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	Author(s) E. do Couto e Silva T. Leisgang	
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Gamma Ray Large Area Space Telescope (GLAST)
Large Area Telescope (LAT)
LAT Science Verification Analysis and Calibration Test
Requirements Plan

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1. **Purpose**

This document defines the Test Requirements Plan for the Science Analysis and Calibration for the Large Area Telescope (LAT) of the Gamma-ray Large Area Space Telescope (GLAST) Mission.

2. **Scope**

This document describes the necessary requirements needed to implement the SVAC Plan (LAT-TD-00446).

3. **Acronyms and Definitions**

3.1. **Acronyms**

ACD	Anti Coincidence Detector
ADC	Analog-to-Digital Count
AGN	Active Galactic Nuclei
CAL	Calorimeter
CNO	Carbon, Nitrogen, Oxygen
CsI	Cesium Iodide
CsI (TI)	Cesium Iodide doped with Thallium
CR	Cosmic Rays
CU	Calibration Unit (four towers)
DAQ	Data Acquisition System
EGRET	Energetic Gamma Ray Experiment Telescope
EGSE	Electrical Ground Support Equipment
ELX	Electronics
EM	Engineering Model (single tower)
ENV	Environmental
Fe	Iron
FEE	Front-End Electronics
FSW	Flight Software
FOV	Field of View
FU	Flight Unit (single tower)
GBM	Gamma-Ray Burst Monitor
GCR	Galactic Cosmic Rays
GLAST	Gamma ray Large Area Space Telescope
GRB	Gamma Ray Burst
GSFC	NASA Goddard Space Flight Center, Greenbelt MD
GUI	Graphical User Interface
HEX1	High-gain low-energy range
HEX8	High-gain high-energy range
IFCT	Integration Facilities Configuration and Test
IOC	Instrument Operations Center
I&T	Integration and Test
LAT	Large Area Telescope (sixteen towers)
LEX1	Low-gain low-energy range
LEX8	Low-gain high-energy range
MC	Monte Carlo

N/A	Non applicable
PMT	Photomultiplier Tube
PSF	Point Spread Function
QU	Qualification Unit
SAS	Science Analysis Software
SLAC	Stanford Linear Accelerator Center
SPAR	Single Photon Angular Resolution
SSD	Silicon Strip Detector
SVAC	Science Verification, Analysis and Calibration Department
TBD	To be determined
TBR	To be reviewed
TEM	Tower Electronics Module
TKR	Tracker
TOT	Time-over-Threshold

3.2. Definitions

Engineering Model (EM): Non-flight hardware that will be used to qualify the design for flight hardware.

Flight Hardware: Hardware intended for flight and tested to flight acceptance levels and durations. Consists of protoflight, follow-on, and spare hardware.

Functional Test: The operation of a unit in accordance with a defined procedure to demonstrate that the performance meets specifications.

Performance Verification: Determination by test, analysis, or a combination of the two that the component or instrument satisfies the performance requirements.

PIN diode: Semiconductor structure made of layers of p and n doped material interleaved with an insulator, generally used as a photodetector, and used in the calorimeter.

Qualification: The process of demonstrating that a given design and manufacturing approach will produce hardware that will meet performance when subjected to defined conditions more severe than expected during its intended use.

Subsystem: LAT subsystems: ACD, CAL, TKR, ELX, IOC, I&T.

System: A functional unit consisting of two or more components, assemblies and/or subsystems

fC: femto Coulomb, 10^{-15} Coulombs

MeV: million electron volts, 10^6 electron volts

μs: microsecond, 10^{-6} seconds

4. Applicable Documents

LAT-SS-00010, "LAT Performance Specification-Level II(b)".

LAT-SS-00016, "LAT ACD Subsystem Specification-Level III".

LAT-SS-00017, "LAT TKR Subsystem Specification-Level III".

LAT-SS-00018, "LAT CAL Subsystem Specification-Level III".

LAT-TD-00191, "Tracker Tower Electrical Tests"

LAT-MD-00404, "LAT Contamination and Control Plan"

LAT-TD-00444, "LAT Beam Test Plan"

LAT-TD-00501, "LAT Mission Phases"

LAT-SS-00570, "LAT– I&T/SAS Interface Control Document for the Engineering Model"

LAT-SS-00571 "LAT – I&T/SAS Interface Control Document for the Calibration Unit"

LAT-SS-00572 "LAT – I&T/SAS Interface Control Document for the LAT"

LAT-MD-00573 "LAT – SVAC Plan for the Engineering Model"

LAT-MD-00574 "LAT – SVAC Plan for the Calibration Unit"

LAT-MD-00575 "LAT – SVAC Plan for the LAT Integration"

LAT-MD-00576 "LAT – SVAC Plan for the LAT Environmental Tests"

LAT-MD-00577 "LAT – SVAC Plan for the LAT Mission Integration"

LAT-TD-00578 "LAT – SVAC Database for the Engineering Model"

LAT-MD-00581 "LAT – SVAC Plan for the LAT Phase 0 on-orbit"

LAT-TD-00579 "LAT – SVAC Database for the Calibration Unit"

LAT-TD-00580 "LAT – SVAC Database for the LAT"

LAT-SS-00613 "GLAST-LAT SVAC Contributed Manpower Plan"

LAT-TD-01055 "LAT I&T Electrical Performance Tests"

LAT-TD-01340 "SAS Calibration Infrastructure"

LAT-TD-01376 "LAT Integration and Test Plan"

LAT-TD-01396 "Calibration of the Van de Graff Photon Flux"

LAT-TD-01588 "Calibration Algorithms for the Engineering Model"

LAT-TD-01589 "Calibration Algorithms for the Calibration Unit"

LAT-TD-01590 "Calibration Algorithms for the LAT"

LAT-TD-01593 "SVAC Results from the Engineering Model"

LAT-TD-01594 "SVAC Results from the Calibration Unit"

LAT-TD-01595 "SVAC Results from the LAT"

5. Overview

The Science Verification, Analysis and Calibration Plan (LAT-MD-00446), hereafter SVAC Plan, is divided into pre and post-launch activities, which are derived from the LAT Performance Specification Document (LAT-SS-00010) and the subsystems' Level III (LAT-SS-00016, LAT-SS-00017, and LAT-SS-00018) specifications. The pre-launch activities are divided according to how the integrated hardware modules are tested during the LAT assembly, whereas the post-launch activities are divided into phases as defined in the LAT Mission Phases document (LAT-TD-00501).

The main goals of the SVAC Plan are

- Measurements of the LAT alignment (internal and with respect to the observatory)
- Calibration of energy scales (ACD, CAL and TKR)
- Measurements of reconstructed photon offsets versus viewing angles (e.g. "fish-eye" effect)
- Measurements of the Point Spread Function (PSF) over the field of view (FOV), versus energy and conversion region
- Measurements of the effective area (over the energy range and viewing angle)
- Measurements of the background rejection level (over the energy range and viewing angle)

To accomplish the tasks mentioned above, the I&T SVAC Department, will coordinate and participate in the following activities during LAT integration (a full description is found in the SVAC Plan –LAT-MD-00446):

- Instrument Calibrations
- Monte Carlo (MC) Validation
- Verification of Science Requirements

This document lists the plan for each hardware test, namely, Engineering Model , Calibration Unit and LAT.

6. Pre-launch Requirements

The SVAC plan builds progressively on the knowledge acquired from testing a single unit (EM), which is used to prototype tools needed for the subsequent hardware tests with multiple towers (CU and LAT). These hardware units will be tested with either cosmic rays and/or particle beams. This document describes the requirements for these tests for the pre launch activities.

6.1. Engineering Model

6.1.1. Hardware Required

6.1.1.1. EM

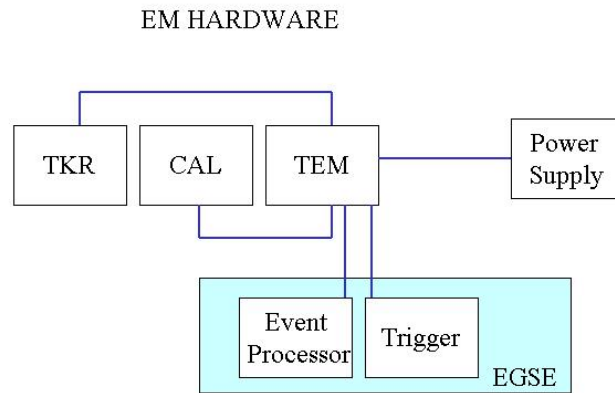
A fully instrumented CAL module and five TKR trays consisting of three XY planes of silicon detectors. A full description of the hardware components required is provided in the “ Engineering Model System Level Plan” (LAT-MD-01137).

6.1.1.2. *Flight Software Required*

There is no requirement from flight software.

6.1.1.3. *Test configuration*

The test configuration below shows the hardware components and interfaces. For details, see the “ Engineering Model System Level Plan - LAT-MD-01137”.



6.1.2. Ground Support Equipment Required

6.1.2.1. *EGSE*

The EGSE must be able to address a single-tower hardware, retrieve data, display data products and produce files that will be subsequently used for final data analysis. It must also allow for an external trigger system. A detailed description is provided in the "Engineering Model System Level Plan" (LAT-MD-01137).

6.1.2.2. *MGSE*

A mechanical fixture to hold the TKR and the CAL will be required. In addition, the EM must be positioned with the top face of the TKR as close as possible (< 10 cm) to the Van de Graaff generator, to keep a high flux of incoming photons. The support structure must also have a lateral window no smaller than 6.35×6.35 cm² to allow the van de Graaff to be positioned at the side of the CAL so that tests with CAL only trigger can be performed.

6.1.2.3. *Test Software*

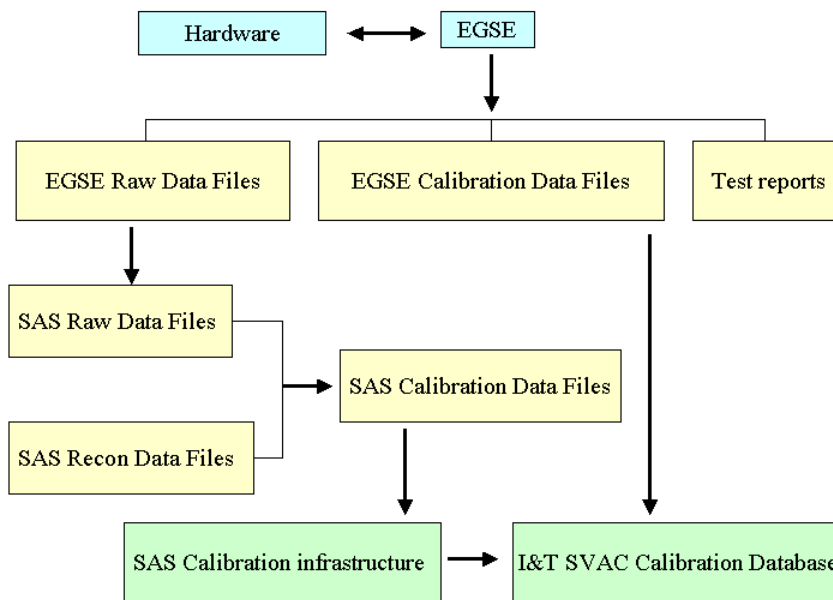
Tested and documented EGSE scripts and SAS algorithms are required to produce the calibration data described in "SVAC EM Plan-LAT-SS-00573".

6.1.2.4. *Support Instrumentation*

For the EM tests, a set of crystals is necessary to measure the flux of particles from the Van de Graaff so that one can estimate the effective area. The necessary hardware for reading out the crystals and analyzing the data must be provided.

6.1.3. Data Reporting and Analysis Requirements

Data analysis and calibration will be performed by using SAS and EGSE data files. The diagram below shows the data flow. The EGSE will control the EM hardware and produce raw data files, calibration data files and test reports. EGSE data files will then be read out by SAS software so that reconstructed data files and SAS calibration data files can be produced. Both EGSE and SAS calibration data files will be retrieved via scripts into the I&T SVAC Database.



6.1.3.1. Test Data Record

Records of the test configuration will be made which document the physical arrangement and settings of test equipments (including external equipment). An electronic database is also required to catalog the data files necessary for data analysis. Results from the overall test will be described in the “SVAC Results from the Engineering Model - LAT-TD-01593.”

6.1.3.2. Data Formats

Raw EGSE Event data (cosmic rays or photons) can be used for calibration using the EGSE. After processing the EGSE will produce output calibration data in the format specified in “Calibration Algorithms for the Engineering Model” - LAT-TD-01588”. Data in FITS format will be processed by SAS software to produce reconstructed data files which will be further process to produce SAS calibration data in the format specified in “Calibration Algorithms for the Engineering Model” - LAT-TD-01588”.

6.1.3.3. Test Products

There will be reports, files from EGSE and files from SAS. Test reports are described in the “LAT I&T Electrical Performance Tests - LAT-TD-01055-01”. A calibration infrastructure will be provided by SAS (“SAS EM Calibration Infrastructure LAT-TD-01340”) to access and store the calibration data for future use in the SAS reconstruction program. The SAS calibration infrastructure will allow data to be retrieved by I&T and to be subsequently stored in the SVAC database for trend studies as described in “SVAC EM database LAT-TD-00578”.

6.1.3.4. Analysis activities

Data analysis and calibration activities will be performed as outlined in the “SVAC EM Plan-LAT-SS-00573”

6.1.4. Test Performance Requirements

6.1.4.1. Environmental Conditions

Tests will be conducted at room temperatures between 20 and 25 degrees C. Humidity will be less than that specified in the LAT handling and transportation plan.

6.1.4.2. Test Performance Procedures

Prior to data taking for calibrations the EM hardware must have successfully passed both acceptance and functional test requirements as described in the “LAT I&T Electrical Performance Tests - LAT-TD-01055-01”. The calibration procedures are described in “Calibration Algorithms for the Engineering Model – LAT-TD-01588”.

6.1.5. Support

6.1.5.1. Facility requirements

Clean room class 100000 is required for the EM test, with window to allow positioning of the Van de Graff close to the EM to allow the data taking configurations described in “SVAC EM Plan-LAT-SS-00573”.

6.1.5.2. Quality Program performance requirements

No quality performance requirements. The EM will represent an opportunity to test the infrastructure necessary for the future hardware tests (CU and LAT).

6.1.5.3. Systems Assurance Requirements

Whenever applicable calibration results from the integrated hardware will be compared to those obtained by subsystems prior to integration.

6.1.5.4. Test Equipment calibration

It is desirable to measure the flux of photons from the Van de Graaff generator so that we can understand the infrastructure necessary for CU and LAT tests. The calibration procedure is described in LAT-TD-01396 “Calibration of the Van de Graff Photon Flux”. However, the lack of knowledge on this number does not invalidate the EM test.

6.1.5.5. Special Test Requirements

No requirements.

6.2. Calibration Unit (CU)

The CU consists of a four-tower unit (QUA, FUB, FU1, FU2), which is fully instrumented and assembled in the same support grid in a 1x4 configuration and with TBD ACD tiles. The CU focus is on verification of science requirements and corresponding validation of MC simulations. This is the only integrated unit to be submitted to the particle beam tests (the CAL EM will undergo heavy ion beam tests). The I&T SVAC department will coordinate the CU data analysis (for details see LAT-MD-00574) to verify the science requirements after validation of MC simulations. Examples of activities are:

- Study effects from interfaces between multiple towers
- Verify the inter-tower alignment algorithm and its effect on the point spread function
- Test all low-level calibration algorithms for ACD, CAL and TKR
- Develop quality check histograms necessary to validate MC simulations and support LAT tests.
- Validate the SVAC database design for the LAT.

The Flight Units (FU) for the calibration Unit will be tested as individual towers, prior to integration. After delivery of the first flight unit (QUA) most of the low and high-level calibrations will be performed; one of the main goals is to verify the intra-tower alignment algorithm. For the remaining units, the algorithms used for the EM will be refined (if

needed) and only low-level calibrations using cosmic rays prior to installation in a beam will be performed. This will allow development of most of the instrument calibration algorithms and quality check histograms prior to the installation in the beam. During the positron beam tests, all instrument calibrations will be performed and the focus will be to study the shower development in the calorimeter, especially near tower edges, and study background from soft positrons. During photon beam tests, we will measure SPAR, energy resolution and number of reconstructed photons for a given set of configurations (see “Particle Beam Test Plan LAT-TD-0444”) and validate the MC simulations. To this end, we will provide new low and high-level calibrations (if those obtained with the positron beam are no longer valid). Finally, we will use the hadron beam to verify on orbit procedures for inter-tower alignment and to verify background rejection using TKR and CAL only. Once the MC is validated, the SAS will use it to evaluate the expected performance for the 16-tower unit (LAT). All high-level and low-level calibrations are performed in the CU, except for LAT & Observatory Alignment, CAL scintillation efficiency and CAL differential linearity. The algorithms to produce the calibration data shall be provided by the SAS in conjunction with TKR and CAL subsystems. The I&T, ACD, CAL and TKR subsystems are responsible for comparing results from these calibrations with those from the MC simulations.

6.2.1. LAT Hardware Required

6.2.1.1. QM/Flight Hardware

A full description of the hardware components required is provided in the “LAT Integration & Test Plan - LAT-MD-01376”, which describes GASU, EP, SIU, PDU or other LAT subsystems which will facilitate operation of the towers.

6.2.1.2. Flight Software

The main goal of this test since is to validate the Monte Carlo simulations, therefore there are no requirements on filters provided by flight software.

6.2.1.3. Test configuration

The test configuration is provided in the “LAT Integration and Test Plan -LAT-MD-01376”..

6.2.2. Ground Support Equipment Required

6.2.2.1. EGSE

The EGSE must be able to address a multiple-tower hardware, retrieve data , display data products and produce files that will be subsequently used for final data analysis. It must also allow for an external trigger system, provide a global system trigger and an event builder. In addition, we must be able to measure individual detector deadtime and compare the time stamp of recorded events with that provided by beam pulses. A detailed description is provided in the “LAT Integration & Test Plan -LAT-MD-01376”.

6.2.2.2. MGSE

A grid is needed to host multiple towers. A detailed description is provided in the “LAT Integration and Test Plan -LAT-MD-01376”.

6.2.2.3. Test Software

Tested and documented EGSE scripts and SAS algorithms are required to produce the calibration data described in “SVAC CU Plan-LAT-SS-00574”.

6.2.2.4. Support Instrumentation

A detailed description is provided in the “LAT Integration and Test Plan -LAT-MD-01376”. and “Beam Test Plan -LAT-TD-00440”

6.2.3. Data Reporting and Analysis Requirements

Data analysis and calibration will be performed by using SAS and EGSE data files using the same infrastructure already prototyped for the Engineering Model activities.

6.2.3.1. *Test Data Records*

Data analysis and calibration will be performed by using SAS and EGSE data files using the same infrastructure already prototyped for the Engineering Model activities. An electronic database is also required to catalog the data files necessary for data analysis. Results from the overall test will be described in the “SVAC Results from the Calibration Unit - LAT-TD-01594.”

6.2.3.2. *Data Formats*

Raw EGSE Event data (cosmic rays or photons) can be used for calibration using the EGSE. After processing the EGSE will produce output calibration data in the format specified in “Calibration Algorithms for the Calibration Unit”- LAT-TD-01589”. Data in FITS format will be processed by SAS software to produce reconstructed data files which will be further process to produce SAS calibration data in the format specified in “Calibration Algorithms for the Calibration Unit”- LAT-TD-01589”.

6.2.3.3. *Test Products*

There will be reports, files from EGSE and files from SAS. Test reports are described in (“LAT I&T Electrical Performance Tests - LAT-TD-01055-01”). A calibration infrastructure will be provided by SAS (“SAS EM Calibration Infrastructure LAT-TD-01340”) to access and store the calibration data for future use in the SAS reconstruction program. The SAS calibration infrastructure will allow data to be retrieved by I&T and to be subsequently stored in the SVAC database for trend studies as described in “SVAC CU database LAT-TD-00579”.

6.2.3.4. *Analysis activities*

Data analysis and calibration activities will be performed as outlined in the “SVAC CU Plan-LAT-SS-00574”,

6.2.4. Test Performance Requirements

6.2.4.1. *Environmental Conditions*

Tests will be conducted at room temperatures between 20 and 25 degrees C. The flight hardware will be kept according to the “LAT Contamination and Control Plan – LAT-MD-00404”.

6.2.4.2. *Test Performance Procedures*

Prior to data taking for calibrations the EM, hardware must have successfully passed both acceptance and functional test requirements as described in (“LAT I&T Electrical Performance Tests - LAT-TD-01055-01”) . Not all procedures for calibration and science performance can be written at this time. These will be described in “Calibration Algorithms for the Calibration Unit – LAT-TD-01589”.

6.2.5. Support

6.2.5.1. Facility requirements

All facilities are described in the Beam Test Plan “LAT-SS-00440”.

6.2.5.2. Quality Program Performance requirements

Requirements are specified “LAT Performance Specification-Level II(b) - LAT-SS-00010” and the SVAC Compliance can be found in “Science Verification Analysis and Calibration Plan – LAT-MD-00446”.

6.2.5.3. Systems Assurance Requirement

Results from particle tests for a set of incident positions, energies and angles will be compared with Monte Carlo simulations. After validation, the latter will be used to evaluate performance at any incident position, energy and angle. Whenever applicable calibration results from the integrated hardware will be compared to those obtained by subsystems prior to integration.

6.2.5.4. Test Equipment calibration

Calibration of the beam test equipment is discussed in the “Beam Test Plan -LAT-SS-00440”. The calibration procedure for the Van de Graaf generator is described in LAT-TD-01396 “Calibration of the Van de Graff Photon Flux”.

6.2.5.5. Special Test Requirements

No requirements.

6.3. LAT

The LAT is a sixteen-tower unit fully instrumented flight hardware. The LAT focus will be on instrument calibrations rather than MC simulations.

Focus is on instrument calibrations, especially the ACD and validation of tower interfaces in the MC simulations. The tracker self-triggering capabilities will be used for the data-taking mode and an external triggering system will be provided. The LAT will be tested under several conditions, post-assembly checkout, environmental test, airplane flight (TBR), Observatory integration and finally we will perform the first set of on orbit calibrations using data from telemetry. The I&T SVAC department will coordinate the LAT data analysis to achieve the following goals:

- Test and refine the final inter-tower alignment algorithm prior to launch
- Verify environmental dependence (temperature, pressure, high trigger rates) for high-level and low-level calibrations
- Test and refine the final SVAC Ground database
- Test and refine all high and low-level calibration algorithms for CAL, TKR, and ACD to be used to analyze data from telemetry.
- Develop quality check histograms (monitoring) to be used to analyze data from telemetry.
- Provide high and low-level orbit calibrations and compare with results obtained during ground tests.

Each individual FU will undergo high-level and low-level calibrations. All ACD tiles will be tested (TBR) after the ACD is integrated. Towers from the calibration unit (QUA, FUB, FU1, FU2) are the last ones to be integrated and do not need to be submitted to the full set of high-level calibrations (except when the inter-tower alignment between the 16 units is performed).

6.3.1. LAT Hardware Required**6.3.1.1. QM/Flight Hardware**

Flight LAT.

6.3.1.2. Flight Software

Flight software with a tagged version to perform calibrations.

6.3.1.3. Test configuration

The test configuration is provided in the “LAT Integration and Test Plan -LAT-MD-01376”.

6.3.2. Ground Support Equipment Required**6.3.2.1. EGSE**

The EGSE is described in the “LAT Integration and Test Plan -LAT-MD-01376”.

6.3.2.2. MGSE

The MGSE is described in the “LAT Integration and Test Plan -LAT-MD-01376”.

6.3.2.3. Test Software

Tested and documented EGSE scripts and SAS algorithms are required to produce the calibration data described in “SVAC LAT Plan-LAT-SS-00575”.

6.3.2.4. Support Instrumentation

The support instrumentation is described in the “LAT Integration and Test Plan -LAT-MD-01376”.

6.3.3. Data Reporting and Analysis Requirements**6.3.3.1. Test Data Records**

We will use the same infrastructure developed for the CU tests. Results from the overall test will be described in the “SVAC Results from the LAT - LAT-TD-01595.”

6.3.3.2. Data Formats

We will use the same infrastructure developed for the CU tests.

6.3.3.3. Test Products

We will use the same infrastructure developed for the CU tests.

6.3.3.4. Analysis activities

Data analysis and calibration activities will be performed as outlined in the “SVAC LAT Plan-LAT-SS-00575”,

6.3.4. Test Performance Requirements

6.3.4.1. Environmental Conditions

The flight hardware will be kept according to the “LAT Contamination and Control Plan – LAT-MD-00404”.

6.3.4.2. Test Performance Procedures

Prior to data taking for calibrations the EM, hardware must have successfully passed both acceptance and functional test requirements as described in (“LAT I&T Electrical Performance Tests - LAT-TD-01055-01”) . Not all procedures for calibration and science performance can be written at this time. These will be described in “Calibration Algorithms for the LAT – LAT-TD-01590”.

6.3.5. Support

6.3.5.1. Facility requirements

Facilities are described in “LAT I&T Facilities – LAT-TD-001386”.

6.3.5.2. Quality Program Performance requirements

Requirements are specified “LAT Performance Specification-Level II(b) - LAT-SS-00010” and the SVAC Compliance can be found in “Science Verification Analysis and Calibration Plan – LAT-MD-00446”.

6.3.5.3. Systems Assurance Requirement

Whenever applicable calibration results from the integrated hardware will be compared to those obtained by subsystems prior to integration.

6.3.5.4. Test Equipment calibration

The calibration procedure for the Van de Graaff generator is described in LAT-TD-01396 “Calibration of the Van de Graff Photon Flux”.

6.3.5.5. Special Test Requirements

No requirements.

6.3.6. Environmental Test

After extensive functional tests, cosmic ray data will be collected for alignment and low-level calibrations (e.g. noise occupancies, pedestals) . The alignment requirements are found in “LAT I&T Survey and Alignment -LAT-MD-01586”

6.3.7. Airplane Test

After extensive functional tests, cosmic ray data will be collected during Airplane test. The airplanes test is functional test; hence, the SVAC plan imposes no requirements on these tests.

6.3.8. Observatory Integration

As scheduled by the spacecraft vendor, after extensive functional tests, cosmic ray data will be collected at observatory and launch pad facilities to allow verification of a set of low-level and high-level calibrations . Details are provided in the “ LAT Integration and Test Plan -LAT-MD-01376”.

7. Post-launch Requirements

These will be developed after Engineering Model tests and in conjunction with the Instrument Operation Center.