### GLAST LAT SYSTEM SPECIFICATION

#### Document Title
**SVAC Engineering Model Plan**

#### Change History Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Effective Date</th>
<th>Description of Changes</th>
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<td></td>
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</tbody>
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1. **Purpose**  
This document defines the Calibration and Data Analysis Plan for the Engineering Model of the Large Area Telescope (LAT) of the Gamma-ray Large Area Space Telescope (GLAST) Mission.

2. **Scope**  
This document defines the infrastructure needed for Data Analysis and Calibration activities.

3. **Acronyms and Definitions**

3.1. **Acronyms**

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

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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-TD-00444, “LAT Beam Test Plan”
LAT-TD-00446, “LAT SVAC Plan”
LAT-TD-00578 "LAT – SVAC Database for the Engineering Model"
5. **Overview**

6. **Hardware Configuration**

6.1. **Trigger**

The main triggering mode used will be the TKR self-trigger. For events entering at the sides of CAL, which do not reach the TKR, the main trigger used will be the CAL-LO trigger. The hardware will allow input from external triggers (e.g. scintillating counters in coincidence) if needed (TBR).

6.2. **Van der Graaf Generator**

A Van der Graaf generator will be used as a source of low energy photons. This photon source is not completely monochromatic. The energy spectrum is expected to peak at 17.6 MeV with a small reflection component at about xx MeV.

6.3. **Data Taking Configurations**

There will be two particle sources. Cosmic rays that come from all directions and photons that will be produced in given configurations. We will collect about $10^6$ cosmic rays needed for calibration and Monte Carlo validation. The number of expected reconstructed low energy photons (TBR) is shown in Table 1. for several data taking configurations (TBR).

<table>
<thead>
<tr>
<th>Source</th>
<th>(X,Y,Z)</th>
<th>(θ,φ)</th>
<th>Reconstructed Events</th>
<th>Estimated data taking (hrs)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>On axis</td>
</tr>
<tr>
<td>Photons</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>Off axis</td>
</tr>
<tr>
<td>Photons</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>On axis</td>
</tr>
<tr>
<td>Photons</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>On axis</td>
</tr>
<tr>
<td>Photons</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>On axis</td>
</tr>
</tbody>
</table>

7. **Infrastructure**

7.1. **Run Catalog**

To support data analysis (see section 5.1), a web accessible catalog with data and Monte Carlo runs will be defined and implemented by SAS and I&T groups. A prototype has already been implemented during the 1999/2000 beam test.

7.2. **EGSE Calibration Scripts**

After going through acceptance and functional tests the EM will be available for data taking. Prior to any data taking period we will perform a subset of functional tests that are directly related to calibrations. To this end, if a EGSE script is needed, it will be adapted from the functional test scripts defined by subsystems in conjunction with I&T IFCT. Most of the calibrations will be done offline using the SAS software.
7.3. Databases

This EM data will be stored in the SVAC database for trend analysis. The database definition and queries are described in LAT-TD-00574. We will also test interfaces between the SAS calibration infrastructure and SVAC database and prototype the format for TKR and CAL reference calibration datasets to be transferred to SAS & I&T.

8. Calibrations

The set of calibrations to be performed has been outlined in the SVAC Plan (LAT-MD-00446). Table 2 shows how often calibrations will be performed and which software will be used to extract the calibration data.

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>SAS Software</th>
<th>EGSE Script</th>
<th>How often?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C9</td>
<td>TKR Single-hit MIP efficiency</td>
<td>●</td>
<td></td>
<td>Once</td>
<td>Measured for the entire tracker as function of TBD incident angles</td>
</tr>
<tr>
<td>C10</td>
<td>TKR Noisy Channels</td>
<td>●</td>
<td></td>
<td>Once</td>
<td>Measured for each layer during CR tests</td>
</tr>
<tr>
<td>C11</td>
<td>TKR Dead Channels</td>
<td>● ●</td>
<td></td>
<td>Once/configuration</td>
<td>Measured for each layer. Prior to data taking at every different configuration run an EGSE script to get reference list of channels.</td>
</tr>
<tr>
<td>C12</td>
<td>TKR Time-Over-Threshold Signal</td>
<td>●</td>
<td></td>
<td>Once/configuration</td>
<td>Measured for both GTRC in each layer to check linearity and saturation</td>
</tr>
<tr>
<td>C13</td>
<td>TKR Time-Over-Threshold Count Distribution</td>
<td>●</td>
<td></td>
<td>Once/particle source</td>
<td>Measured for each layer to check mean and widths as function of energy and particle type</td>
</tr>
<tr>
<td>C14</td>
<td>CAL Light Asymmetry</td>
<td>●</td>
<td></td>
<td>Once</td>
<td>Function of position in a log</td>
</tr>
<tr>
<td>C15</td>
<td>CAL Light Attenuation</td>
<td>●</td>
<td></td>
<td>Once</td>
<td>Function of position in a log</td>
</tr>
<tr>
<td>C16</td>
<td>CAL Light Yield</td>
<td>●</td>
<td></td>
<td>Once</td>
<td>Measured for each face and for the sum of faces of the log</td>
</tr>
<tr>
<td>C17</td>
<td>CAL Scintillation Efficiency</td>
<td>●</td>
<td></td>
<td>Once</td>
<td>Only measured prior to delivery to I&amp;T in a heavy ion beam test</td>
</tr>
<tr>
<td>C18</td>
<td>CAL Pedestals</td>
<td>● ●</td>
<td></td>
<td>Once/configuration</td>
<td>Prior to data taking run an EGSE script to get reference centroid and widths for all energy ranges</td>
</tr>
<tr>
<td>C19</td>
<td>CAL Electronic Gain</td>
<td>● ●</td>
<td></td>
<td>Once/configuration</td>
<td>Prior to data taking run an EGSE script to get reference gains for all energy ranges</td>
</tr>
<tr>
<td>C20</td>
<td>CAL Integral non-linearity</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C21</td>
<td>CAL Differential non-linearity</td>
<td>●</td>
<td></td>
<td></td>
<td>Only measured prior to delivery to I&amp;T</td>
</tr>
<tr>
<td>C22</td>
<td>CAL Noisy Channels</td>
<td>●</td>
<td></td>
<td>Once</td>
<td></td>
</tr>
<tr>
<td>C23</td>
<td>CAL Dead Channels</td>
<td>● ●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C24</td>
<td>CAL LO Discriminator</td>
<td>●</td>
<td></td>
<td>Once/configuration</td>
<td></td>
</tr>
<tr>
<td>C25</td>
<td>CAL HI Discriminator</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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9. **Data Analysis**

9.1. **Validation of Monte Carlo distributions**

Monte Carlo Simulations will be tested prior to data analysis following a test suite developed by SAS. After these acceptance tests, the Monte Carlo simulations will be compared with data for different configurations. Table 3 shows the minimum set of Monte Carlo distributions to be validated with data.

<table>
<thead>
<tr>
<th>Table 3. Minimum set of Monte Carlo distributions to be validated with Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cosmic Rays (muons)</strong></td>
</tr>
<tr>
<td>TKR Strip hit multiplicity for each layer (on axis)</td>
</tr>
<tr>
<td>TKR Strip hit multiplicity for each layer (off-axis)</td>
</tr>
<tr>
<td>TKR Cluster multiplicity (num strips) for each layer (on-axis)</td>
</tr>
<tr>
<td>TKR Cluster multiplicity for each layer (off-axis)</td>
</tr>
<tr>
<td>TKR ratio of double/single hits for each layer (on-axis)</td>
</tr>
<tr>
<td>TKR ratio of double/single hits for each layer (off-axis)</td>
</tr>
<tr>
<td>TKR TOT count distribution for each layer (on-axis)</td>
</tr>
<tr>
<td>TKR TOT count distribution for each layer (off-axis)</td>
</tr>
<tr>
<td>CAL Raw Energy Deposition for each layer (on-axis)</td>
</tr>
<tr>
<td>CAL Raw Energy Deposition for each layer (off-axis)</td>
</tr>
<tr>
<td>CAL Shower Longitudinal Profile (on-axis)</td>
</tr>
<tr>
<td>CAL Shower Longitudinal Profile (off-axis)</td>
</tr>
<tr>
<td>CAL Shower Transverse Profile (on-axis)</td>
</tr>
<tr>
<td>CAL Shower Transverse Profile (off-axis)</td>
</tr>
<tr>
<td>CAL MIP Energy Peak (on-axis)</td>
</tr>
</tbody>
</table>

9.2. **TKR Alignment**

Since the TKR is not fully instrumented the EM will be used only to test the alignment algorithms develop to date. There is no requirement to verify the alignment precision since we are only prototyping alignment algorithms.

9.3. **Measurement of the Energy Spectrum**

For the EM test the only requirement is to measure the energy spectrum. The goal is to demonstrate the feasibility of the Van der Graaf generator as a possible source of low energy photons to be used for future hardware tests (CU and LAT).
9.4. Energy Resolution for Low Energy Photons

For the EM test we do not have to verify our energy resolution requirement. This measurement is intended to prototype algorithms to do energy estimation, mostly for events that deposit a large fraction of their energy in the TKR (low energy photons).