GLAST Large Area Telescope: I & T Peer Review

Science Verification, Analysis and Calibration

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Outline

- SVAC system Responsibilities
- Requirements Flow
- Timeline
- Operations Flow
- On Orbit Calibration
SVAC System Responsibilities

- Capture Science and Calibration requirements from Subsystems Plans. (LAT-MD-00446)
- Prepare the SVAC plan (with review from subsystems). (LAT-MD-00446)
  - To verify Science and Calibration Requirements
  - Provide the final I&T calibration products to SAS and IOC
  - Develop Calibration Compliance Matrices for pre and post launch operations
- Coordinate Data Analysis (with support from subsystems LAT-MD-00613) using data obtained from particle beams and cosmic rays during LAT assembly, environmental and spacecraft integration tests
- Demonstrate that the LAT is calibrated prior to launch and perform the first on-orbit calibration prior to hand off to IOC after fabrication phase is completed
Science Performance (SE, IS, and I&T)

- Particle tests
- Calibration
- Science verification tests

Produce a Scientifically Working Instrument
Using Engineering Model as an example

Level IV Technical Documents – Contents

- **Test Plan/Results**
  - LAT-MD-00573 – SVAC EM Plan
    - Describes the hardware data taking configurations, infrastructure needed for calibrations, calibration types, data analysis requirements. Run time estimation using MC simulation
  - LAT-MD-01593 – SVAC Results from the Engineering Model Test
    - Describes the results and how requirements were met

- **Calibrations**
  - LAT-TD-01588 – Calibration Algorithms for the Engineering Model
    - Describes the calibration algorithms developed in conjunction with SAS and subsystems

- **Simulations**
  - LAT-TD-00582 – EM Geometry for the Monte Carlo Simulation
    - Describes the geometry used in the simulation, includes table to translate nomenclature from software developers to engineers and also contains traceability

- **Database**
  - LAT-TD-00578 – SVAC Database for the Engineering Model
    - Describes the table schema and how a web based engine will allow access to a subset of calibration data for the purpose of tracking changes in time.

- **Interfaces**
  - LAT-TD-00571 – SVAC/SAS Interface Control Document
    - Describes the responsibilities between SAS and SVAC for data analysis (Statement of work)
  - LAT-TD-01340 – SAS Calibration Infrastructure
    - Describes SAS calibration infrastructure that hold the primary calibration data
Main Documents - Contents

Co owned with Project Scientist, Level 3.

- LAT-MD-00446 - SVAC Plan
  - Instrument Calibrations
  - SVAC Compliance
  - Pre Launch Test Matrix
  - Post Launch Test Matrix

Contributed Manpower Plan
Level 3

- LAT-MD-00613 - SVAC Plan
  - Engineering Model
    - TKR,CAL,SAS
  - Calibration Unit
    - ACD,TKR,CAL,SAS,IOC, Contributed Manpower from GLAST collaboration.
  - LAT
    - ACD,TKR,CAL,SAS,IOC, Contributed Manpower from GLAST collaboration.

Internal I&T Doc level 4.

- LAT-MD-01587 – SVAC Test Plan
  - Hardware Required
  - Flight Software Required
  - Test Configuration
  - EGSE Required
  - MGSE Required
  - Test Software
  - Support Instrumentation
  - Test Data Record
  - Data Format
  - Test Products
  - Analysis Activities
  - Environmental Conditions
  - Test performance Procedures
  - Facility Requirements
  - Quality Program Performance Requirements
  - System Assurance Requirements
  - Test Equipment Calibration
### SVAC Plans and Technical Documents

**LEVEL III**
- **LAT-MD-00446**
  - Co-owned with Project Scientist

**LAT-MD-00613**  
Contributed Manpower Plan

**LAT-TD-00570,1,2**
I&T-SAS ICDs, EM, CU, LAT

**LEVEL IV**

<table>
<thead>
<tr>
<th>Hardware Test</th>
<th>Plan/Results</th>
<th>Calibrations</th>
<th>Simulations</th>
<th>Databases</th>
<th>Interfaces</th>
</tr>
</thead>
</table>
| **Engineering Model**  
  EM | LAT-MD-00573  
LAT-TD-01593 | LAT-TD-01588 | LAT-TD-00582 | LAT-TD-00578 | LAT-TD-01340 |
| **Calibration Unit**  
  CU | LAT-MD-00574  
LAT-TD-01594 | LAT-TD-01589 | LAT-TD-00583 | LAT-TD-00578 | LAT-TD-01340 |
| **LAT** | LAT-MD-00575  
LAT-MD-00576  
LAT-MD-00577  
LAT-MD-00581  
LAT-TD-01595 | LAT-TD-01590 | SAS responsibility | LAT-TD-00580 | LAT-TD-01340 |

Existing docs are shown in **red boldface**

Document: LAT-PR-01779-01
Functional Test -> Calibration, Science Verification flow

Reconstruction and Monte Carlo Software (SAS)

Functional Tests (IFCT) → Low-Level Calibration (SVAC) → High-Level Calibration (SVAC) → Science Verification (SVAC)

I&T

LAT subsystems hardware, EGSE scripts and reference calibration datasets (ACD, CAL, TKR, ELX)
SVAC Timeline

2003 Engineering Model 1

- Prototype algorithms and database infrastructure
- Prototype interface with EGSE and SAS
- Calibrations

2004 Calibration Unit

- Calibrations (prototype inter tower alignment)
- Science Verification (Monte Carlo Validation)
- Validate SVAC database design
- Prototype of on-orbit low level calibration scheme

2004 LAT

- Final alignment
- Validation of on orbit calibration scheme
- Calibration dependence on environment
- Calibration time history prior to launch

2005
SVAC Operations Flow

I&T Flow

Instrument Calibrations
EM

Prototype calibration tools and procedures

Instrument Calibrations
CU – Beam Test

MC Validation
CU - Beam Test

Science Verification
CU - Beam Test

SVAC Calibration Products

SAS
Instrument Response Functions

Instrument Calibrations
LAT

Instrument Calibrations
LAT – Environmental test

Calibrated LAT Instrument

IOC
On orbit Calibrations

Document: LAT-PR-01779-01
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Science Verification

- Science verification relies on a LAT-wide collaboration effort and on the guidance from the LAT Instrument Scientist
  - Individual Subsystems and Science Requirements are captured in a compliance matrix in LAT-MD-00446
  - Contributed Manpower is described in LAT-MD-00613
  - Infrastructure needed is described in LAT-MD-001587

- Science Verification is a 3-step Process
  1. Preparation
     - Develop and Test Monte Carlo Simulations prior to particle beam tests
     - Calibrate Beam Test Modules
  2. Validation with Particle Beams
     - Use beam test data with calibrated modules to validate Monte Carlo simulations for a set of energies, incident angles and impact points.
  3. Demonstration by Analysis
     - Prove that we met the Science Requirements by evaluating the LAT performance in a larger set of energies, angles and impact points
Data Analysis

• SVAC analysis is essentially offline and relies on reduced data produced by the
  – GSE software for calibration purposes
  – SAS software for calibration purposes
    • For calibration types, which can be performed with both GSE and SAS software, results from the former are used as a reference.
  – SAS software for Science Verification

• Two important aspects of the data analysis
  1. Calibration Data
     – Verify the electronics requirements, thus calibrate the instrument
     – Provide pre-launch history of calibration (including changes due to environmental effects)
     – Provide a metric to monitor procedures during Integration and Test
     – Provide required input to the SAS software used for Science Verification
  2. Science Verification Data
     – Determine the LAT performance
Calibration

- Calibration relies on a LAT-wide collaboration effort and cooperation with the LAT Instrument Scientist, System Engineering and the Instrument Operations Center
  - Individual Subsystems and Science Requirements are captured in a compliance matrix in LAT-MD-00446
  - Contributed Manpower is described in LAT-MD-00613
  - Infrastructure needed is described in LAT-MD-001587

- Calibration is a 3-step Process
  1. Preparation
     - Develop and Test GSE scripts, calibration algorithms, databases, report capabilities using the Engineering Model
     - Update tools and calibrations to provide a calibrated unit (4 modules) for science verification
     - Develop concepts for on-orbit calibrations
  2. Demonstration by pre launch tests
     - Prove that we met the Calibration Requirements by calibrating the LAT on the ground
     - Test and Verify concepts for on-orbit calibrations
  3. Demonstration by post launch tests
     - Update calibrations by perform on-orbit calibrations during checkout phase
     - Implement procedures within the IOC framework
On-orbit Calibration

On-orbit Calibration relies on a LAT-wide collaboration effort and leadership from Instrument Operations Center. The I&T participation is strong since
- I&T and IOC will share a scientist to ensure a smooth transition between pre and post launch operations
- I&T will support the development and testing of operational concepts during the pre-launch activities (e.g., data monitoring, diagnostics, and trend analysis)
- I&T will deliver a calibrated instrument to the IOC after commissioning on orbit.

On-orbit Calibration Strategy (these must be revised as IOC enters in its CDR phase)

1. There are two special data taking modes
   - Selected events from Galactic Cosmic Rays (survey, energy calibration, ...)
   - Charge injection to verify front-end electronics (low level calibration)

2. Post-launch Calibration tasks
   - Are identified in LAT-MD-00446
   - The following tasks will be fully defined by the IOC CDR
     - Whether data is reduced on-orbit or on the ground
     - The frequency that calibrations are to be performed
Back up slides – EM example
Science Verification, Analysis and Calibration (SVAC) System

- **Science Requirement Document**: 443-SRD-00010
- **Level II**: LAT-SS-00010
- **Levels III and IV**: LAT-SS-00016, LAT-SS-00017, LAT-SS-00018, LAT-SS-00152, LAT-SS-00210
- **ACD, CAL, TKR Specifications**: LAT-SS-00016, LAT-SS-00017, LAT-SS-00018, LAT-SS-00152, LAT-SS-00210
- **Basis of SVAC WBS**: LAT-MD-00446
- **GLAST LAT SVAC Plan**: LAT-MD-00446
- **Science Verification**
- **Data Analysis**
- **Calibration**
SVAC Activities Flow

Prototype Calibration tools and procedures

Instrument Calibrations (EM)
SLAC

Prototype Calibration tools and procedures

Instrument Calibrations (CU)
SLAC-Beam test

Calibration tools and procedures

Instrument Calibrations (CU)
SLAC-Beam test

Science Verification (CU)
SLAC-Beam test

MC validation (CU)
SLAC-Beam test

Instrument Calibrations (LAT-FM)
SLAC Room Temperature
SLAC Thermal Cycling
NRL-Environmental Tests

Validated calibration Dataset (LAT-FM)

Calibrated Instrument (LAT-FM)
Delivered to Spacecraft vendor

Science Verification (LAT-FM)
validated MC