Ad Hoc Committee on End-to-End Testing

Findings and Recommendations

Number: LAT-MD-03489-02
Created: 23 March 2004
Updated: 25 June 2004
Printed: 25 June 2004

The End-To-End Testing Report summarizes the efforts and conclusions of an ad hoc committee charged with examining system aspects of the LAT testing effort. Verification of the Trigger and DataFlow systems were the primary concern.

Hard copies of this document are for REFERENCE ONLY and should not be considered the latest revision

Record of Changes

Version	Date	Title Or Brief Description	Entered By
0.1	11 March 2004	Draft Release	S.Ritz, W. Atwood
0.2	14 March 2004	Added startup and trigger section, formalized document	J.J.Russell
0.3	15 March 2004	Incorporated fixes to Appendix B (cut the verbiage to only the necessary), added content to Appendix A (charge and membership), reworded Section 1	J.J.Russell & M.E.Huffer
0.4	16 March 2004	Moved items in Issues and Answers sections to relevant sections where appropriate. Other items where eliminated	J.J.Russell & M.E.Huffer
0.5	17 March 2004	Lots of clean-up and organizational work	M.E. Huffer
0.6	17 March 2004	Added additional recommends, particularly with regard to a trigger group. Cleaned up trigger test section	J.J.Russell & M.E.Huffer
0.7	17 March 2004	Minor spelling fixes before release	M.E.Huffer
0.8	23 March 2004	Addressed comments from committee members, first semi-official release	J.J.Russell & M.E.Huffer
0.9	28 March 2004	Final committee comments. First release to Peter	M.E.Huffer
1.0	30 March 2004	Comments from Peter and Elliott. Released to Peter	M.E.Huffer

Contents

Figures

Tables

1 Introduction and Executive Summary

The LAT test plan[1] flows properly from the requirements verification matrix. However, there is a class of tests that can be missed using a pure requirements verification methodology. These are End-to-End (E2E) system tests which function more as risk mitigation than requirements verification. Nevertheless, E2E testing forms an essential component of the LAT test plan. Proper design of an efficient, coherent, and meaningful suite of these types of tests requires detailed knowledge of the LAT as well as prior experience with complex instruments. The LAT Principal Investigator charged a small committee to sort through the many issues and to develop a proposal for a suite of E2E tests to be performed. The committee charge and membership are contained in Appendix A.

The committee bases its recommendations on the following two findings:

I. The testing laid out in the charge are really tests of the ***Trigger and Dataflow System*** (T&DF). The committee therefore kept a fixed focus, restricting discussion to E2E testing of the T&DF system and defining the scope of this system as from the detector's digital outputs to the instrument's output telemetry. Of course, there is more to the LAT than the T&DF system, but the committee became convinced that testing of those aspects is outside the scope of the T&DF system and is the responsibility of the subsystems in conjunction with I&T[2].

II. The Engineering Model tests already performed and leading up to the integration phase of the LAT provide an adequate base for implementing the recommendations of this committee.

The recommended tests assume subsystems have been tested at a unit level with the individual subsystem tests and the calibration tests outlined in the SVAC plan. The recommendations of the committee may be summarized as follows:

- Although the responsibility for trigger decisions resides in the global trigger (GEM), the trigger system is itself distributed across different modules of the T&DF system and is highly integrated across the different subsystems. However, the committee

---

[1] LAT-MD-02730, used as input to LAT-MD-13120

[2] These aspects would be enumerated in the individual subsystem test plans and the calibration tests in the SVAC plan, LAT-MD-00446.

notes that no single person or entity has been called out for responsibility of the trigger system as a whole. For that reason, the LAT trigger system should be given higher visibility within the LAT system engineering, integration and test planning. In particular, the committee recommends that an explicit trigger group (within the electronics subsystem) be identified that will call on LAT subsystem resources as needed to develop an integrated system trigger verification plan and procedures.

- A complete suite of tests must be defined to test every aspect of the T&DF system, including initialization (power-on, boot, and configuration), triggering, and data transport. A definition of this test suite is included in the report.
- Careful testing of the system over the full range of event rates and data volumes (sometimes called high-rate testing) must be performed. A test suite exercising the T&DF system over the full range of event rates and data volumes is included in this report.
- The Airplane Test, while appealing, is unnecessary and should therefore not be part of the LAT test plan. Van de Graaff testing as described below should be included in the test plan.

2 Tests

In this section we enumerate the E2E *functional* tests. In keeping with the charge to the E2E group, we restrict the list to those tests that explicitly involve the data system at the complete system level. In particular, we assume that the subsystems have been adequately tested as units. We also do not include here end-to-end science *performance* tests and calibration checks.

For each test, we give a description, rationale, pass criteria, and program phasing (when). A summary table is provided in section 2.5. The recommended event statistics and test durations are suggestive and are added for reference to allow definition of the procedures; however, it is expected the numbers will be optimized as the test procedures are developed and practical realities are better understood. We also do not attempt to distinguish between full and limited functional testing here. Instead, we describe the full functional tests and leave the definitions of the more limited versions of the same tests to the LAT Test Plan. While the tests described are for the entire LAT, they are also appropriate as input to the planning for tests during integration.

Ideally we would like to enumerate the tests without reference to methodology. However, we distinguish between those tests that could be accomplished with the LAT testbed[3] and those that require the flight LAT. While the architecture and design of the T&DF can (and should) be fully validated with the testbed, there must be detailed testing of the flight's T&DF to uncover potential EMI and other system issues. Flight LAT tests must be done over the full operating temperature range.

2.0 Power on Sequencing, Boot Process, and Configuration Setup

Before the T&DF can function, it must first be powered up, booted, and configured. Every aspect of the system is involved in this process and must be well understood to ensure the reliable operation of this crucial process. All subsequent testing, diagnosing, and functionality checking – both on the ground and on orbit – completely depend on these processes. Only after successful execution of these steps is the LAT ready to take data reliably.

Note that there is sometimes great pressure to skip over these tests or to reduce the priority of diagnostic investigation of these steps, with the primary objective of just getting the system "to work". Because correct operation of not only the T&DF but the entire LAT depends on the robust

---

[3] The LAT testbed is consists of a T&DF system and a Front-end Electronics Simulator (FES). A complete description of the LAT testbed is given in LAT-TD-XXXX (TBR) and the FES in LAT-TD-02895.

and reliable operation of this process, the committee strongly recommends that no short-cuts be taken in their testing. Any problems encountered during testing of this process must be both understood and solved.

2.0.0 Introduction

The LAT power-up sequence proceeds in two phases. The first phase is applying power to the SIU and the main power feeds. This phase is entirely controlled by the Spacecraft (S/C). This first phase can be exercised by using the Spectrum-Astro supplied Spacecraft Instrument Interface Simulator (SIIS).

Once power has been applied to the SIU and 1553 communications have been established, powering on the remainder of the LAT is done by ground telecommands issued to the SIU. Again one can use the SIIS as the user-interface to send the appropriate commands[4] to the SIU. Given that power cycling the actual LAT is not a benign operation, careful consideration should be given to how often this is done, weighing the benefits of frequent testing against the risks inherent in power cycling the instrument.

Power-up tests include both cold and warm boots. A cold boot begins with no power applied to the LAT or SIU. A warm boot begins with the SIU and LAT main feeds powered, but not necessarily the remainder of the LAT, *i.e.* the GASU, TEMs and Front-End Electronics. Both cold and warm boots can be exercised regularly on the testbed. This will iron out procedural and operational problems, but does not guarantee that the flight LAT will respond correctly.

Once all the Trigger and DataFlow elements (the GASU, TEMs, *etc.*) and the front-ends are powered, the LAT can be configured. The suggested test is to load known configurations into the LAT and verify the just loaded configurations by reading them back. These tests are benign and relatively fast so that they can be regularly run.

2.0.1 Required Tests

To be explicit, these are the required tests

1. **LAT Main Feed Power-Up Test**
   Starting from a position with no power on the LAT, the SIIS is used to turn on the main feeds to the LAT. The results of powering the main feeds are monitored via the discrete analog signals sent back from the LAT to the SIIS and must be within nominally established limits. Both primary and redundant *feeds* and primary and redundant *PDU*s must be tested.
2. **SIU/EPU Power-Up Test**
   Starting from a position with the LAT main feeds powered, the SIIS is used to turn on the power to the SIU. The results of powering the SIU are monitored by the SIIS. The SIU, in turn, power-ups the EPU. The results of powering the EPUs are monitored by the SIU. Powering up the SIU/EPU will result in the power-on reset circuitry initiating a cold primary boot procedure. Establishment of 1553 communications (in the case of the SIU) or LCB communications (in the case of the EPU) and a primary boot success message issued over the communication channel indicates successful completion of the primary

---

[4] The LAT power on sequence is outlined in LAT-TD-1536.

boot procedure. This test needs to be performed on all crates[5], exercising both primary and redundant power feeds.

3. **SIU/EPU Warm Boot via Hardware Reset**
   Once the success of test 2 is established, the reset lines can be tested. Upon receiving a reset signal, all crates execute the warm primary boot procedure. Success is as indicated in test 2. All primary and redundant resets to all crates must be tested.
4. **SIU/EPU Warm Boot via Hardware Watchdog Timer Expiration**
   Using special software in the SIU/EPU, the hardware watchdog timer will be allowed to expire, initiating a warm boot. Success of this procedure is indicated by the same criteria as in test 2.
5. **SIU/EPU Cold/Warm Boot via Command**
   A 1553 message (SIU) or a LCB command (EPU) will be issued instructing the target CPU to execute either a warm or cold reboot. Success is determined by the success criteria of the warm or cold (test 2) primary boot procedure.
6. **LAT Power Up**
   The remainder of the LAT[6] is powered up. The success is determined by monitoring the LAT housekeeping stream, checking that all voltages and currents are acceptable.
7. **LAT Configuration**
   Once the LAT has been successfully powered up, the LAT must be configured. This involves loading registers not already configured during power-up sequencing. These are primarily the registers of the subsystems Front-End-Electronics. Success is determined by reading back the configuration and matching it against expectations.

2.1 Trigger

The testing addressed here deals with integrating multiple towers and the ACD with the trigger. However, some input from trigger unit testing is necessary, as described in the following subsection. During discussions the committee could not identify *who* is tasked with the responsibility for unit testing of the trigger as a system.

2.1.0 Unit Testing

From the perspective of E2E testing, the necessary result of unit testing is the establishment of the relative offsets and trigger jitter of the TKR, CAL and ACD trigger request lines with respect to a well-defined T_0[7].

2.1.1 System Testing, Overview

There are two categories of trigger tests:

1. Timing and control signal tests. These tests ensure the fast trigger signals from the subsystems to the trigger are correct and arrive at the expected relative times with adequate margin to ensure a stable system. In addition, tests must be done to show that

---

[5] There are five crates, two SIUs and three EPUs.

[6] The remainder of the LAT is defined as everything downstream of and including ACD FREE Boards and TEMs.

[7] The trigger jitter time has been specified to be less than 250 nanoseconds.

the signals generated by the trigger are delivered back to the subsystems to ensure high data capture efficiency.

2. Data tests. These tests ensure that the trigger's contribution to an event is correct.

The first timing and control signal test is a timing sweep to test for edge margins. Delays are introduced individually into each logic input signal to the global trigger and into the control signals out of the global trigger. To map out the edges, the trigger window width must be enlarged to ensure efficient capture of the trigger signals. Given the low rate of cosmic rays, pile-up will not be a problem, so this width can be expanded over the nominal 500 nanosecond width. However, as increasing window width increases trigger latency and, so at some point, data capture efficiency suffers. Of course, this is almost the point of the exercise; can one find a width that will maximize both trigger and capture efficiency and minimize deadtime? At least 10k cosmic ray and noise triggers are taken at each setting so that errors are understood at the 1% level or better. The setting range must be wide enough to map out a timing plateau. This jitter needs to be measured. In this context, the jitter is defined as the time needed to rise from 5% to 95% (TBR) of the plateau value. Except for a normalization correction due to deadtime, the plateau curve should be independent of trigger rate.

The timing sweep test should also be run during thermal-vac testing, to verify the behavior over the full temperature range, and also on orbit during the initial checkout

The trigger data tests are performed at the same time as the general data handling tests, covered in section 2.2 below, but at the nominal timing settings and with very high statistics. Using the testbed, there should be 100% correspondence between the logic inputs and the trigger's event contributions. In the LAT, the trigger's contribution to the event should be consistent with the detector's contribution to the event. For example, suppose that one set-up a 3-in-a-row tracker trigger using only six planes in a given tower. One expects to see the six hits in the six triggering planes *almost all the time*. However, due to latching inefficiencies, there will be times when one or more such hits will be missing. An example of a gross inconsistency would be if *almost all the time* a different set of six planes appeared in the data.

2.1.2 Required System Tests

The trigger jitter, as measured by unit testing, effectively determines the width of the trigger window. The differences in the relative timings will be taken out by adjusting the various timing registers available in the T&DF system. The tests described below are designed to find the optimal window width and TACK delays back to the detectors. Establishing a minimal window width is important as it affects deadtime (the wider the window-turn the more deadtime) and the latching efficiency (the TACK cannot be delivered until some fixed time after the window closes). Thus increasing the window width will have a tendency to increase triggering efficiency (at least until pile-up effects set in) and decrease latching efficiency.

1. **Global Timing Trigger/Data Efficiencies**
   Varying the window width, the overlap of various trigger signals are measured. This establishes the timing margins (> ~250 nanoseconds) and the overall trigger efficiency for cosmic rays The trigger efficiency, false veto rate and data capture efficiency must be as specified in TKR-LAT-SS-00017, CAL-LAT-SS-00018 and ACD-LAT-SS-00016 .
2. **Data Testing**
   In the nominal configuration, including all timings set at their nominal values, the trigger's contribution to the event data should match expectations in the ACD, TKR and CAL event contributions. Due to different signal shaping, discriminator setting and deglitching, the trigger signals and the detector signals are not expected to be in 100% agreement. The absolute level of correlation needs to be established, but certainly relative correlations

between like members, be they tower-to-tower or ACD tile-to-ACD tile, should be consistent at the >99% (TBR) level.

3. **CNO and $\mathrm{CAL}_{\mathrm{high}}$ Trigger Signals**
   Given that these signals will not react to cosmic rays, another test needs to be defined. The best alternative appears to be using the calibration strobe signals. The difficulties with this approach are
   i. Establishing that the calibration strobe signals are delivered at the same time across all subsystems.
   ii. Understanding any limitations due to the fact the shape of the calibration signal does not match an actual signal shape.
4. **False Triggers**
   When possible, data taken should be examined for anomalous features. In particular, evidence of self-triggering should be looked for. Examples of signatures of false-triggering would be
   i. Appearance of a galloping trigger rate
   ii. Similarity of adjacent events
   iii. Similarity in trigger patterns in adjacent events
   iv. Non-Poisson distribution in arrival times of cosmic rays

   The GEM has two elapsed time counters, one measuring the time from the last trigger and the other measuring the time from the last window turn. These counters may aid in these types of investigations by defining events that are candidates for self-triggering.

2.2 Event Data Handling Tests

A calibrated detector will be required for these tests. Calibration results will also have an impact on reference histograms, comparisons, and trending. For example, there will be updates to the bad channel lists as well as gain calibrations. We expect that calibrations are done as part of normal testing.

Event filtering is not required for these tests and, while running the standard flight filter in pass-through mode could accomplish this objective, it would not contribute any useful information to a test and could negatively impact its performance. However, some tests described here will demand software that will select events for output, particularly when the data volume required of the test will exceed the available output bandwidth. These very simple selections are included in the test definitions.

2.2.0 Nominal-rate testing considerations for the flight LAT

Testing the system at the event rates expected during operations is sometimes called “high-rate” testing. Because the *non-vetoed* orbit-average trigger rate will routinely be in the range 1-5 kHz, with maximum rates a factor 2-4 higher, we prefer to call these nominal-rate tests. The nominal-rate event handling tests are the most detailed set of tests. This is where we answer the key question in the charge to the E2E Committee: "How do we know the T&DF system doesn't hang or corrupt event data under all expected operating conditions?"[8]

---

[8] In addition, this set of tests should be performed at maximal rates (margin testing).

It has been suggested that lowering the TKR thresholds would provide a means to run the T&DF system at nominal rates. By finding the cosmic-ray induced muon events (subsequently called “cosmic rays” in this document), and demonstrating that those events are independent of trigger rate[9], *i.e.*, demonstrating that the rate, angular distribution, CAL deposition patterns, and noise occupancy are independent of trigger rate, we can validate the T&DF system. However, we have realized this will not be an effective test for at least two essential reasons: First, the trigger timing changes with threshold and second, the TKR noise occupancy obviously changes with threshold. A TKR threshold scan is still valuable because we must verify that the T&DF works over a range of thresholds, but it cannot be a precise E2E test of the data system.

There are two simple alternatives:

1. Turn *ON* alternating TKR trigger layers and use the expected noise occupancy to generate triggers at high rate. This technique is described in Appendix B. The resulting events will have the same timing and noise occupancy characteristics independent of rate. There will be a small change in the accepted angular and energy distributions of the cosmic ray events, but that can be removed with an analysis (not trigger) selection requiring an appropriate energy deposition in the calorimeter. Note: it is very important not to use the ACD as the trigger for these tests: if there were problems in the system that made triggering on gammas, but not backgrounds, inefficient, we’d miss them.
2. Use the so-called “Solicited” condition as a trigger. The solicited condition is simply an on-demand trigger initiated under program control. Thus the T&DF system has the capability to self-trigger at selectable times. A buffer of solicited triggers decouples the instantaneous CPU utilization from the triggers, so the timing is asynchronous. The time for each trigger is a command parameter, so a full range of timing profiles can be tested, and the maximum selectable rate is a healthy 100 kHz. Randomly interspersing solicited-condition triggers with standard cosmic ray events will provide the needed high-rate environment.

Of these two, we believe the solicited-condition trigger should be the standard nominal-rate tool. The layer *ON* technique should also be used early to validate the solicited-condition technique, and to test for gross high-occupancy data transport errors, comparing the results for the two techniques. Once the solicited condition technique is validated, the layer *ON* technique is still available as a backup technique.

Using this tool, the full space of LAT data configurations can be explored over long periods of time to high precision. Once a baseline configuration is established in one mode, detailed comparisons can be made with all operating modes and differing conditions over sustained periods of time. The tests based on this tool are described in section 2.2.1.

Two other methods for nominal-rate running have been proposed:

1. **The Airplane Test.** This idea stems from the realization that cosmic-ray induced airshowers at aircraft altitudes would provide a real particle flux over all angles at high rate. Indeed, the airplane test is the only idea suggested thus far that directly provides the flight LAT with background particle fluxes similar to those encountered on orbit. However, in addition to the practical concerns outside the scope of this document[10] there are the following essential issues and problems:
    i. The relatively brief flight time would not support a wide range of detailed, robust testing (see section 2.2.1). As a consequence, the airplane flight is largely a feel-

---

[9] After deadtime correction

[10] In particular, operation of the LAT in an environment that lies outside its design requirements.

good test: did the system hang? While appealing, the brief flight time necessarily means that question could only be answered for a limited number of configurations and only for a few hours at most.

   ii. Detailed tests are difficult to define. The particle flux is not well understood, so precision comparison tests are not possible. There is no reference sample beyond Monte Carlo as a control. Pass/fail criteria are therefore difficult to quantify.

   iii. There are alternative means (see below) to test everything about the T&DF system that would be tested by the Airplane Test, and the alternative tests do not suffer from the above limitations.

Thus, from a T&DF perspective, we recommend that the Airplane Test should not be included in the LAT test plan.

2. **Van de Graaff (VDG) tests.** These tests offer several attractive features, most notably providing triggering on events that do not pass through the LAT, as cosmic ray events tend to do, but gammas do not. The down side is that these are very low-energy events, residing outside the design energy range of the LAT. Because meaningful, simple, and quantitative tests can be defined using the VDG, we include a limited set of these tests in the suite of required tests. We note that more detailed analyses can be performed with the same data set, but these are outside the scope of this document. There are two methods for collecting VDG data at high rates.

   i. Improve the VDG performance to increase the flux by a factor ~100. I&T personnel are actively exploring this possibility, but this improvement has not yet been demonstrated, so we provide an alternative option:

   ii. Use the VDG flux demonstrated during EM testing[11] and concurrently issue solicited condition triggers. In both cases the analysis is the same: demonstrate that the distributions for data taken at different rates are consistent.

Option (i) is preferred, but option (ii) is an acceptable alternative.

2.2.1 Required tests

Table 3 summarizing the tests is given at the end of section 2. The required tests are:

1. **Baseline CR Test**.
At nominal temperature, voltage, timing, and thresholds, and standard data taking configuration[12], record cosmic ray (CR) events. Typical runs will record ~ 1 million events (approximately one hour of data taking). The pass criteria are: *No* data system hangs and transport errors (parity errors, timeouts, etc.). The test also requires basic data quality measures, which include: total trigger rate; trigger rate per tower and per layer from both TKR and CAL; TKR, CAL, and ACD hit and noise occupancy rates; reconstructed angular distribution; reconstructed energy distribution; TOT distributions; CNO trigger functionality, deadtime per second distribution. This is intended as an initial list and must be iterated and expanded for inclusion in the Test Plan. The test should be performed at least once per week, and more frequently when practical, up to once per day, during the whole I&T program for trending and history analysis. The distributions and

---

[11] The VDG flux was 1KHz into 4 π, corresponding to ~80Hz into a single tower.

[12] The configuration includes, but is not limited to the trigger setup, GTRC splits, discriminator thresholds etc.

rates should match expectations to within the statistical precision. Longer runs, lasting a day or more, should be done periodically, at least once per month.

2. **Condition Scan CR Test**
   Same as item (1), but done over full operating ranges in temperature[13], spacecraft voltage, timing, thresholds (both TKR and CAL separately), and TKR readout configuration. It is not necessary to cover all combinations: each condition should be varied independently, while all other conditions are held at nominal. The one exception is a possible anti-correlation between temperature and voltage, which should be tested explicitly. Since the system clock is not adjustable on orbit, there is no reason to test the system routinely over the full clock operating range; it should, however, be done at least once to check for operating margin.

3. **Baseline CR Trigger Subtests**
   Same as item (1), but in each trigger configuration (TKR alone, CAL$_{\text{-low}}$ alone, CAL$_{\text{high}}$ alone, each veto[14] activated alone, and each combination in permutation). This test should be performed at least once very early after completion of integration and once again prior to instrument delivery. Care must be taken to ensure the results are valid. The pass criterion is simple: the distributions must match those of (1) within statistical precision for the same trigger selections.

4. **Nominal-Rate CR Test**
   At nominal temperature, voltage, timing, thresholds and trigger configuration, but using solicited-condition triggers to raise the rate. Set the triggers so the data system runs at 1 kHz, 5 kHz, 10 kHz, and 20 kHz. Same tests as (1). Demonstrate that all distributions are invariant (after deadtime correction) to within the statistical precision of the distributions, which should be better than 5% in all cases. The nominal-rate CR tests should be performed at least once very early after completion of integration, and should also be performed regularly for long periods, whenever the instrument is otherwise idle. Run durations should be somewhere between that of one orbit (90 minutes) and one day. NOTE: The data system and EGSE[15] can not write out all the events at these rates. Therefore, a simple filter selection will be run on the EPUs, requiring a TKR, CAL$_{\text{-low}}$ or CAL$_{\text{-high}}$ trigger plus a pass-through of 1%-10% (TBR) prescaled computer-generated triggers.

5. **Nominal-Rate Condition Scan CR Test**
   Same as (2), but at rates as in (4).

6. **CAL Nominal-Rate CR Test**
   At nominal temperature, voltage, timing, TKR and ACD thresholds and trigger configuration. However, the CAL$_{\text{-low}}$ and CAL$_{\text{-high}}$ thresholds should be lowered to run the system at 1 kHz, 5 kHz, and 10 kHz. Same tests as (1). In particular, verify that the selection on TKR triggers (and NOT CAL$_{\text{-low}}$) give the same distributions as (1), after deadtime correction. The pass criteria for this test are otherwise relaxed: the system must not hang or give parity errors. The trigger timing change makes detailed data comparisons not very useful.

---

[13] Only done during thermal-vac testing.

[14] Sometimes referred to as the trigger *throttle*.

[15] Electrical Ground Support Equipment

7. **Baseline CR Data Volume Sub-Tests**
   The same as item (1), but switches off CAL and ACD digital zero suppression both separately and together to exercise the system over all levels of data volume loading. Pass criteria are no system hangs or parity errors; and, after offline zero suppression cuts, identical results to (1).

8. **Nominal-Rate CR Data Volume Sub-Tests**
   The same as item (4), but turn off or down CAL and ACD digital zero suppression separately and together to exercise the system at nominal rates over all levels of data volume loading. In an alternative configuration, Four-range readout should be configured to acquire CAL events with information on all four-range settings.

9. **VDG tests**
   Run the VDG to collect 1 million (TBR) events at mean trigger rates of 100 Hz and 1 kHz (rates TBR). This test can be accomplished using either the VDG alone or the low-rate VDG mixed with solicited condition triggers as described above. Produce the following plots:

   i. A two-dimensional spatial image of the reconstructed VDG source in instrument coordinates. The images at higher and lower rates must match each other to 10%.

   ii. Histograms of time intervals between sequential events, and the accompanying FFT power spectrum. The deadtime corrected histograms of time intervals and resulting power spectrum is made for different trigger rates and for selected reconstructed energy bins. No unexplained, statistically significant features should be present in the power spectrum.

   iii. Reconstructed VDG energy spectrum. The higher-rate and lower-rate data sets must match.

10. **Deliberate Introduction of Errors**
    A class of these tests which introduce deliberate transport errors can be accomplished with the flight LAT by setting configuration registers that reverse the expected parity. To the extent that one expects the bit streams to produce the expected parity, this technique will artificially induce errors. This technique can be applied wherever the T&DF moves information including command/response, trigger and event information. There is more flexibility in the Test Bed for inducing cable level errors, since one can construct cable level bit streams containing these errors at any desired duty cycle.

2.2.2 Additional Analyses

During the discussions, a number of analyses were suggested that are not required but that are worth performing if possible. All these analyses can be done using the same test data (no additional runs are needed). They are therefore retained as goals.

1. Find the gamma component in the cosmic rays.
2. Find the π^0 component in the cosmic rays by reconstructing two coincident gammas in the flight (vertically oriented) LAT consistent with a common production point. The distribution of the common production point would also be interesting. Initial estimates by Julie McEnery, based on airshower Monte Carlo modeling, gives a clean event rate of O(1)/hour, TBR.

3. Plot the TOT distribution and show that one can differentiate a 1 versus 2 MIP signal.

2.3 Filter and onboard science processes

The functionality and robustness of the filter algorithms can be tested in detail both offline and in the testbed. The main issue here is the system impact of the filter in real time as a component in the data flow. That is best done in the testbed. The filter will also be run during all the testing in 2.2.1 in pass-through mode.

The functionality and robustness of the onboard science algorithms will be tested in detail both offline and in the testbed. In the full LAT, tests must be performed to verify that the message handling and interfaces external to LAT function. This can be done in one of the following two fashions:

1. Load a dummy science algorithm that detects large rates in an ACD tile and then trigger the transient using an external radioactive source
2. Use the real onboard science algorithm adjusting the parameters so that it triggers on the VDG, which can certainly look like a low-energy burst.

Option (2) is preferable because it involves the real algorithm. We suggest holding option (1) as a backup if the VDG is unavailable.

2.4 Housekeeping and monitoring

From the E2E test perspective, no additional data taking appears to be necessary to verify the housekeeping and monitoring functions. Verification of that functionality can be done by analyzing the test data described in section 2.2 and in the thermal-vac testing.

2.5 Summary

We summarize the tests from section 2.2.1 in the Table below. As stated previously, the recommended event statistics and test durations are suggestive to allow for the definition of the procedures; however, these numbers should be optimized as the test procedures are developed and practical realities are better understood.

The test duration does **not** include setup time. For some tests, the setup time may dominate the test's total time.

Test		Pass/Fail Criteria	Readout Mode	Duration	When
1	LAT Main Feed Power-Up Test	Voltage and currents are as expected. Readout is via the SIIS and its dedicated analog channels to the LAT	N/A.	~5 min	Typically 1/day and at least 1/week for reference on the testbed. Testing on the real LAT will weigh the risk of power cycling against the benefit of continuous testing.
2	SIU/EPU Power-Up Test	Voltage and currents are as expected. Readout is via the SIIS and its dedicated analog channels to the LAT and in the case of the EPU, via the LAT housekeeping The SIU/EPU successfully executes a cold primary boot as demonstrated by establishing 1553 communications with the SIIS (SIU) or with over the LCB fabric to the SIU (EPU)	N/A	~5 min	Typically 1/day and at least 1/week for reference on the testbed. Testing on the SIU will weigh the risk of power cycling against the benefit of continuous testing.
3	SIU/EPU Warm Boot, via Hardware Reset	Same as the Cold Boot criteria	N/A	~5 min	Typically 1/day and at least 1/week for reference.
4	SIU/EPU Warm Boot, via Watchdog Timer Expiration	Same as the Cold Boot criteria plus checking of the reboot diagnostic area for the correct reboot reason	N/A	~5 min	Typically 1/day and at least 1/week for reference
5	SIU/EPU Cold/Warm, via Command	Either as in the Cold or Warm boot success criteria	N/A	~5 min	Typically 1/day and at least 1/week for reference
6	LAT Power On	LAT Housekeeping indicates all voltages and currents are acceptable	N/A	~5 min	Typically 1/day and at least 1/week for reference
7	LAT Configuration	Read back configuration matches the expected configuration	N/A	~5 min	Typically 1/day and at least 1/week for reference

Table 1 Start-Up Test Definitions

Test		Pass/Fail Criteria	Readout Mode	Duration	When
1	Global Timing Test	The trigger efficiency, false veto rate and data capture efficiency must be as specified in TKR-LAT-SS-00017, CAL-LAT-SS-00018 and ACD-LAT-SS-00016.	Normal	~1 hr[2]	Million events: typically 1/day and at least 1/week for reference, trending and uncovering developing problems. Longer runs, lasting 1 day or more, should be done ~1/month.
2	Data Testing	The trigger data, expressed in the GEM contribution must be consistent with the data from the individual contributors.	Normal, including all timing values set at their nominal values	~1 hr[2]	Million events: typically 1/day and at least 1/week for reference, trending and uncovering developing problems. Longer runs, lasting 1 day or more, should be done ~1/month.
3	CNO and CAL_{high} Trigger signals	Special tests needed to verify proper functioning of the CNO and CAL_{high} trigger signals. This test must recognize the limitations of using cosmic rays in testing these signals	Normal	~1 hr	Typically ~1/month
4	False Triggers	The data taken should only contain the expected triggers. Inter-event times should be examined to show that they have the proper time distribution.	Normal	~1 hr[2]	Million events: typically 1/day and at least 1/week for reference, trending and uncovering developing problems. Longer runs, lasting 1 day or more, should be done ~1/month

Table 2 Trigger Test Definitions

[1] It may be possible to perform all three tests more or less simultaneously, particularly if a muon telescope can be used as an external trigger.

[2] It may be possible to perform these tests more or less simultaneously with other tests, particularly the tests in the Data section.

Test		Pass/Fail Criteria	Readout Mode	Duration	When
1	Baseline CR	Zero data system hangs and transport errors; standard quality checks (see text).	Standard mode (no filter applied). Rate is ~500 Hz full LAT.	One hour (~1 million events full LAT) nominally.	Million events: typically 1/day and at least 1/week for reference, trending and uncovering developing problems. Longer runs, lasting 1 day or more, should be done ~1/month.
2	Condition Scan CR	Match with baseline references (see text). Initial scans will establish operating thresholds and timing ranges.	Standard mode (no filter applied). Rate is ~500 Hz full LAT.	~1 hr/condition (5 voltages, 10 thresholds, 10 timing settings) TBR. Total: 2-3 days.	Timing and threshold scans at each major integration step for a subset of trigger rates, and full range of rates pre/post-ship. Temp/voltage scans in ENV testing.
3	Baseline CR trigger sub-tests	Match with baseline CR with trigger selections.	Standard mode (no filter applied). Rates will vary by trigger type. Veto-enabled runs will be very low rate.	~1hr/configuration, 8 configurations. Total: 8 hours.	At each major integration step and pre/post ship.
4	Nominal-rate CR	Match with baseline CR.	Simple filter applied, requiring TKR OR CAL_{low} trigger plus a fraction of pass-through (1%-10% TBR) solicited condition empty triggers.	90 minutes each Total: 24 hours.	After each major integration step and pre/post ship; plus as often as possible, consistent with schedule (whenever system is otherwise idle). At least once, the test should be done using the alternative Layer-ON technique described in the text.
5	Nominal-rate condition scan CR	Same as condition scan CR above.	Same as above	1 hour/condition. Same condition set as Condition Scan CR test above Total: 2-3 days.	After each major integration step and pre/post ship.
6	CAL nominal-rate CR	Match with baseline CR after selecting on TKR trigger only events (no $\text{CAL}_{\text{-low}}$).	Lower CAL_{low} or CAL_{high} thresholds. Simple filter applied requiring a TKR trigger plus a fraction of pass-through (1%-10% TBR) CAL triggers.	90 minutes $\text{CAL}_{\text{-low}}$ and 90 minutes $\text{CAL}_{\text{-high}}$. Total: 3 hours	After 2-tower, 16-tower, and full LAT integration; plus at least once after observatory integration.
7	Baseline CR data volume sub-tests	Match with baseline CR after offline zero suppression cuts.	Nominal, but turn off CAL and ACD digital zero suppression. In a 2nd configuration, the CAL four-range readout should be forced on.	90 minutes Total: 24 hours.	After each major integration step and pre/post ship; plus as often as possible consistent with schedule (whenever system is otherwise idle).

8	Nominal-rate CR data volume sub-tests	Match with CR baseline after offline zero suppression and trigger selection cuts.	Simple filter applied, requiring TKR OR CAL_{low} trigger plus a fraction of pass-through (1%-10% TBR) solicited condition empty triggers	90 minutes Total: 24 hours	After 2-tower, 16-tower, and full LAT integration; plus at least once after observatory integration.
9	VDG two-rate tests	Reconstructed energy spectrum and reconstructed source (spatial profile) match at lower and higher rates. No unexplained significant features in timing histograms (see text)	Standard data-taking mode. Run VDG intensity to trigger instrument at 100 Hz and 1kHz (TBR) equivalent full LAT.	Full LAT: 1 million events at normal incidence at both trigger rates. Total: 4 hours.	After 2-tower, 16-tower, and full LAT integration.
10	Deliberate Introduction of errors	T&DF systems should respond to induced errors as expected	Standard data-taking mode	1 Event per type of induced error	Once at the beginning and once after integration

Table 3 Data Handling Test Definitions

3 Appendix A

3.0 Charge

The original charge from Peter Michelson was as follows:

To ensure success, it is necessary for the GLAST LAT Project to have detailed and carefully-designed end-to-end tests and procedures for the LAT. Plans already exist for the subsystems to verify the Level III and lower requirements, and for LAT scientific verification and calibration, however end-to-end tests cover a broader system-level scope. The charge to this group is to ensure that the LAT Comprehensive Performance Test (as indicated in MD-1312-01) adequately verifies the detector through spacecraft science data interface and to define the objectives and requirements for LAT through IOC ground end to end tests. The resulting plan should include enough detail for the I&T and SE groups to produce from it a detailed and complete LAT test procedures document.

Because of the inherently broad nature of this plan, there will be some overlap with the content of the existing test plans. It is not necessary to spend significant effort determining which test should be in which plan, or to determine whether a test is a functional test or a performance test; rather it is much more important to determine that there are no missing elements, and to provide that comprehensive analysis in a single document. Where appropriate, it should be shown how the individual subsystem tests tie together at the LAT level. To avoid duplication, existing tests in other documents should be referenced explicitly.

In addition to providing a component of the formal documentation of the Level II requirements verification, the end-to-end test plan is the document that will be consulted when someone asks, for example, "How do we know the data system doesn't hang, or corrupt the data, under all expected operating conditions?"

We would like a preliminary outline of the report by XXXX (TBR), along with any feedback on the charge, and a first draft by XXXX (TBR). At that point, we will assess how best to proceed, based on your results. Our intention is to have the plan complete and carefully reviewed by members of the team and a few outside experts, and to place the plan under project control, by the end of February 2004 (TBR).

This charge was amended in the first meeting (attended by Peter) to limit the scope of the committee to the LAT's Data Handling Systems.

3.1 Membership

- Bill Atwood, UCSC (Tracker)

- Eduardo do Couto e Silva, SLAC (Integration & Test)
- Mike Huffer, SLAC (Electronics and *chair*)
- Neil Johnson, NRL (Calorimeter)
- Tom Leisgang, SLAC (Systems Engineering)
- Steve Ritz, GSFC (Instrument Scientist and *ex officio*)
- J.J. Russell, SLAC (Flight Software)

3.2 Meetings

The committee met ten times from September, 2003 to March 2004. By common consent meetings were limited to two hours. Much of the work was accomplished off-line through assigned "homework". The committee's efforts could be broken down into three phases: acquisition of necessary background information, analysis of data and findings, and consolidation of these findings into a report. The meeting schedule was as follows:

September 3, 2003	Discussion of charge. Agree to limit committee's scope to Data Handling Systems
September 24, 2003	Survey and discussion of current requirements
October 9, 2003	JJ gives an overview and tutorial on the LAT's Data Handling Systems
November 19, 2003	Committee begins analysis of background information
December 11, 2003	Committee concludes analysis. Steve and Bill agree to write pre-draft using the committee's findings
January 22, 2004	Committee refines findings based on Steve and Bill's pre-draft
January 26, 2004	Committee discusses structure and content of final report
February 2, 2004	Committee discusses role of pre-cursor testing
February 12, 2004	Presentation by Eduardo of I & T plans concerning VDG. Steve agrees to write rough draft by consolidating findings of previous two meetings with pre-draft
March 12, 2004	Committee deliberates on Steve's rough draft. Steve incorporates comments. Mike and JJ agree to write first draft from rough draft
March 14, 2004	JJ and Mike attempt to polish Steve's rough draft. Not clear whether they got the sign right…
March 28, 2004	Final report approved by the committee.

3.3 Background material

The committee had a working website, where more background material may be found. The URL of the website:

http://www-glast.slac.stanford.edu/IntegrationTest/DataHandling/default.htm

4 Appendix B

4.0 Rate Estimates with Alternative Noise Trigger

The main-stay of GLAST triggers is the “3-in-a-row” trigger from the tracker. This is a 6 fold coincidence between adjacent silicon planes within a single tower (hence 3X hits + 3Y hits). The estimated random trigger rate is projected to be very small given the small noise occupancy observed in prototype detector / front end sensors. This rate can be increased by reducing the number of coincidences required. The easiest way to do this is to artificially “turn-on” silicon planes for purposes of triggering, an option provided for in the TEM trigger system. The combinatorics for various simple and symmetric cases has been computed as a function of the noise occupancy rate and is plotted below.

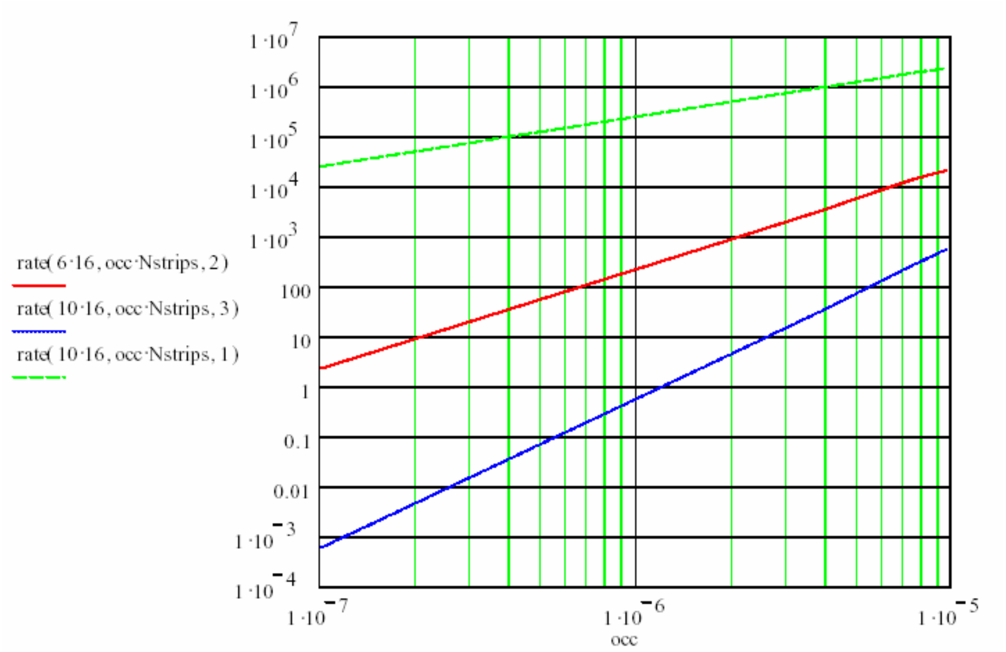

Figure 1 Tracker Trigger Rates by Occupancy

The good news is that there is a very broad range of rates to choose from with simple selections, which means this technique will work with any occupancy. The bad news is that the control over the rate is very coarse.

The 2-fold coincidence configuration (red line above) appears to be the optimal choice for our expected occupancy of a few x 10^{-6}. To get rates as high as 10 kHz, however we may have to lower the thresholds on the silicon strips or increase the number of 2-fold coincidences with a less symmetric pattern of layers held in the ON state.