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Document Title **Calorimeter Module Assembly, Test, and Calibration Requirements**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter Module Assembly, Test, and Calibration Requirements

DOCUMENT APPROVAL

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
1		Initial Release

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1 PURPOSE

This document specifies the requirements for assembly, test, and calibration of the GLAST calorimeter Modules.

2 DEFINITIONS

2.1 Acronyms

CAL	LAT calorimeter subsystem
FWHM	Full Width Half Maximum
GLAST	Gamma-ray Large Area Space Telescope
LAT	Large Area Telescope
TBD	To Be Determined
TBR	To Be Resolved

2.2 Definitions

γ	Gamma Ray
μsec, μs	Microsecond, 10^{-6} second
Analysis	A quantitative evaluation of a complete system and /or subsystems by review/analysis of collected data.
cm	centimeter
Demonstration	To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results.
eV	Electron Volt
Inspection	To examine visually or use simple physical measurement techniques to verify conformance to specified requirements.
MeV	Million Electron Volts, 10^{6} eV
mm	millimeter
μsec, μs	Microsecond, 10^{-6} second
ph	photons
s, sec	seconds
Simulation	To examine through model analysis or modeling techniques to verify conformance to specified requirements.
Testing	A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements.
Validation	Process used to assure the requirement set is complete and consistent, and that each

requirement is achievable.

Verification — Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products.

3 APPLICABLE DOCUMENTS

Documents relevant to the Calorimeter Module Assembly, Test, & Calibration include the following.

3.1 Design Documents

Calorimeter Module Assembly and Test Plan, LAT-SS-00262.

Calorimeter Muon Telescope Requirements Specification.

Calorimeter Performance Acceptance Standards and Tests, LAT-SS-00231.

4 Introduction

This document was developed under the following assumptions.

1. Nineteen CAL PEMs will be built in France.
2. CAL AFEE boards are tested and validated prior to integration with the PEM.
3. PEM A and B arrive at NRL on 14 February 2003 and 7 March 2003, respectively. PEM A is the Qualification Model. PEM B is the flight spare.
4. PEM 1 arrives at NRL on 2 May 2003. PEM 1 is the first of the flight units.
5. Completed CAL modules A and B must be ready for integration (RFI) at SLAC on 15 August 2003.
6. Completed CAL modules 1 and 2 must be RFI at SLAC on 3 Nov 2003.
7. Completed CAL modules 3 and 4 must be RFI at SLAC on 2 January 2004.
8. Completed CAL modules 15 and 16 must be RFI at SLAC on26 March 2004. This item and previous item imply a production delivery rate of one module approximately every week, unless deliveries begin prior to the required time.
9. Each CAL crystal will be subject to at least 12 full thermal-vac cycles during test. Four cycles are required before delivery of completed CAL module to SLAC. Any cycles completed in France on the CDEs prior to delivery of PEM to NRL are not counted in the required 12 cycles. NRL must perform the four cycles regardless of the cycles on the CDEs in France. One cycle at NRL shall be thermal-vacuum with functional test at temperature and pressure excursions.
10. This sequence includes acceptance tests for the PEMs, but it assumes that elements to be integrated with the PEMs – the AFEE boards, calorimeter Tower Electronics Modules (TEMs), and flight (TBR) power supplies – are accepted and verified separately, prior to entry into this sequence. We expect to integrate flight TEMs and deliver them to the Instrument Integration site as part of the CAL.

5 Organization Structure

The *A&T Manager* will be in direct control of all A&T activity and will lead a core team of key personnel. The A&T Manager and Deputy are responsible for planning, overall scheduling, resources, and execution of A&T plans and procedures. They are also assigned responsibility for the health and welfare of all flight equipment, as well as personnel safety. The core team is comprised of the A&T Manager, *Deputy A&T Manager*, lead subsystem engineer, lead mechanical engineer, lead electrical engineer, lead test conductor, and quality assurance personnel.

The *cognizant Subsystem Engineer* (CogE) bears overall technical responsibility for the subsystem under test and for the definition, establishment, and maintenance of test configurations. The CogE will prepare (or assist in the

preparation of) the appropriate assembly and functional test procedures. The CogE has prime responsibility for the operation of the subsystem during testing, including data evaluation and the investigation and resolution of anomalies.

The *Subsystem Lead Mechanical and Electrical Engineers* may act as Test Directors during specialized testing, such as vibration and thermal vacuum testing. They have overall responsibility for all aspects of the test including detailed planning, coordination of team formation, direction of the test team and of the actual setup and performance of the test and test data evaluation.

The *Test Conductor(s)* will develop the overall system test procedures. The test conductor is the sole authority on the floor during the performance of any test and maintains a daily Test Conductor's Log of activities and anomalies.

Technicians perform the hands-on work along with or under the guidance of the CogE for the test. Their work will follow instructions detailed in test plans and procedures. It will include setup and tear down of test configurations as required, as well as performance of the tests.

The *Quality Assurance Representative* monitors all tests, signs off on results, and makes sure that problem reports and resolutions are written when necessary. QA will inspect all hardware work for conformance with the requirements and quality of workmanship. QA will maintain a daily log of the authorized work to be done and work completed.

6 Documentation and Reporting

6.1 Test Plans

Approved test plans and procedures will be required throughout all phases of assembly and test of the CAL Modules. Test reports shall be written as a follow-up to all major tests, and quality records will be maintained. The plans and procedures shall be reviewed and approved by the A&T Manager, the Subsystem Lead, and the QA Manager.

A subsystem test plan shall be prepared for each element of the CAL by the Subsystem Lead. The plan shall describe the overall requirements to integrate and test the element within the subsystem and/or on the LAT. It shall describe the care and safety, any special handling required (e.g. ESD, contamination, etc.), GSE required, integration flow requirements, etc.

Test plans in general shall include the following items.

1. Description of the test to be performed.
2. Component, element, or Module configuration.
3. GSE required.
4. Personnel required.
5. Facility and facility configuration required.
6. Test sub-procedures to be used.
7. Requirements for the test, levels, and tolerances.
8. Data collection, processing, and reporting requirements.
9. Test results expected, and pass/fail criteria.
10. Handling and safing procedures.

6.2 Test Reports

After completion of a major test, such as Comprehensive Performance Testing or environmental testing, a Verification Test Report shall be completed by the A&T Manager or Lead Engineer, with support from the Lead Test Conductor. A report summary shall accompany the Verification Test Report form that will describe highlights of the test and identify test deviations, problems, and success status. Test reports will be provided within three days after test completion.

Each report and associated resolution activity will be monitored by QA.

The status of all discrepancies, functional anomalies, subsystem failure-free operating hours, and out-of-tolerance levels detected during the A&T process will be generated and presented to the Pre-ship Review Board prior to

shipment of a CAL Module to the LAT instrument integration site. This review will contain all items written against the CAL Module. The pre-ship report shall accompany the Module through the integration process at the instrument integration site.

Test procedures and Test Reports shall be retained as official records.

6.3 Test Conductor's Logbook

The test conductor shall maintain a logbook that is used to record key events of the test activity in progress. The date and time of pertinent events and statement of the event itself will be recorded as determined by the test conductor. The configuration status, anomalous conditions, and anomalous results shall be noted.

6.4 Post-Test Critiques

Following tests of Engineering Model and Flight hardware, formal critiques will be held if requested by the A&T Manager or other members of the core A&T team. Test data, procedures, and reports will be reviewed to determine or enhance their conformance with test requirements. Reports of these critiques may be issued and procedures and plans modified as needed.

6.5 CAL Module Properties Database

A database containing measurements and test results for each CAL Module shall be maintained.

7 Assembly and Test Sequence

The following is an outline of the assembly and test activity for the 19 PEMs. A complete description of the sequence is given in Calorimeter Module Assembly and Test Plan, LAT-SS-00262.

1. Receipt at NRL. Comparison with shipping logs to confirm identity of items shipped. Visual inspection for shipping damage.
2. Mass Properties Measurement #1. Establishes weight and physical dimensions of PEM.
3. PEM Checkout Electronics Integration. Install PEM in PEM-CES for readout of large and small PIN diodes of each log face. Limited functional test of EGSE hardware.
4. Muon Calibration #1. Confirms quality of PIN diode bonds and generates light attenuation maps. Minimum run time = 24 hrs. Document results.
5. AFEE Integration. Attachment of CAL AFEE boards. Attachment of 192 flex cables. Inspection.
6. CAL TEM and PS Integration. Integration and simple aliveness test. Document results.
7. Comprehensive State Functional Testing #1. Establishes full functionality of integrated CAL Module. Analyze and document results.
8. Electronic Calibration. Charge injection calibration. Analyze and document results.
9. Muon Calibration #2. Establishes baseline gain of integrated system. Analyze data. Compare with PEM-CES response and known gain of AFEE. Document results.
10. Mass Properties Measurement #2. Establishes weight, center-of-mass, and physical dimensions of assembled CAL Module.
11. Thermal-Vac Testing. Four cycles over qualification or workmanship range (as appropriate for the module under test), with temporal gradient <10C per hour and holding temperature limits at least 2 hours. The plateau time shall be based on the time required to perform performance/functional tests, but shall not be less than 2 hours. Require operation and functional tests during only one cycle at the hot and cold plateau. Limited performance test following each cycle. Document results.
12. Vibration Testing. The vibration testing comprises three components: modal frequency verification, sine burst testing, and random vibration testing. Includes limited performance test. Document results.

13. Electromagnetic Compatibility Testing. Establishes electromagnetic noise production and susceptibility. Test is performed only on EM and QM models. Document results.
14. Muon Calibration #3. Establishes no degradation in performance during environmental testing and handling.
15. Comprehensive Performance Testing #2. Establishes no degradation in operation during environmental testing and handling.
16. Mass Properties Measurement #3. Establishes no change in weight, center-of-mass, and physical dimensions of assembled CAL Module during environmental testing.
17. Pre-ship Review and Sign-off. Establishes readiness for shipment.
18. Shipment to LAT Instrument Integration Site.

8 Environmental Tests

The following environmental tests have been identified for the Assembly, Test, and Calibration of CAL modules.

8.1 Thermal-Vacuum Tests

Thermal-vacuum testing of PEM and CAL Module shall be performed to demonstrate satisfactory operation in representative functional modes at mission operating temperatures, at temperatures in excess of the extremes predicted for the mission, and during temperature transitions. PEM and Module units shall be tested in a non-operational mode at cold and hot limits to demonstrate that permanent degradation will not result from exposure to survival mode temperatures defined for the GLAST mission. In addition, components of the CAL Module able to powered at low-temperature survival heater settings shall be tested in a powered mode to demonstrate operation without degradation, although the components need not meet their performance specifications until the operational test limit temperature is reached.

Components of the CAL Modules shall be subjected to a minimum of four hot-cold cycles with a hot temperature of +50C and a cold temperature of –30C. The test duration shall be based on the time required to perform performance/functional testing of the Module or sub-components at each hot and cold temperature plateau but, as a minimum, two-hour soak periods shall be conducted. Components shall be operated during the transition times, and turn-on demonstrations shall be made at both cold and hot extremes.

The temperature and pressure ranges and the duration of the test will comply with the requirements specified in LAT-TBD, which is the document of final authority on these tests. Temperatures and pressures listed herein shall not be considered to be authoritative if they disagree with LAT-TBD.

The thermal-vacuum tests shall fulfill the bake-out function.

8.2 Vibration Testing

The vibration testing shall comprise three subsets: minimum modal frequency verification, sine-burst strength testing, and random vibration testing.

8.2.1 Minimum Modal Frequency Verification

Each CAL Module shall be subjected to a low-level sine-sweep vibration test to verify its minimum modal frequency in each of three mutually perpendicular axes, one of which is the LAT Z axis. Compliance with the design minimum modal frequency shall be checked. This test should be performed in conjunction with the sine burst vibration test.

Testing shall be performed in accordance with the procedures and requirements of LAT-TBD.

8.2.2 Sine Burst Strength Test

Each CAL Module shall be subjected to a sine-burst vibration test to verify its strength against launch loads. Test frequencies shall be selected that are low enough to assure rigid body motion of the Module under test. The number of sinusoidal dwells or reversals made at specified levels during the test shall be 10 plus or minus 5 cycles. The test shall be performed in each of three orthogonal axes. This test should be performed in conjunction with the random vibration test.

Testing shall be performed in accordance with the procedures and requirements of LAT-TBD.

8.2.3 Random Vibration Test

Each CAL Module shall be subjected to a random vibration test at flight levels. The test shall be performed in each of three orthogonal axes. This test should be performed in conjunction with the modal frequency and sine burst vibration tests.

Testing shall be performed in accordance with the procedures and requirements of LAT-TBD.

8.3 Electromagnetic Compatibility Testing

The Engineering (EM) and Qualification Model (QM) CAL Modules shall be subjected to electromagnetic compatibility (EMC) testing to ensure that it will be neither a source of electromagnetic interference (EMI) nor susceptible to EMI when integrated with other components of the LAT and spacecraft. EMC/EMI testing of the 16 flight CAL Modules is not required: verification of compliance with EMC/EMI requirements shall be by assessment of similarity with the QM.

Testing shall be performed in accord with the procedures and requirements of LAT-TBD.

9 Ground Support Equipment (GSE)

9.1 Mechanical GSE

9.1.1 Lifting Fixture

Lifting fixtures for handling two individual PEMs or CAL Modules are required at NRL. At least one fixture must be portable to allow handling of PEMs or Modules near the stationary thermal-vac chamber and muon telescopes.

9.1.2 Transportation Cart

Carts for mounting and moving nine individual CAL Modules are required: (1) five of these carts are required at NRL for the four Modules under assembly and test at any given time; (2) two carts at required at NRL to support contingencies in the assembly schedule; and (3) two carts are required at SLAC to support integration with the LAT.

The cart shall be capable of securely mounting either a PEM or a completed CAL Module. The PEM or Module shall be held vertically at table height. The cart shall be wheeled, and it shall be narrow enough to negotiate a standard laboratory door.

9.1.3 Rotation Mount

Two (TBR) rotatible assembly jigs for PEM-to-AFEE integration are required at NRL.

The rotation mount shall be capable of securely mounting either a PEM or a completed CAL Module. The mount shall have one free axis of rotation in the horizontal plane with sufficient mass to counterbalance an attached Module. The mount shall also allow an indexed rotation about the Module Z axis with four stops corresponding to the four Module faces.

9.1.4 Dry Storage and Shipping Container

Dry storage containers for 19 PEMs or CAL Modules are required. The dry storage containers shall also function as shipping containers.

9.1.5 Translation Table

One automated x-y translation table for movement of a single CAL Module for beam tests is required.

The Translation Table shall have the capacity to hold and translate one CAL Module within a plane. It shall have a full travel of at least 70 cm in both dimensions, and it shall locate the Module reproducibly to less than 1 mm. The motorized drive shall be controlled and read out by a PC-based system.

9.2 Electrical GSE

9.2.1 PEM Checkout Electronics System

The PEM Checkout Electronics System (CES) provides readout, digitization, acquisition, and analysis of all 384 PIN photodiodes in a PEM. It shall comprise at least 192 channels of low-noise preamplifiers, shaping amplifiers with shaping time compatible with CsI(Tl) scintillation pulses, and analog-to-digital converters. It shall support both self-triggering by the PEM and external triggering. It shall contain sufficient discriminators and logic to allow a trigger on any of the 96 crystals of a PEM.

The PEM CES requires a PC-based data acquisition, archiving, and analysis system. The data acquisition system shall be compatible with either CES or Module Controller data streams.

The PEM-CES mechanical structure shall allow for safe and reliable mating of Kapton flex cables from the PIN photodiodes.

9.2.2 EGSE Cal Controller

Ten (TBR) Calorimeter Controllers are required. The Cal Controller is identical to the flight TEM, or provides identical functionality.

Four Controllers are required at NRL for the four Flight CAL Modules under assembly at any one time, two for the QM A and B CAL Modules, and one spare. Two Controllers and one spare (TBR) are required at the instrument integration site for Integration and Test activities.

9.2.3 General Purpose Lab Test Equipment

This set of equipment is comprised of oscilloscopes, voltage/current/impedance meters, milliohm meters, strip chart recorders, spectrum analyzers, and various hand tools.

Various breakout boxes and test cables are required to support the electrical integration of components. The signals of the electrical interfaces are observed using oscilloscopes and meters before and after electrical mating.

9.3 Muon Telescope

Two muon telescopes capable of providing 3 (TBR) mm (one sigma) positioning simultaneously in two dimensions in all layers of a CAL Module are required. Each telescope must be sufficiently large to enclose a single CAL Module.

One telescope is necessary to meet the delivery schedule for CAL Modules. The second telescope is available as a spare or to meet contingencies in the assembly schedule.

10 Facility Requirements

10.1 Assembly and Test Facilities

10.1.1 PEM Electronics Integration Area

An area of approximately 400 square feet is required for the PEM electronics integration.

10.1.2 Muon Calibration Area

An area of approximately 100 square feet is required for the Muon Telescope setup.

10.1.3 EMC Facility

10.1.4 Vibration Facility

10.1.5 Thermal and Thermal-Vacuum Facility

The CAL Module thermal-vacuum tests require one thermal-vacuum chamber with internal dimensions sufficiently large to hold a single, assembled CAL Module and controller. Sufficient electrical feed-throughs shall be provided to

permit data links to the module for control and data i/o. The chamber must cover the temperature range form –30C to +50C and pressure from one atmosphere to 10^{-5} Torr (TBR). The number of usage days is five per Module, for a total of 90 days for all 18 Modules.

10.2 Shipping and Storage Facilities

Dry storage and shipping containers for 19 PEMs are required.

The storage room at NRL shall have the capacity to store 12 PEMs (TBR) in their storage containers.