GLAST Large Area Telescope:

LAT System Engineering

Pat Hascall
SLAC

hascallp@slac.stanford.edu
650-926-4266

Performance and Operations Test Plan (LAT-MD-02730)

- **Status**
  - **Out for signature, all pre release review comments incorporated**
  - **Contains testing through two towers, could be used up through 16 towers without flight GASU, EPU, SIU or PDU.**
- **Future plans**
  - **Utilize FSW capabilities as the definition matures to define more efficient testing that matches in orbit operations**
  - **Refine testing based on experience gained on single and two tower tests**
  - **Rich Baun leading this effort**

End-to-End Test Status

- End-to-End recommendations have 4 broad categories
  - Power up and initialization (deferred until FSW is available)
  - Detector performance tests (included)
  - Trigger tests (subset included)
  - Data flow tests (subset included)
- Eduardo has prepared a summary of the data flow, trigger, and SVAC tests in the following charts
- There is potential for descope in the data flow tests
  - Have some ideas, not yet reviewed by key personnel (Huffer, I&T and ETE Committee)
  - Plan is to:
    - Detail the potential descope ideas
    - ETE committee reviews plan and descope
    - One meeting to discuss, refine and update
    - Results presented in an engineering meeting

Tests Phases

- Tower A
  - tests defined in LAT-TD-02730 released for signature
  - Acquire experience with integrated hardware
  - Tests
    - LPT, CPT, Trigger, E2E trigger and data flow, SVAC
- N towers
  - tests to be updated as we learn from tower A
  - adapt tests to multi-tower and FSW environment
  - Environment for data analysis
  - Tests
    - LPT, CPT, Trigger, E2E trigger and data flow (only for 2 towers), SVAC
- LAT
  - R. Baun is leading the effort to define tests
  - many issues to address
    - redundancy paths, schedule pressures, parallelism etc…
  - Tests
    - LPT, CPT, Trigger, E2E trigger and data flow, SVAC
      - » ACD tests are included in this case

Two tower tests

- Defined in LAT-TD-02730
- LPT (~ hour)
  - Abbreviated set of tests to verify functionality
  - So far we inherited a subset of tests from TKR and CAL
- CPT (~hours)
  - Coarse performance evaluation
  - So far inherited a subset of tests from TKR and CAL
- Trigger tests (~1 day)
  - Designed to time-in the integrated tower using muon telescope whenever possible
  - Nominal time settings may change depending on threshold settings
- E2E tests for trigger and data flow (~90 hours)
  - Cosmic rays, photons and Am241 source tests
  - Short tests (1h long) to be compared with baseline run
- SVAC tests (1 day of charge injections + 39 hours of muons/photons)
  - Charge injection calibrations (TKR and CAL)
  - Muons with flight configuration (4h)
  - Muons with no zero suppression for calibrations (1h)
  - Muons with CAL high energy muon gain for calibrations (15h)
  - Photons with VDG photons (16 h)
    - And muons for background estimation at horizontal position (3h)

Tower A tests - Executive Summary

- **Part 1**
  - **Overview of E2E tests for trigger and data flow**
    - **86 data taking configurations (each lasts from 1 to 1.5 hrs)**
    - **Configurations are arranged in 9 logical groups (1 to 9)**
    - **To be tested at 3 phases:**
      - » **tower A, towers A and B and LAT**
- **Part 2**
  - **Overview of additional I&T tests**
    - **4 data taking configurations (each lasts from 1 to 1.5 hrs)**
    - **Configurations are arranged in 1 logical group (C)**
    - **To be tested at 3 phases:**
      - » **tower A, every time 2 towers are placed in a grid and LAT**
- **Part 3 (only the ones highlighted in red will be discussed in this note)**
  - **Overview of SVAC tests**
    - **27 data taking configurations (variable duration)**
    - **Configurations are arranged in 1 logical group (B)**
    - **To be tested at 3 phases:**
      - » **tower A, everytime 2 towers are placed in a grid and LAT**

Relevant Documentation

- Relevant documents are
  - LAT-TD-04136
    - *VG and CR Data Runs for LAT Integration* version from Feb 3, 2005
  - LAT-MD-00575-01
    - *SVAC LAT Plan for LAT Integration at SLAC (version 2 is being updated by E. do Couto e Silva)*
  - LAT-MD-02730-01
    - *LAT Performance and Operations Test Plan*
  - LAT-MD-03489-02
    - *Report from Ad Hoc Committee on End-to-End Testing*
  - LAT-TD-04980
    - *Use of Am241 source for high rate triggers (in preparation by G. Godfrey)*
- Back-up slides contain a summary of the E2E tests for trigger and data flow and tests which are currently being implemented by I&T
  - Full details to appear in documentation which is currently in progress
  - We describe to some level of details a matrix containing all these tests which are now maintained by Gary Godfrey in LAT-TD-04136

Back-up slides containing details of E2E tests

Nominal configuration for E2E tests

- The nominal configuration for registers are given below
  - Timing
    - TREQ delay in TKR = 50 ns
    - TREQ delay in CAL = 0 ns
    - TREQ delay in ACD = 80 ns
    - TACK delay in TKR = 0 μs
    - TACK delay in CAL = 2.4 μs
    - TACK delay in ACD = 0 μs
  - Front-End Discriminators
    - TKR DAC = 30 range 0, ¼ Mip
    - CAL DAC FLE, FHE = 100 MeV, 1GeV
  - GEM
    - All triggers are allowed to open the trigger window otherwise it will be explicitly stated
    - Clock is assumed to run at 20 MHz (means clock ticks = 50 ns)
    - TEM diagnostics is turned on otherwise it will be explicitly stated
      - » Note that on-orbit nominal is corresponds to TEM diagnostics OFF
    - Zero suppression is turned on otherwise it will be explicitly stated

Part 1- E2E tests for trigger and data flow

- The purpose of these tests were to test the system at some stringent conditions when a tower or towers + ACD are fully integrated
  - PASS/FALL criteria
    - No transport errors
    - No system hangs
  - Current status
    - Need to identify errors (if any) which are allowed to occur
    - Error logs will be generated by online scripts

- Data Analysis
  - Compare distributions with those from a baseline run
    - Expect no difference between distributions after a muon selection criteria has been applied
  - Current status
    - Distribution have not been defined until data for first tower is taken
    - Current philosophy is to develop 4 algorithms for muon selection (TBD)
      - » 1: cut on CAL variables look at TKR distributions
      - » 2: cut on TKR variables look at CAL distributions
      - » 3: cut on CAL and TKR variables look at CAL and TKR distributions (loose selection)
      - » 4: cut on CAL and TKR variables look at CAL and TKR distributions (tight selection)

E2E- Baseline Cosmic Rays

- Purpose
  - To establish baseline for comparison of subsequent runs
- Test ID
  - 1/X , where X corresponds to a particular subtest
  - 7/X , corresponds to a data volume subtest
- Duration
  - 3 h (3x1h)
- Data Taking configurations
  - 1/1: Baseline cosmic rays (1h)
    - All register settings are nominal
  - 1/2: Baseline cosmic rays low FLE (1h)
    - All register settings are nominal except CAL FLE ~ 20 MeV
  - 7/1: Baseline cosmic rays without zero suppression (1h)
    - All register settings are nominal except zero suppression

E2E- Condition Scan Cosmic Rays

- Purpose
  - Fix all register settings to nominal and change only one value at the time to explore data taking at “extreme” conditions
- Test ID
  - 2/X , where X corresponds to a particular subtest
- Duration
  - 27 h (27x1h)
- Data Taking configurations for voltage and heat exchanger
  - 2/1 and 2/2: Vary unregulated S/C voltage (1h each)
    - min, max : 27 V, 29 V
  - 2/16 and 2/17: Vary analog voltages TKR AVDDA and CAL AVDD by +- 5% (1h each)
    - TKR min, max : 1.43 V, 1.57 V, CAL min, max : 3.14 V, 3.46 V
    - In this case TKR and CAL voltage are set at the same time for each run
  - 2/18 and 2/19: Vary analog voltage TKR AVDDB by +- 5% (1h each)
    - min, max : 2.52 V, 2.78 V
  - 2/20 and 2/21: Vary digital voltage TKR DVDD by +- 5% (1h each)
    - min, max : 2.52 V, 2.78 V
  - 2/22 and 2/23: Vary digital voltage CAL DVDD by +- 5% (1h each)
    - min, max : 3.14 V, 3.46 V
  - 2/24 and 2/25: Vary heat exchanger temperature (1h each)
    - min, max : -15 C, 20 C
  - 2/26 and 2/27: Vary heat exchanger temperature and S/C unregulated voltage at the same time (1h each)
    - min : heat exchanger (-15 C), max: S/C voltage(29)
    - max : heat exchanger (20 C), min: S/C voltage(27)

E2E- Condition Scan Cosmic Rays (cont'd)

- Data Taking configurations for subsystem register settings
  - 2/3 and 2/4: Change rate by varying TKR DAC (1h each)
    - min, max : 22, 40 (flat muon region expected to be >26. ¼ mip ~ 30)
  - 2/5: Increase time to latch data in TKR (1h)
    - Set TKR TACK DELAY to 6 ticks (0.3 μs) nominal is 0 ticks (0 μs)
  - 2/6 and 2/7: Verify TKR timing does not change w.r.t to GTRC splits (1h each)
    - Read out only using LEFT or RIGHT cables
  - 2/8 and 2/9: Change rate by varying CAL FLE and CAL FHE (1h each)
    - Value is 20 MeV (timing registers will have different nom setting)
  - 2/10 and 2/11: Increase time to latch data in CAL (1h each)
    - Set CAL TACK DELAY to 34 ticks (1.7 μs) and 54 ticks (2.7 μs)
  - 2/12 and 2/13: Change rate by varying ACD DAC (1h each)
    - min, max : 0.15, 0.6 (in units of MIPs)
    - TKR is not allowed to open the trigger window
  - 2/14 and 2/15: Increase time to latch data in ACD (1h each)
    - Set ACD TACK DELAY to 0 ticks (0 μs) and 5 ticks (0.25 μs)
    - TKR is not allowed to open the trigger window

E2E- Nominal Condition Scan Cosmic Rays

- Purpose
  - Fix all register settings to nominal and change only one value at the time to explore data taking at "extreme" conditions
  - Configuration is identical to Test IDs 2/X but now there is an external signal from a pulse generator used to exercise triggers at a 10 KHz rate
- Test ID
  - 5/X , where X corresponds to a particular subtest
- Duration
  - 27 h (27x1h)
- Data Taking configurations for voltage and heat exchanger
  - 5/1 and 5/2: Vary unregulated S/C voltage (1h each)
    - min, max : 27 V, 29 V
  - 5/16 and 5/17: Vary analog voltages TKR AVDDA and CAL AVDD by +- 5% (1h each)
    - TKR min, max : 1.43 V, 1.57 V, CAL min, max : 3.14 V, 3.46 V
    - In this case TKR and CAL voltage are set at the same time for each run
  - 5/18 and 5/19: Vary analog voltage TKR AVDDB by +- 5% (1h each)
    - min, max : 2.52 V, 2.78 V
  - 5/20 and 5/21: Vary digital voltage TKR DVDD by +- 5% (1h each)
    - min, max : 2.52 V, 2.78 V
  - 5/22 and 5/23: Vary digital voltage CAL DVDD by +- 5% (1h each)
    - min, max : 3.14 V, 3.46 V
  - 5/24 and 5/25: Vary heat exchanger temperature (1h each)
    - min, max : -15 C, 20 C
  - 5/26 and 5/27: Vary heat exchanger temperature and S/C unregulated voltage at the same time (1h each)
    - min : heat exchanger (-15 C), max: S/C voltage(29)
    - max : heat exchanger (20 C), min: S/C voltage(27)

E2E- Condition Scan Cosmic Rays (cont'd)

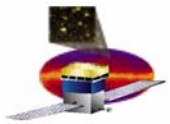
- Data Taking configurations for subsystem register settings
  - 5/3 and 5/4: Change rate by varying TKR DAC (1h each)
    - min, max : 22, 40 (flat muon region expected to be >26. ¼ mip ~ 30)
  - 5/5: Increase time to latch data in TKR (1h)
    - Set TKR TACK DELAY to 6 ticks (0.3 μs) nominal is 0 ticks (0 μs)
  - 5/6 and 5/7: Verify TKR timing does not change w.r.t to GTRC splits (1h each)
    - Read out only using LEFT or RIGHT cables
  - 5/8 and 5/9: Change rate by varying CAL FLE and CAL FHE (1h each)
    - Value is 20 MeV (timing registers will have different nom setting)
  - 5/10 and 5/11: Increase time to latch data in CAL (1h each)
    - Set CAL TACK DELAY to 34 ticks (1.7 μs) and 54 ticks (2.7 μs)
  - 5/12 and 5/13: Change rate by varying ACD DAC (1h each)
    - min, max : 0.15, 0.6 (in units of MIPs)
    - TKR is not allowed to open the trigger window
  - 5/14 and 5/15: Increase time to latch data in ACD (1h each)
    - Set ACD TACK DELAY to 0 ticks (0 μs) and 5 ticks (0.25 μs)
    - TKR is not allowed to open the trigger window

E2E- Baseline Cosmic Ray Trigger Subtests

- **Purpose**
  - Fix all register settings to nominal and allow only one trigger type to open the trigger window
- **Test ID**
  - 3/X , where X corresponds to a particular subtest
- **Duration**
  - 6 h (6x1h)
- **Data Taking configurations for different trigger types**
  - 3/1: Only TKR is allowed to trigger
  - 3/2: Only CAL is allowed to trigger
    - FLE is set to 100 MeV
  - 3/3: Only CAL HI is allowed to trigger
    - FHE is set to 1 GeV
  - 3/4: Only CNO is allowed to trigger
    - CNO DAC is lowered to a value (TBD) to trigger on muons
  - 3/5: Only ACD ROI-1 is allowed to trigger
    - ROI1 is defined in LAT-TD-00575 (all sides are allowed to trigger)
  - 3/6: Only TKRVetoed is allowed to trigger

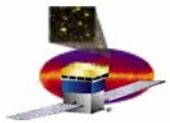
E2E- Nominal rate Cosmic Rays

- Purpose
  - Fix all register settings to nominal and increase the trigger rate by using
    - an external pulse generator or
    - Americium source
- Test ID
  - 4/X , where X corresponds to a particular subtest
- Duration
  - 8 h (8x1h)
- Data Taking configurations for different external source types
  - 4/1 to 4/4: use pulse generator at rates of 1,5, 10 and 20 KHz
    - Prescale external triggers to 0.01, 0.002, 0.001, 0.0005
  - 4/5: use americium source at rates of 4.4 KHz
    - Am241 (60 keV xrays) sits on top of top TKR tray
  - 4/6: Pulse generator gives a high rate of 1 KHz
    - Pulser 1KHz+Am241 (60 keV xrays) sits on top of top tray.



E2E- CAL Nominal Cosmic Ray Scan

- **Purpose**
  - **Fix all register settings to nominal and exercise CAL FLE and FHE to lower values**
- **Test ID**
  - **6/X , where X corresponds to a particular subtest**
- **Duration**
  - **8 h (8x1h)**
- **Data Taking configurations for different trigger rates**
  - **6/1 to 6/3: take data at high rates (1,5,10 kHz) by lowering FLE settings**
    - **Since all trigger types can open the window use a filter to reduce the rate**
      - » **Current filter rejects events with > 10 hits in TKR (TBR)**
  - **6/4 to 6/6: take data at high rates by lowering FHE settings**
    - **Since all trigger types can open the window use a filter to reduce the rate**
      - » **Current filter rejects events with > 10 hits in TKR (TBR)**

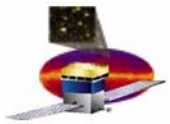


E2E- Nominal Cosmic Ray Data Volume subtests

- **Purpose**
  - **Fix all register settings to nominal and exercise data volume with high rates when using an external pulse generator**
- **Test ID**
  - **8/X , where X corresponds to a particular subtest**
- **Duration**
  - **8 h (8x1h)**
- **Data Taking configurations**
  - **8/1 to 8/5: Nominal settings, vary rates**
    - **0,1,2,5,10 kHz, in which events are prescaled to 0.01, 0.01, 0.002, 0.001, 0.0005 respectively.**
  - **8/6 to 8/9: Nominal settings, vary rates**
    - **1,2,5,10 kHz, in which events are prescaled to 0.01, 0.01, 0.002, 0.001, 0.0005 respectively.**
    - **CAL in configured in 4 range read out mode**

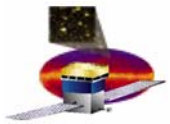
E2E- Baseline VDG test

- **Purpose**
  - **Take Low energy photons using a VDG generator.**
  - **Fix all register settings to nominal and exercise data volume with high rates when using an external pulse generator**
- **Test ID**
  - **9/X , where X corresponds to a particular subtest**
- **Duration**
  - **4 h (4x1h)**
- **Data Taking configurations**
  - **9/1 to 9/4: Nominal settings, vary rates**
    - **0,1,2,5,10 kHz, in which events are prescaled to 0.01, 0.01, 0.002, 0.001, 0.0005 respectively.**
  - **9/6 to 9/9: Nominal settings, vary rates**
    - **1,2,5,10 kHz, in which events are prescaled to 0.01, 0.01, 0.002, 0.001, 0.0005 respectively.**
    - **CAL in configured in 4 range read out mode**



Part 2 - I&T Additional Tests

- **Purpose**
  - **Scan FLE and FHE with muons**
  - **Note: this test does not use CAL scripts but I&T developed scripts**
- **Test ID**
  - **C/X , where X corresponds to a particular subtest**
- **Duration**
  - **6 h (4x1.5h)**
- **Data Taking configurations**
  - **C/1 to C/4: Trigger on CAL_LO only and scan DAC settings**



Part 3 - SVAC Tests – Executive Summary

- **Before SVAC tests**
  - **Integrated tower is timed in and nominal settings are known**
- **SVAC tests**
  - **Tower A outside flight grid**
    - **Used for the development path**
  - **Partially populated LAT in a flight grid (Only these are presented in the next slides)**
    - **from 1 to 16 towers**
  - **LAT**
  - **ACD tests**

SVAC – Charge Injection: partially populated LAT

- **Purpose**
  - **Change injections to support the SVAC offline calibrations with muons**
    - **performed inside the flight grid every time a tower is added**
      - » **Only performed on the new added tower**
    - **performed right before the muon data taking**
- **Duration**
  - **Approximately 1 day (TBR)**
- **Tests**
  - **TKR tests**
    - **TE604 – Threshold Dispersion**
    - **TE601 – Threshold Calibrations**
    - **TE602 – TOT conversion parameter calibrations**
  - **CAL test suites**
    - **calibDAC – FLE/FHE characterization charge injection**
    - **calibGen – calibrations with charge injection**
    - **muTrig – FLE/FHE characterization with muons**

SVAC - muon tests: partially populated LAT

- Occur every time any pair of towers (TKR+CAL+TEM/PS) is integrated in the flight grid
  - Assume electronic calibrations have been performed
  - Assume all nominal settings are known
- Test ID
  - B/X , where X corresponds to a particular subtest
- Duration
  - 39h for first pair of towers in grid
  - 23h for any other pair of towers
- Data Taking configurations
  - B2: Flight configuration (4h)
    - vertical orientation
  - B10: Muon Calibrations (15h)
    - » vertical orientation
    - » CAL High energy muon gain, FLE 100 MeV
    - » TEM Diagnostics ON
  - B13: same as B10 but zero suppression OFF (1h)
  - B11: same as B10 but horizontal orientation (3h)
    - » Background estimation before tests with VDG photons
  - B16: same as B2 horizontal orientation but TEM diagnostics is ON (16h)
    - » Only occurs for 2 towers when tested with VDG photons