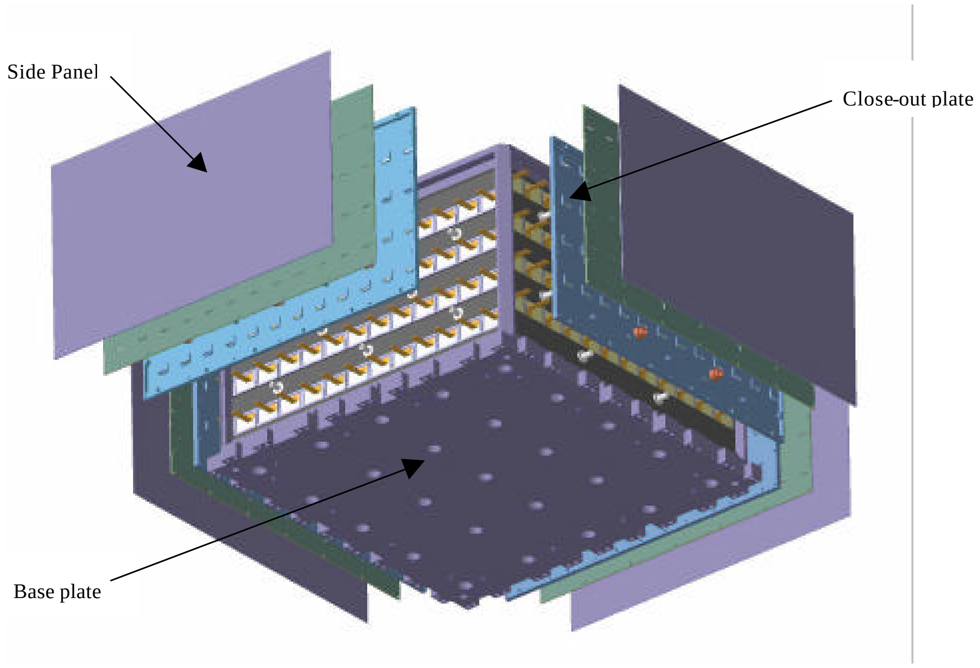


Figure 1: Exploded view of a Calorimeter Module

# 3 MISSION

## 3.1 LIFETIME

The materials, processes and structural assemblies used to build the mechanical structure of the CAL modules shall be able to withstand the environmental loads that they are exposed to during the service life of the instrument. The service life include 10 years of on-orbit operation plus all the ground operations (assembly, testing, storage, etc.), which could last up to 2 years for the first modules.

## 3.2 LOAD EVENTS

The environmental load events that will be experienced by the CAL modules during the lifetime of the instrument are listed below. The thermal loads are presented separately.

### *3.2.1 Ground and Test Loads*

#### 3.2.1.1 Assembly and Integration Loads

No load event is applied on the mechanical structure during the assembly of the PEMs. Integration procedures of the CAL modules are still to be defined (TBD) but no particular load events are expected during this operation, except the ones resulting from the handling of the modules.

#### 3.2.1.2 Handling

The CAL modules are lifted from the top when moved between assembly or test areas. The modules can be integrated in any orientation as defined in the ***LAT Mechanical Performance Specification (MPS), paragraph 6.4.2***. The load event is given by the weight of a fully assembled module, i.e. a 1g acceleration applied along any orientation.

#### 3.2.1.3 Test Loads

During science performance tests, muons test or beam test, the load applied on the mechanical structure is a 1g acceleration along any orientation (weight of a module). In case of a test in a beam, the modules are move and oriented in the beam line. Expected dynamic loads are negligible since motion is slow.

Structural test loads are defined according to launch loads and are therefore specified in the corresponding paragraphs, for both qualification and acceptance.

#### 3.2.1.4 Transportation

Road and air transportation are used to ship the CAL modules between the different assembly and test areas. During this operations, the mechanical structure undergoes random vibration and thermal load events during several hours. The shipping containers shall be designed to guarantee that the load levels remain below acceptance levels.

#### 3.2.1.5 Thermo-Elastic Loads

During ground operations and transportation, the temperature range to which the CAL module can be submitted is 0 to 40°C ***(LAT MPS Table 6.2-2)***. The mechanical structure shall be able to withstand the loads due to a 20°C temperature increase or decrease, assuming that the assembly was manufactured at 20°C. The thermo-elastic loads result from different coefficients of thermal expansion between the composite structure, the aluminum alloy parts and the printed circuit boards. The stress levels in the mechanical part shall remain below yield loads, with a safety factor of 1.25 (TBR). The parts shall be able to withstand the loads for several hours (TBD) without creep effect.

### *3.2.2 Launch Loads*

#### 3.2.2.1 Static Loads

Quasi-static loads for the GLAST mission are defined in the ***LAT MPS document, in paragraph 6.1.1***. The values are derived from DELTA II launch vehicle Payload Planner Guide. The levels for the primary structures are given in Table 3.2-1. The levels are given in g unit, with 1 g = 9.81 m/s².

| | Event | |
|---|---|---|
| Axis | Liftoff / Transonic | MECO |
| Thrust | +3.25 / -0.8 | +6.0 ± 0.6 |
| Lateral | +/- 4.0 | +/- 0.1 |
| (+) Indicates compression and (-) tension in the thrust axis<br>Acceleration levels are specified in g | | |

**Table 3.2-1: Delta II Static launch load levels**

The CAL modules are defined in the LAT MPS document as secondary structures, paragraph 6.1.1. The corresponding static limit load levels are +/- 12 g applied independently to X, Y or Z axis.

#### 3.2.2.2 Random Vibration

The random vibration levels for the systems and subsystems are specified in ***paragraph 6.1.2 of the LAT MPS document***. The envelop of the input ASD is used to specify both acceptance and qualification levels. The levels are corrected for mass above 22.7 kg, according to the Table 3.2-2.

| | ASD in g²/Hz | Comments |
|---|---|---|
| dB Reduction | = 10 log (W/22.7) | |
| ASD (50 – 800 Hz) | = 0.16 (22.7 / W) | For protoflight |
| ASD (50 – 800 Hz) | = 0.08 (22.7/ W) | For acceptance |
| W indicates component weight<br><br>The slopes shall be maintained at + and – 6 dB/oct for components weighting up to 59 kg. Above that weight, the slopes shall be adjusted to maintain and ASD level of 0.01 g²/Hz at 20 and 2000 Hz. | | |

**Table 3.2-2: Delta II random vibration load levels**

With a conservative rounded value of 90 kg per fully assembled CAL module, the corrected ASD levels that shall be withstand by the mechanical structure are given in the Table 3.2-3, for qualification and acceptance.

| Frequency in Hz | ASD level in g²/Hz | |
|---|---|---|
| | Qualification | Acceptance |
| 20 | 0.01 | 0.01 |
| 20 - 50 | +4.55 dB/oct | +2.28 dB/oct |
| 50 - 800 | 0.04 | 0.02 |
| 800 - 2000 | -4.55 dB/oct | -2.28 dB/oct |
| 2000 | 0.01 | 0.01 |
| Overall acceleration level | 7.63 gRMS | 5.65 gRMS |

**Table 3.2-3: CAL modules random vibration load levels**

The CAL mechanical structure shall be able to preserve the safety of the CAL modules under random vibration levels that meet the qualification levels, applied along each axis independently, for a duration up to 2 minutes (TBR).

#### 3.2.2.3 Acoustic Noise

The CAL modules are dense, compact elements, buried inside the bays of the grid. Therefore, acoustic noise is a negligible load event for the mechanical structure. Acoustic testing is not performed at CAL modules level but at the instrument level. The CAL modules shall be capable of normally operating after application of the acoustic loads defined in Table 6.1-5 of the LAT MPS document.

#### 3.2.2.4 Shock Loads

The shock loads levels to which the CAL mechanical structure shall be qualified are limited to pyroshock loads, produced by explosive nuts during the launch vehicle separations. The mechanical structure shall effectively protect the CAL modules under the shock load levels ***defined in 6.1-6 of the LAT MPS document***.

#### 3.2.2.5 Depressurization

The depressurization curves for the mission are given in ***Figure 6.1-7 of the LAT MPS document***, derived from DELTA II LV Payload Planner's Guide. The CAL modules shall be able to withstand the corresponding time rate of change of pressure. No air shall be trapped inside the composite cells. Sufficient venting path shall be preserved between the side panels and the bottom plate to allow the release of all gas volume within the CAL module. The air shall path shall be minimized between the side panels and the top frame to prevent the air from filling the volume between the top of the CAL modules and the bottom of the tracker towers.

#### 3.2.2.6 Thermo-Elastic Loads

The CAL mechanical structure shall be able to withstand the thermo-elastic loads due to variations of temperature between 0 and 30°C. The loads can be applied independently, or in combination with the previously defined static loads or dynamic loads.

### *3.2.3 On-Orbit Loads*

#### 3.2.3.1 Operational Pressure

The CAL mechanical structure materials, parts and assemblies shall preserve the full functionality of the CAL modules at the operating pressure of 10-5 Torr, ***as defined in the LAT MSP document, paragraph 6.1-5***.

#### 3.2.3.2 Thermo-Elastic Loads

During on-orbit operation, the CAL structure shall be able to withstand the thermo-elastic loads due temperature cycling within the survival range –30°C to +50°C, resulting from CTE mismatch between the composite and the aluminum parts (including effects due to the grid). The stress levels in the mechanical part shall remain below yield loads, with a safety factor of 1.1 (TBR).

#### 3.2.3.3 Hygroscopic Loads

The composite structure shall be able to withstand the hygroscopic loads due to variations in moisture content. The change in the mechanical properties of the material shall not influence the structural functionality of the CAL mechanical structure. The change in the dimensions of the composite structure due to change in moisture content shall not influence the functionality of the CAL modules.

## 3.3 THERMAL LOADS

Thermal loads are split into 2 categories: environmental thermal loads and heat power dissipated by the electronics, which are attached to the mechanical structure. In this category, two different sources shall be taken into account: the AFEE boards attached to the close-out plates and the TEM boxes and power supplies attached on the bottom plate.

### *3.3.1 Environmental Thermal Loads*

The materials, parts and assemblies of the CAL mechanical structure shall be able to keep their full functionality inside the temperature ranges, defined for the entire instrument. The temperature ranges are presented in Table 3.3-1, and are classified according to the different phases of the service life.

| | Environmental thermal loads | | | | | |
|---|---|---|---|---|---|---|
| | Assembly Integration | Storage Transport | On LV | Launch | Operational | Survival |
| $T_{max}$ qualif. Test (1) | | | | | 35 °C | 50 °C |
| $T_{max}$ design accept | 25 °C | 40 °C | 26.7 °C | 30 °C | 25 °C | 40 °C |
| $T_{min}$ design accept | 20 °C | 0 °C | 12.8 °C | 0 °C | -10 °C | -20 °C |
| $T_{min}$ qualif. Test (1) | | | | | -20 °C | -30 °C |
| Nbr of cycles | | | | | 120 | 120 |
| $dT/dt_{max}$ (2) | | | | | 5 °C/hr | 5 °C/hr |

(1) Test temperature set at 10 °C higher than maximum design temperature and 10 °C lower than minimum design temperature, per GEVS-SE rev A
(2) Maximum time rate of change of temperature

**Table 3.3-1: Mission environmental thermal loads**

The mechanical structure shall be qualified for up to 120 thermal cycling within the survival temperature range, with a 5 °C per hour time rate of change of temperature. The main constraint for the structure is the thermo-elastic loads, ***which have been detailed in paragraph 1.7***.

### *3.3.2 On-Orbit Heat Flux*

The CAL modules are protected by the thermally controlled walls of the grid. They are not exposed to Earth or Sun heat flux.

### *3.3.3 Heat Power from Electronics*

The power dissipated by the CAL AFEE boards are not direct thermal loads for the mechanical structure but must considered in the functionality requirements because it's the mechanical structure that transfer the heat dissipated by the components to the thermally controlled grid.

The power dissipated by the LAT T&DF subsystem components (e.g. TEM, Power Supplies, and SIU boxes) mounted to the CAL baseplate is thermally isolated from the CAL. This heat is dissipated by heat pipes attached directly to the LAT radiators.

## 3.4 LOAD FACTORS

Load factor shall be used to define the relevant loads for design, test and qualification of the mechanical structure. These factors shall be applied to the limit loads ***defined in paragraph 1.7***. The values for the different factors are given in Table 3.4-1.

| Load factors | |
|---|---|
| Design load KD | 1.3 |
| Qualification factor KQ | 1.25 |
| Acceptance factor KA | 1.1 |

**Table 3.4-1: Summary of load factors**

For Gaussian distributed random loads, with zero mean value, the standard deviation multiplied by 3 shall be used as the limit load contribution.

# 4 FUNCTIONALITY

## 4.1 Mass and Inertia Properties

The mass of mechanical structure shall be minimized. It shall not exceed 10.5 Kg (TBR). The shape of the mechanical parts shall be optimized to maintain the required functionalities with the minimum amount of material. The mass of all the mechanical parts shall be known with a precision of 5%. The position of the center of gravity of the mechanical structure shall be known with a precision of 5 mm. The first moment of inertia about 3 axis of the mechanical structure shall be known with a precision of 10%.

## 4.2 Strength

### *4.2.1 Strength Under Static Load*

The mechanical structure shall be able to withstand the different load events without yielding, failing or exhibiting deformations that can influence the performance of the CAL modules or any other system or sub-system.

Under a +/-12 g static load, the mechanical structure shall have adequate stiffness in order to maintain a .5 mm maximum displacement of any point on the structure as defined below:

- X-axis loading shall not cause any point of the structure to exceed the maximum displacement so that contact with the grid walls is avoided
- Y-axis loading shall not cause any point of the structure to exceed the maximum displacement so that contact with the grid walls is avoided
- Z-axis loading shall not cause any point on the top of the structure to exceed the maximum displacement
- Z-axis loading shall not cause any point on the bottom of the structure to exceed the maximum displacement so that mechanical loads on the TEM boxes, which are attached below the CAL modules, are minimized.

### *4.2.2 Strength Under Dynamic Load*

Under the qualification random vibration environment defined in Table 3.2-3, the mechanical structure shall provide adequate stiffness in the following directions in order to maintain a maximum difference of the RMS displacements between any two points defined below:

- Adequate stiffness in the X and Y directions to maintain a .25 mm maximum displacement difference between any two points on the side panels
- Adequate stiffness in the Z direction to maintain a .50 mm maximum displacement difference between any two points on the top plate of the structure
- Adequate stiffness in the Z direction to maintain a .25 mm maximum displacement difference between any two points on the bottom plate of the structure

## 4.3 Stiffness

The mechanical structure shall provide a minimum fundamental frequency greater than 100 Hz to a CAL module, isolated from other systems. The influence of the boundary conditions, attached on the grid, shall be evaluated.

## 4.4 Thermal

### *4.4.1 Thermal control of AFEE boards*

The AFEE boards are attached to the close-out plates on the four sides of the CAL modules. The components of each boards dissipates a total power of 1 W (TBR). This power must be transferred by the mechanical structure to the grid, whose temperature is regulated.

The total thermal resistance of the mechanical structure, from the attachment tabs to the circuit board interface, shall be low enough to maintain a 10 °C maximum temperature difference between the contact surface of the grid walls and any point on the circuit boards.

The thermal resistance of the contact between the close-out plates and the printed circuit boards shall be low enough to maintain the temperature gradient of the boards below 5 °C. This assumes that the in-plane thermal conductivity of the boards is greater than 100 W/m°C and the transverse conductivity grater than 0.8 W/m°C.

Furthermore, if up to 1 W of power is dissipated by one of the circuit boards, the mechanical structure shall provide an efficient vertical heat flow so that the variations of temperature remain below 5 °C in three of the other boards.

### *4.4.2 Thermal control of PIN photodiodes*

The mechanical structure shall guarantee that the photodiodes are sufficiently isolated from the power dissipated by the AFEE boards. Their temperature shall not change by more than TBD °C per hour.

### *4.4.3 Thermal control of the TEM, SIU and power supplies*

A TEM box is attached below each CAL module on the bottom plate. On four of the modules, a power supply and SIU box are mounted on the TEM box. The worst-case total power dissipated by these elements is 50 W (TEM + SIU + power supply). The heat must be transferred to the grid walls through the bottom plate of the CAL mechanical structure.

The thermal resistance of the bottom plate shall be low enough to keep below 5 °C the gradient of temperature between the interface plane with the TEM boxes and the top of the tabs of the bottom plate.

The structure, which provides a thermal path between the TEM boxes to the grid, shall guarantee that the temperature distribution in the AFEE boards does not change by more than 3°C when the power dissipated from the TEM, SIU, and associated power supplies is raised from 0°C to its nominal value.

## 4.5 Tolerances and alignment

### *4.5.1 Outer dimensions*

The design of the mechanical structure and the associated system of tolerances shall guarantee the conformance to the geometrical interface requirements presented in the Interface Control Document between the CAL module and the other systems and sub-systems.

The parts shall be built and assembled with enough precision to guarantee that the outer transverse dimensions of the CAL modules remain below 363 x 363 mm² (tabs not included).

The parts shall be built and assembled with enough precision to guarantee that the height of the structure from the top of the tabs to the top of the frame attached to the composite structure remains below 209 mm.

### *4.5.2 Alignment of parts*

The alignment between the top frame, the composite structure and the bottom plate shall be better than 0.15 mm.

### *4.5.3 Planarity of sides*

The end surface of the inserts attached to each side of the composite structure shall remain between two planes, distant by less than 0.2 mm.

### *4.5.4 Attachment of close-out plates*

The surfaces of the side inserts, top frame and bottom plate in contact with the close-out plates shall remain between two planes, distant by less than 0.2 mm.

The distance between the +X close-out plate and the –X close-out plate shall be 342 mm ±0.1 mm. The distance between the +Y close-out plate and the –Y close-out plate shall also be 342 mm ±0.1 mm.

## 4.6 Electrical conductivity

Once the mechanical structure is assembled, the composite structure and all the metallic parts shall be electrically connected. Required electrical resistance of the between parts of the structure structure is as follows:

- The electrical resistance between any two points of the composite structure, including the side, bottom and top inserts, shall be less than 10 Ω (TBR).
- The electrical resistance between any two points of the metallic parts shall be less than 0.1 Ω (TBR), once the mechanical structure is assembled.
- The surface finishing and surface treatment of the top of the tabs shall guaranty that the electrical resistance between the bottom plate and the grid wall remains below 0.1 Ω (TBR).

## 4.7 Electromagnetic compatibility

The CAL mechanical structure shall provide effective shielding of the AFEE circuit boards, which are attached to the sides of the modules. The circuit boards shall be enclosed inside at least 0.5 mm thick aluminum walls. The enclosure is provided by the close-out plates and the side panels.

The only openings allowed are the holes for the cables:

- The slots on the bottom plate to connect the AFEE boards to the TEM boxes and power supplies
- The slots in the close-out plate to connect the PIN photodiodes to the AFEE boards.

The distance from slot edge to slot edge shall be grater than 1.5 times the width of the slot.

# 5 Interface

## 5.1 Definitions

The interfaces by which the CAL mechanical structure is concerned can be split into four groups.

- **Mechanical Structure Inner Interface -** connection between the different mechanical parts.
- **Inner PEM Interfaces -** connection between the mechanical structure and the CDEs.
- **Inner CAL Interfaces -** connection between the PEM mechanical structure and the AFEE boards
- **Outer Interfaces -** connection between the CAL modules, the grid and electronic boxes (TEM, SIU, power supplies)

Only the requirements relative to the CAL modules are presented in this document. The outer interfaces are defined in the Interface Control Document between the CAL modules and other systems and sub-systems (LAT-SS-00273, LAT – CAL ICD, and LAT-DS-00233, CAL – LAT Interface Drawing).

## 5.2 Mechanical structure interface

### *5.2.1 Surface finishing*

The functional faces of the mechanicals parts shall be machined with sharp tools and machining parameters adapted to the material to guaranty an average roughness Ra of 1.6 or better.

### *5.2.2 Surface treatment*

A surface treatment shall be performed on all the aluminum alloy parts to protect them from corrosion. A Chromate conversion treatment ALODINE 1200 shall be used for thermally or electrically conductive parts. A black anodizing shall be used for non conductive parts.

## 5.3 Interface with CDEs

### *5.3.1 Description*

A CDE is inserted inside each of the cells of the carbon epoxy composite structure. It is positioned and supported inside the cell by four silicone elastomeric cords placed between the corners of the cell and the chamfers of the crystals. The longitudinal displacement of the logs is stopped by two elastomeric damper frames, which are placed between the log ends and the close-out plates.

### *5.3.2 Dimension of cells*

A CsI log whose size and shape are within specifications shall inside any of the 96 cells of a composite structure, with 1 mm diameter elastomeric cords placed along the four chamfers. The specifications of the CsI logs are defined in LAT-DS-00095-02 document.

## 5.4 Interface with AFEE boards

### *5.4.1 Description*

The mechanical structure and the AFEE boards share mechanical, thermal and electrical interfaces. Each structure supports one AFEE printed circuit board on each of its four lateral sides. The boards are mechanically attached to the close-out plates with bolts.

Flex KAPTON cables pass through slots machined on the close-out plates and connect the PIN photodiodes to the circuit boards. During assembly, all the flex cables must simultanously pass through all the slots on the circuit boards and the close-out plates. Additional cables connecting the AFEE boards to TEM boxes or power supplies are routed through slots machined in the bottom plate.

Once the boards are mounted and the cables connected, the module is closed with four side panels.

### *5.4.2 Mechanical interfaces*

All the geometrical specifications for the mechanical integration of the AFEE boards are defined in the engineering drawing numbered GLT.XX.03.12 and GLT.XX.03.13 (XX number refers to the model i.e. 05 for VM2). The drawing includes all the dimensions and tolerances to allow the assembly.

### *5.4.3 Volume allocated to the boards*

The mechanical structure shall provide room on its four sides to integrate 333 x 194 mm² printed circuit boards. A clearance of at least 0.5 mm between the board and the edges of the close-out plate is required to ensure proper mounting. The distance between the close-out plates and the side panels shall be greater than 8.5 mm, except above the photodiodes connections. This defines the available volume for the boards.

The circuit boards shall be centered in the previously defined volume by the mechanical structure.

A clearance greater than 0.8 mm shall remain between the close-out plates or side panels and the top of the components that are mounted on boards.

### *5.4.4 Attachment of the boards*

The mechanical structure shall provide attachment points at the four corners and along the four edges of the circuit boards. The mechanical structure shall provide ten attachment points on the surface of the boards.

The planarity of the surface on which the boards are attached to shall be lower than 0.2mm (all fixation points shall remain inside two 0.2 mm apart planes).

### *5.4.5 Cables*

Four slots shall be machined on each side of the CAL bottom plate to connect the cables of the AFEE boards to the TEM boxes. The width of the slots is 20 mm ± 0.2mm, imposed by the tabs pattern.

Edges shall have a TBD radius to avoid damaging the cables during contact against the mechanical parts.

Attachment points for the cables shall be provided by the mechanical structure (TBD).

### *5.4.6 Thermal interface*

The thermal resistance of contact between the AFEE boards and the close-out plates shall be less than (TBD) to ensure an efficient heat transfer by conduction.

The faces of the aluminum close-out plates in contact with the boards shall be surface treated to preserve the properties of the thermal contact.

The mechanical structure shall ensure the thermal control of the AFEE boards as described in ***paragraph 4.4***, "thermal control of AFEE boards".

### *5.4.7 EMI / EMC*

Requirements for electrical and electromagnetic interfaces are described in chapter 4.6 and 4.7.

# 6 Design

## 6.1 Inspectability

It shall be possible to control the optical performance of the CDEs of a module at any stage of their integration inside the composite structure.

## 6.2 Interchangeability

All the parts of the mechanical structure shall be identified by an item number. The parts with the same item number shall have the same functionality and be dimensionally interchangeable so that they can be integrated in any of the CAL modules.

The design and the assembly of the mechanical structure shall guaranty that all the CAL modules have the same geometry to allow the integration in any of the 16 bays of the grid.

## 6.3 Maintainability

Until the AFEE boards are integrated, it shall be possible to access any of the 96 CDEs of a modules without damaging the components of the mechanical structure or the CDEs themselves.

## 6.4 Design concept

The design concept is described

## 6.5 Materials

### *6.5.1 Materials selection*

All materials that are used to build the mechanical structure of the CAL modules shall have been qualified for space application by the ESA or NASA or through a dedicated qualification procedure.

The material shall pass contamination and out-gassing requirements as specified in the contamination control plan LAT-MD-0000404.

### *6.5.2 Metals*

All metallic components shall be built using metals listed in MSFC-522-B Table I documents to avoid stress corrosion cracking.

### *6.5.3 Composite structure*

A process control plan shall be developed to ensure the uniformity of the characteristics of the carbon epoxy composite material. The process used to manufacture the structure shall guaranty that the fiber to resin volume ratio is controlled within 10%.

Test samples shall be processed and cured with each structure and their mechanical properties measured.

Out gassing measurements shall be made on test coupons in accordance with TBD procedure. These test coupons are cured during the same thermal cycle as the composite structures.

### *6.5.4 Elastomeric parts*

The mechanical and out-gassing properties of each batch of elastomeric parts shall be controlled. The mechanical properties measurements shall include durometer and compression set. For the silicone cords, elongation at break and ultimate tensile strength shall be measured in addition.

# 7 Verification

The verification plan of the mechanical structure is described in the document named “Mechanical Structure Verification Plan” and numbered LAT-XXXXX.

# 8 Production and manufacturing

## 8.1 Procurements

The procurements for the materials and parts of the mechanical structure shall be made according to written specifications. Acceptance requirements shall be clearly identified.

## 8.2 Manufacturing process

The components of the mechanical structure are standard machined metallic parts except for the composite structure which is produced according to specific techniques. Its manufacturing process is detailed in document named "Composite Structure Design and Manufacturing" and numbered LAT-XXXX. Requirements for quality control are identified in this document.

## 8.3 Tooling

The manufacturing of the composite structures requires a complex, dedicated tooling. The description of the tooling and the associated specifications are defined in the document named "Composite Structure Design and Manufacturing" and numbered LAT-XXXX.

## 8.4 Assembly

### *8.4.1 Assembly stages*

The CAL mechanical structure is assembled in 3 stages:

- Attachment of the top frame and bottom plate on the composite structure
- Attachment of the close-out plates once the CDEs are mounted inside the cells
- Closing of the module with the side panels once the AFEE boards are mounted

### *8.4.2 Assembly of the top and bottom plate*

The top frame is mounted on the inserts located on the top of the composite structure and the bottom plate on those located on the bottom of the structure.

- 16 M4 screws used to attach the top frame shall be tighten with a TBD torque.
- 25 M5 screws used to attach the bottom plate shall be tighten with a TBD torque.

The top frame and bottom plate shall be aligned to less than 0.1 mm once attached to the composite structure.

The height between the top of the tabs and the top of the structure shall be less than 209 mm.

The parallelism between the top and bottom faces of the structure shall be better than 0.2 mm

### *8.4.3 Assembly of the close-out plates*

The close-out plates are fastened to the bottom plate, top frame, corners and side inserts of the composite structure.

- 20 M3 screws used to attach the close-out plates to the bottom plate shall tighten with a TBD torque.
- 20 M3 screws used to attach the close-out plates to the top frame shall tighten with a TBD torque.
- 10 M2 screws used to attach the close-out plates to the corners shall tighten with a TBD torque.
- 10 spacers that attach the close-out plates to the side inserts of the composite structure shall be tighten with a TBD torque.

The planarity of the close-out plate, once assembled, shall be better than 0.2 mm.

The distance from close-out plate to close-out plate shall be 342 mm with a tolerance of ±0.1mm.

### *8.4.4 Assembly of the side panels*

The side panels are fastened to the bottom plate, top frame, corners and side inserts of the composite structure.

- 30 M2.5 screw that fasten the side panels to the other mechanical parts shall be tighten with a TBD torque.

The surface of the side panels shall remain inside two 0.25 mm apart planes, perpendicular to the top of tabs of the bottom plate.

## 8.5 Packaging, handling and transportation

### *8.5.1 Packaging*

The mechanical parts shall be protected inside sealed bags until move to the assembly clean room.

### *8.5.2 Handling*

Because of their mass (100 kg), handling devices are used to manipulate the CAL module during assembly, test and integration. The mechanical structure shall provide attachment points to connect the handling devices to the modules.

It shall be possible to lift the CAL modules from the top so that they can be moved with a crane between assembly areas or transferred inside a container. Four attachment points shall be provided, each one able to support at least a 50 kg load.

The bottom plate of the CAL structure shall have 4 M10 threaded holes to attach steel cylindrical legs so that the modules can be raised for integration of the PEM and power supply boxes.

## 8.6 Protection

The tabs of the bottom plate shall be protected to avoid any damage in case of a shock against a hard surface.

The top of tabs shall remain protected until the CAL modules are assembled on the grid to preserve the quality of the interface.

The face of the bottom plate on which the TEM boxes are attached shall be protected to prevent any scratch that could increase the thermal contact resistance.

## 8.7 Cleanliness

All the mechanical parts shall be cleaned according to procedure adapted to the materials they are built of. Mechanical parts shall be stored inside sealed bags or inside a clean room to avoid dust. The composite structure and the elastomeric parts shall be protected from humidity. Airtight sealed bags with dry air shall be used to store them until assembly starts.

## 8.8 Identification and Marking

Each Mechanical Structure base plate shall be uniquely marked using an identification code that is visible after integration with the LAT Grid.

### *8.8.1 CAL Module ID*

This ID code shall become the completed module ID which is entered into a database which tracks the manufacturing, performance and calibration information of the components that are contained in the CAL module.

### *8.8.2 CAL Coordinate System*

The Mechanical Structure base plate shall uniquely identify the coordinate system for the CAL module. This marking shall be visible during assembly of the module as well as during installation of the completed module into the LAT Grid.

# 9 Data exchange

## 9.1 Design and manufacturing

Data shall be exchanged by mean of manufacturing drawings, documents or CAD files. HPGL format shall be used to exchange engineering drawings.

## 9.2 Design and structural analysis

If possible, surface or solid geometry shall be exchanged using native CAD format. Otherwise, ISO STEP format shall be used.

# 10 Deliverables

Deliverables are defined in the PEM Requirements document, numbered LAT-XXXX.