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Document Title LAT ACD Assembly, Integration & Test Plan		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

ACD Assembly, Integration & Test Plan

DRAFT

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes

1. Purpose

This document provides plan for GLAST ACD subsystem integration & test. This plan is aimed to qualify all new designs and process used in the ACD, and verify workmanship of the flight hardware.

2. Definition

ACD	The LAT Anti-Coincidence Detector Subsystem
ADC	Analog-to-Digital Converter
AEM	ACD Electronics Module
ASIC	Application Specific Integrated Circuits
BEA	Base Electronics Assembly
CAL	The LAT Calorimeter Subsystem
DAQ	Data Acquisition
EGSE	Electrical Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FM	Flight Module
FMEA	Failure Mode Effect Analysis
FREE	Front End Electronics
GAFE	GLAST ACD Front End – Analog ASIC
GARC	GLAST ACD Readout Controller – Digital ASIC
GEVS	General Environmental Verification Specification
GLAST	Gamma-ray Large Area Space Telescope
HVBS	High Voltage Bias Supply
ICD	Interface Control Document
IDT	Instrument Development Team
I&T	Integration and Test
IRD	Interface Requirements Document
JSC	Johnson Space Center
LAT	Large Area Telescope
MGSE	Mechanical Ground Support Equipment
MLI	Multi-Layer Insulation
MPLS	Multi-purpose Lift Sling
PCB	Printed Circuit Board

PDR	Preliminary Design Review
PMT	Photomultiplier Tube
PVM	Performance Verification Matrix
QA	Quality Assurance
SCL	Spacecraft Command Language
SEL	Single Event Latch-up
SEU	Single Event Upset
SLAC	Stanford Linear Accelerator Center
TACK	Trigger Acknowledge
TDA	Tile Detector Assembly
T&DF	Trigger and Data Flow Subsystem (LAT)
TBD	To Be Determined
TBR	To Be Resolved
TSA	Tile Shell Assembly
TSS	Thermal Synthesizer System
TKR	The LAT Tracker Subsystem
VME	Versa Module Eurocard
WBS	Work Breakdown Structure
WOA	Work Order Authorization

3. Applicable Documents

Documents relevant to the ACD Assembly and Test Plan include the following.

1. LAT-SS-00016, LAT ACD Subsystem Requirements – Level III Specification
2. LAT-SS-00352, LAT ACD Electronics Requirements – Level IV Specification
3. LAT-SS-00437, LAT ACD Mechanical Requirements – Level IV Specification
4. LAT-SS-00448, LAT ACD Electronics Subsystem Specification
5. LAT-SS-00449, LAT ACD Mechanical Subsystem Specification
6. LAT-TD-00435, LAT ACD Grounding and Shielding Plan
7. LAT-MD-00039-01, LAT Performance Assurance Implementation Plan (PAIP)
8. LAT-MD-00099-002, LAT EEE Parts Program Control Plan

9. LAT-SS-00107-1, LAT Mechanical Parts Plan
10. LAT-MD-00078-01, LAT System Safety Program Plan (SSPP)
11. ACD-QA-8001, ACD Quality Plan
12. ACD-REQ-7002, Requirements for ACD MGSE

4. Introduction

The ACD Subsystem is comprised of two primary assemblies, the Base Electronics Assembly (BEA) and the Tile Shell Assembly (TSA). The BEA is the mechanical support structure for the ACD. It supports the TSA and houses the ACD electronics as well as provides the mechanical and electrical interfaces to the LAT. It is an aluminum structure and it is mechanically symmetric. The Base Frame also provides the mechanical interface between the ACD and LAT. There are eight mounting points between the ACD and LAT, at the four corners and at the center of each side. The TSA supports the Tile Detector Assemblies (TDA's) and their associated fiber cables as well as the Micrometeoroid Shield/Thermal Blanket.

This document was developed under the following assumptions that the ACD subsystem will receive from the LAT project the following items for the development:

5.Five ACD Electronic Modules (AEM) units with cable interfaces to ACD.
6.Three (3) EGSE with Front End Workstations and SCL control executive and LabVIEW GUI.
7.AEM operating and handling manuals.
8.AEM timing diagrams that describes every mode of operation.

5. ACD Subsystem Integration & Test

The ACD Integration & Test requires to integrate and test the elements that make up the ACD subsystem at GSFC prior to delivery. The elements to be combined include the Tile Shell Assembly (TSA), Base Electronics Assembly (BEA), and Micrometeoroid Shield/ Thermal Blanket Assembly. Once combined, these elements create the ACD Flight Model.

5.1 ACD Subsystem Mechanical Integration & Test

ACD Subsystem mechanical and thermal structural subassemblies, which include the Shell, the Tile Detector Assembly (TDA), the TDA Tiedowns, the Base Electronic Frame (BEF), the Micrometeorite Shield and Thermal Blanket (MS&TB), and the Mechanical Ground Support Equipment (MGSE).

The testing required for each component and/or subassembly is listed in the Test Matrix of the Appendix. Tests that may be required are listed below:

- Performance and/or Functional Test
- Mass Properties Measurement
- Sine Vibration Test
- Random Vibration Test
- Frequency Determination Test/Sine Sweep

- Acoustic Test
- Thermal Vacuum/Non-vacuum

Mechanical integration of the TSA and the BEA can be performed in parallel. Subsystem integration shall start when the Tile Shell and/or Base Frame delivered to I&T team. These efforts require the flight structures of the TSA and the BEA, and components and/or subassemblies shall be fully qualified prior to I&T delivery.

In order to minimize the effects of gaps between scintillator tiles, all tiles are overlapped by 1cm in one direction, and have gaps in the other. The gaps are required to be ~ 3 mm (0.7mm for wrapping and 2mm for thermal expansion). These gaps are covered by scintillating fiber ribbons. Tiles will be mounted onto the TSA in the row of 5 tiles at a time, and will follow with an aliveness test of those 5 tiles to insure there is no damage to the tiles during integration. The final segmentation of active area on the sides is 3 rows of 5 tiles each, plus a bottom row consisting of a single tile. The reduced segmentation design for the ACD is 5 by 5 tiles on the top and 16 tiles on each side (89 tiles in total).

The BEA houses and protects the ACD onboard electronics as well as provides the electrical interface to the LAT. The flight base frame shall be qualified using mass models. Onboard electronic components shall also be qualified individually prior to deliver to I&T. Each Event Board (FREE board) along with PMT and HVBS shall be mechanically integrated onto the BEA. Aliveness test shall be run on each electronic component after it's integrated.

On the Y sides of the BEA, there are two single row Event Board Modules. Each Event Board Module has the capability to hold 18 PMT's. Therefore on each of the Y sides there are a total of 36 PMT's. Thirty-Two of the PMT's are for the TDA's and the other 4 PMT's are for the fiber ribbons. We are currently modeling the fiber routing on the Y sides.

On the X sides there are two double row Event Board Modules. This is because the output from the TDA's on the top (+Z side) is read out on the X sides. Essentially half of the TDA outputs from the top go to the +X side and the other half go to the –X side. Therefore each of the Event Board Modules on the X sides will have inputs from both the top (+Z) and their respective X side. The fiber routing on the X sides has been modeled, and while it is fairly complicated, it is feasible.

Final integration of ACD subsystem involves the mating of the TSA and the BEA modules after both modules have been fully integrated. This process includes the mechanical integration of the TSA onto the BEA; then, each TDA will be electrically mated to a pair of PMTs through the fiber optic cables,

5 ACD Subsystem Electrical Integration

During electrical integration of the ACD Subsystem, precautions are taken to ensure that electronic equipment is not damaged by connecting incorrect electrical signals to it. The electrical signals appearing at each connector pin are measured to verify that they are of the proper polarity and level prior to connection to the mating equipment. All electrical equipment is checked during acceptance testing prior to integration to ensure that, when the equipment is properly energized, signals of the proper levels and polarity appear at its interface connectors.

The exact sequence followed during electrical integration is a function of the box being tested. For example, it may be necessary to integrate certain control signals from connector one before integrating power from connector two, that must be integrated before the integration of connector one can be completed. This interdependence is unique for every box and will be spelled out in the detailed integration procedures. However, open-circuit voltage checks and isolation/continuity checks must always be performed before a connector is first mated. And the first time a box is powered, IPTO testing must be performed.

For a typical box, electrical integration consists of the following:
- For each connector on the component:

1. With all instrument power removed, install connector savers on the component.
- And also on the harness if space allows.
2. Install Break-Out Box (BOB), with all jumpers removed, between the component and the harness;
3. Perform an isolation/continuity check.
4. Supply power to the component and perform an open-circuit voltage check. Remove power from the component.
5. If connector supplies power, perform Initial Power Turn-On (IPTO). Remove power from the component.
6. Install jumpers, reapply power, and verify connector performance;
- Perform functional test (with BOBs installed)
- Remove all BOBs and re-mate the harness to all the connectors.
- Re-run the functional test.

Approved procedures shall be used during all operations. Rules for mating and de-mating connectors shall be followed at all times.

Note: If a connector needs to be de-mated and then re-mated, and no changes have been made to that connector or to any connector or harness electrically connected to that connector, then the steps above do not need to be repeated. . However, QA shall inspect all flight contacts before/after all mate/de-mate operations. The Lead Electrical Technician will track all work performed on the harness and will be consulted on whether re-verification needs to be performed before a mating operation.

Note: Power is always removed before mating or de-mating connectors or adding jumpers to a BOB.

5.3 ACD Subsystem Functional Tests

5.3.1 TDA Production Level Test.

This test spreads through the stages of TDA production and includes the following:

a) visual inspection of tile machining and bending (after grooving)

b) visual inspection of fiber gluing quality (into grooves)
c) visual inspection of fiber gluing into connectors
d) TDA inspection after wrapping, including the light tightness test (with PMT attached)
e) Light yield test (TBA with Fermilab)

Every tile is allowed to go to the next step only after passing the previous step test. GSFC representative is required to participate in steps (a) through (c).

5.3.2 TDA Pre-Assembly Test

This test is performed at Goddard after receiving TDAs from the manufacturer. The task of this test is to certify the TDAs for the installation in TSA. It includes:

a) Light tightness test. Performed with PMT attached looking at the count rate by the oscilloscope
b) Light uniformity test with the purpose of checking if there are broken fibers. Use test setup TS. Takes approximately 3 hours per tile
c) Efficiency measurement. Data from previous step (light uniformity test) is used to determine the efficiency.

5.3.4 ACD Aliveness Test

Aliveness Tests are performed during acceptance test sequence for each component, subassembly, and subsystem, and environmental tests to demonstrate that the environmental tests have not degraded the functional capability of the hardware.

All TDAs are connected with their flight PMTs and FREE. ACD is in normal position (top side looks at the zenith). The VETO rates from every channel (PMT) are measured at thresholds of 0.1 MIP and 0.4 MIP at nominal HV.

During ACD assembly there could be a need to perform aliveness test for every TDA (every TDA row) after the installation on TSA. If BEA with FREE circuit cards is not installed yet by that time, this test can be done by using one set (of two) dedicated PMT, NIM rate counter and external HVPS. It will probably require extra soldering. So, this test should be thought out, it can be undesirable.

5.3.5 ACD Limited Functional Test

Limited Performance Tests (LFTs) are performed during and after environmental tests to demonstrate that the environmental tests have not degraded the functional capability of the hardware. The measurements taken during LFTs are established based on the objectives of the particular test sequence with which they are associated and the feasibility of making the desired measurements under the conditions imposed by the test. In ACD level testing, the LFTs include a health check of all active components. This consists of a computer-driven sequence in which two types of measurements are made: (a) change in power consumption when each component is turned on or off as an indication that the component is actually operating and drawing the proper amount of power, and (b) a command functional test in which commands are sent to every item, the response of which can be monitored by telemetry. The ACD LFTs may include other measurements as required to complete the health check.

In case of ACD, LFT includes the following:

a) Aliveness test – also checks the light tightness
b) Gain calibration test.
c) Light uniformity test is performed only on TDA which have questions after Gain calibration test

5.3.5 ACD Full Functional Test

A Full Functional Test (FFT) is performed at the beginning of the qualification or acceptance test sequence for each component, subassembly, and subsystem. The purpose of the FFT is to verify that the equipment meets all of its specified performance requirements within allowable tolerances. As a minimum, the test is repeated at hot and cold temperature extremes and at the conclusion of the environmental test sequence. The initial FFT provides a baseline against which the data from the subsequent FFTs can be evaluated.

At the subsystem levels, the FFT provides a detailed demonstration that the equipment meets the performance requirements in all operating modes within the allowable tolerances. It also verifies that all redundant equipment and interconnecting signals are performing within tolerance. The FFT contains tests which enable comparison to data taken at the subsystem or component level to data taken during the ACD FFT when known stimuli are applied.

Much of the ACD FFT is performed before environmental test, and repeated at the post-ship check out at SLAC. This test verifies not only instrument performance, but also that the test measurement complex is properly set up and operating prior to commencing this expensive and important test. During the thermal-vacuum test, Limited Functional Test measurements are performed at hot and cold temperatures to verify that the instrument performance meets the specified requirements at the orbit temperature extremes. To the extent that it is practicable, the performance test includes measurements at temperature margins of 15 ºC for qualification and 5 ºC for acceptance.

ACD is in normal position (top side looks at the zenith). FFT includes the following:

a) Aliveness test
b) Light Uniformity test for all tiles (takes 1 month)
c) Gain calibration test
d) Efficiency measurement using data from Light Uniformity test. Remark – since the ACD will not be rotated, efficiency will be overestimated for side tiles due to longer muon paths.

5.3.6 Trend Data

Critical performance parameters are used for monitoring ACD performance trends during qualification and acceptance programs. The trend data is stored in a computerized database to facilitate data retrieval and display. ACD performance parameters are automatically stored in high-capacity magnetic disk storage media. Data is available for retrieval, display and printout.

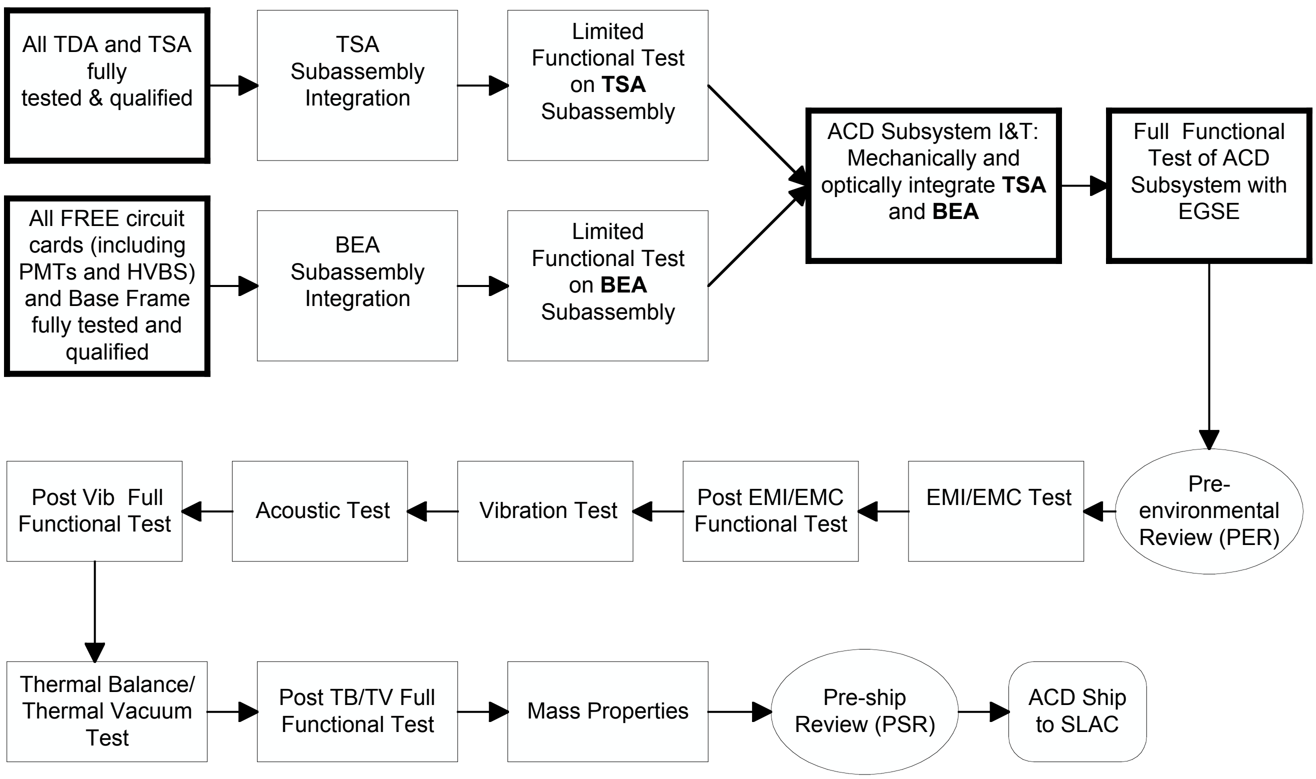

Figure 1. ACD Subsystem Integration and Test Flow

6. ACD Subsystem Environmental Tests

All ACD environmental tests shall be conducted at GSFC facilities. The exact levels and duration, the order of the tests, as well as any customizations to these tests, are described in “LAT ACD Assembly, Integration, and Test”, LAT-TD-00430. Environmental tests list below are not necessary performed in the listed order. Unless specified, the tests are only performed on the ACD Flight Unit.

- Electromagnetic Compatibility (EMC)/ Electromagnetic Interference (EMI)
- Acoustic testing
- Vibration (vibration & shock) on both the EM and FM
- Thermal Vacuum (Thermal Balance, Thermal Cycling, Thermal ACD and/or Characterization)
- Mass Properties

6.1 Electromagnetic Compatibility

It is necessary to verify the ability of the ACD to withstand the effects of electrostatic discharge as a result of satellite charging in the orbit environment and an all up RF link test to verify self-compatibility. The requirements for verification of conducted and radiated emissions and Susceptibility tests have been established based on the expected launch and orbital operations of the ACD. Verification is accomplished by qualification test and analysis. Guidelines for the test and analysis program are shown below:

a. Radiated and conducted susceptibility and emissions tests for new or substantially modified microwave components.
b. Conducted susceptibility and emissions tests on new or substantially modified digital or power components.
c. Electrostatic discharge tests per MIL-STD-1541 on all new or substantially modified digital components.

6.2 Vibroacoustics

The ability of the ACD hardware to withstand the launch vibroacoustic environment is verified by tests at the component and ACD levels. ACD flight support equipment components are qualified to random vibration at verification levels based on the maximum expected flight environment plus 3 dB. Vibration is applied in each of three orthogonal axes with the equipment operation and meaningful performance parameters monitored. The ACD is mounted in the launch configuration and is monitored for these tests. An LFT is conducted after the application of the environments to verify no performance degradation has occurred. Acceptance tests are conducted in the same way as the qualification tests, except that the vibration and acoustic levels are maximum expected flight levels.

6.3 Vacuum, Thermal, and Humidity

6.3.1 Thermal-Vacuum

The basic thermal-vacuum test requirements are as follows:

a. Four thermal cycles at component level
b. Four thermal cycles at LAT level
c. Thermal-vacuum on components sensitive to vacuum
d. A 15 ºC margin beyond mission allowable for qualification test
e. A 5 ºC margin beyond mission allowable for acceptance test
f. Turn-on capability demonstrated under vacuum at least twice at low and high temperatures, as applicable
g. Operation during at least one cycle of thermal-vacuum
h. Operation and monitoring during thermal cycling, including transitions

The test program includes a minimum of four temperature cycles at the component level during which the turn-on capability is verified twice, as required, and full performance testing is conducted at temperature extremes. The temperatures are 15 ºC beyond mission allowable qualification tests on the component and 5 ºC for acceptance of flight units. The component thermal cycling is conducted in a vacuum for receivers and power amplifiers due to the possible effects of the outgassing of these items. Components that do not receive testing as part of the LAT are subjected to eight thermal cycles at the component level.

The flight LAT is subjected to four thermal cycles at vacuum. Performance is measured during temperature transitions and at high and low mission allowable temperatures, plus the 15 ºC margin for the PFM LAT and 5 ºC margin for acceptance. In establishing the 15 ºC temperature margin, temperature levels throughout the LAT are monitored. No component is allowed to go beyond the 15 ºC margin.

6.3.2 Thermal Balance

The thermal design is verified with an analytical model that is confirmed by tests conducted on the PFM LAT. The tests are conducted in conjunction with the thermal-vacuum performance tests.

The thermal balance test program will be considered successful if (a) the LAT analytical model can correlate with the test data to within ± 5 ºC, and (b) all diode and transistor

6.4 Mass Properties

Verification of meeting mass property requirements for the ACD will be performed by experimental measurements and analyses or by a combination of measurement and analysis.

7. Ground Support Equipment

7.1 Mechanical Ground Support Equipment (MGSE)

The requirements for the ACD MGSE can be found in ACD-REQ-7002. There are six main pieces (or groups) of MGSE: the BEA dolly, TSA dolly, ACD multi-purpose lift sling, ACD multi-purpose test fixture, ACD templates, and ACD mass simulators. The following is a brief description of each piece of MGSE.

- BEA dolly: The BEA dolly has to support and transport the BEA during the integration and testing of the BEA. It will also be used as the ACD instrument dolly.

- TSA dolly: The TSA dolly will support and transport the TSA during its integration and testing. It will have the same basic design as the BEA dolly, however the attachment points will different from the BEA dolly.

- ACD Multi-Purpose Lift Sling (MPLS): The ACD MPLS will be used to lift the ACD Instrument, BEA, and TSA. If the ACD MPLS can not be used at SLAC because of limited crane hook height, an additional special lift sling will be required.

- ACD Multi-Purpose Test Fixture: This test fixture will be a simulation of the LAT Grid. Therefore it will provide the same mounting points as the LAT Grid. It will be used for vibration and thermal/vacuum testing of the ACD. For the thermal vacuum test a combination of heaters and temperature-controlled tubes will be used to control the temperature of the fixture. This will allow the fixture to simulate the operating temperature of the LAT Grid.

- ACD templates: Templates will be required to position and install the flexure inserts on the composite shell and to locate the TDA's on the composite shell. The same template that is used to install the flexure inserts in the composite shell can also be used to locate and drill the interface holes in the base frame.

- ACD mass simulators: Mass simulators for the TDA's, Event boards, and MS/TB will be required for qualification testing of the flight structure. In addition to these mass simulators, a mass simulator of the ACD instrument will be required to test the shipping container isolation system.

7.2 <u>Electronics Ground Support Equipment (EGSE)</u>

There are four main pieces (or groups) of EGSE: AEM's, Event Simulator, HVBS Test Fixture and ASIC test stations. The following is a brief description of each piece of EGSE.

- Five AEM's are needed from the LAT team for FREE circuit card development and I&T. The AEM's should include three NT workstations for using the AEM's.

- Event Simulator for FREE circuit cards. This unit will simulate the input of the 18 PMT's for the FREE circuit card, allowing timing, coincidence, and spectroscopy tests to be performed on the electronics. This unit is a custom-designed circuit board assembly, a computer (& software), and laboratory test equipment, such as pulse generators, multimeters, and oscilloscopes. This is need prior to functional testing of the FREE circuit cards.

- High Voltage Bias Supply Test Fixture. This GSE is required to test the flight HVBS prior to integration with the BEA. This is needed prior to vacuum testing the HVBS.

- ASIC Test Stations (2). We will require a test station for the evaluation of the analog ASIC and a test station for the evaluation of the digital ASIC. This will be a combination of a custom-designed circuit board with a computer and COTS lab equipment. This is needed for the screening of the ASICs.