Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Integration & Test Subsystem

LAT Test Plan for Airplane

Preliminary Draft
<table>
<thead>
<tr>
<th>Revision</th>
<th>Effective Date</th>
<th>Description of Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>-01</td>
<td>4/8/02</td>
<td>Initial release. Preliminary draft.</td>
</tr>
</tbody>
</table>
1. **Purpose**

The LAT Airplane Test program will be a demonstration of system functionality. As an end-to-end functionality test, the LAT Airplane Test program is designed to ensure the DAQ performance of the LAT. In particular, it will be demonstrated, before launch into orbit, that the LAT DAQ is able to handle the orbital cosmic ray trigger rates with the L1T deadtime and with the software filtered data rate to disk as expected from simulation.

The Airborne Cosmic Ray test may be found in the Table 12 (Science Verification) of the LAT Program Instrument Performance Verification Plan LAT-MD-00408 where it is one of the particle test verifications of the LAT.

2. **Scope**

2.1. **Items to be tested**

The LAT Airplane Plan describes the planned test of the sixteen-tower fully instrumented LAT flight hardware. It includes the fully instrumented ACD.

3. **Definitions**

3.1. **Acronyms**

ACD  Anti-Coincidence Detector
BFEM  Balloon Flight Engineering Module tower
DAQ  Data Acquisition system
GLAST  Gamma-ray Large Area Space Telescope
EGSE  Ground Support Electronics
LAT  Large Area Telescope.
NRL  Naval Research Lab in Washington, DC
RFI  Request For Information
SLAC  Stanford Linear Accelerator Center in Menlo Park, California
TBD  To Be Determined
TBR  To Be Reviewed

4. **Applicable Documents**

[1] LAT-MD-00408 (found in LAT-408.0)  LAT Program Instrument Performance Verification Plan
5. **Expected Cosmic Ray rates**

For the latitude of Palestine, Texas, Figure 5 and Table 2 give the 3-in-a-row tracker L1T trigger rate of the BFEM as a function of altitude. Notice, that at 25,000 feet the L1T rate is the same as it will be in orbit. The in-orbit L1T rate is ~22 higher than the ground L1T rate. This few hour airplane ride will be the only exposure of the flight configuration LAT to the full in-orbit cosmic rate.

![BFEM Trigger Rate vs Altitude](image)

*Figure 5. This is the Balloon Flight Engineering Module (BFEM) L1T trigger rate measured over Palestine, Texas in August, 2001. The BFEM front area is 1/25 that of the full LAT.*

<table>
<thead>
<tr>
<th>Altitude [feet]</th>
<th>L1T [Hz]</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25</td>
<td>Ground</td>
</tr>
<tr>
<td>25,000</td>
<td>540</td>
<td>Same rate as in orbit</td>
</tr>
<tr>
<td>35,000</td>
<td>900</td>
<td>Airplane flight</td>
</tr>
<tr>
<td>50,000</td>
<td>1175</td>
<td>Pfotzer max</td>
</tr>
<tr>
<td>127,000</td>
<td>540</td>
<td>Approx orbital rate</td>
</tr>
</tbody>
</table>

6. **Description of the elements of the LAT Airplane Test**

6.1. **LAT Flight Unit Shipping Container**

The LAT will be packed in a protective shipping container at all times during its transport from SLAC to Thermal-Vac. This container will protect against shocks to the instrument and will provide a clean air, low humidity (no condensation), and controlled temperature environment for the LAT.
The LAT must be able to operate and record data during the entire airplane flight while in the container.

The design of the shipping container must incorporate several features:

- Mechanical shock mounting between the container and support points on the LAT grid
- Liquid cooled heat exchanger bolted to grid radiator surfaces
- Hermetic penetrations of the container for LAT power, LAT data cables, data logger cables, and coolant pipes to the LAT heat exchanger.
- Thermal insulation so that the internal container temperature is mainly determined by the LAT power dissipation, the coolant temperature, and the coolant flow rate.
- The shipping container must be able to be picked up from below by a fork lift, and from above by a crane.

In addition, some peripheral equipment will accompany the shipping container. This equipment includes the EGSE, a portable 2 Kw liquid chiller, and a portable air dehumidifier (or dry nitrogen gas bottle). Some provision may be made for attaching this equipment to the exterior of the shipping container for ease in handling while the equipments’ electrical and hose connections to the shipping container remain intact.

6.2. Trucking from SLAC to the departure Airport

The truck interior will be temperature controlled (“refrigerated”) at nominally room temperature (TBD). The truck will also have an air ride suspension that is adjusted to minimize accelerations to the LAT from roadway bumps. The LAT will be powered off during trucking. Since no power will be on inside the shipping container, there will be no need for internal cooling of the shipping container, and the chiller will be turned off. Clean dry air will continue to be circulated through the shipping container. Two battery operated data loggers will redundantly read out acceleration, temperature, pressure, and humidity within the shipping container. A third data logger within the shipping container will provide real time output to a laptop computer being monitored by an I&T team member riding along in the truck.

6.3. Airplane Flight

6.3.1. Power required from aircraft

Power from the aircraft will be required to operate the EGSE (TBD Kw), a portable liquid chiller (~2 Kw), and a portable air dehumidifier (~1 Kw) during the entire time of the flight.

6.3.2. People required to accompany and operate the LAT on the aircraft

At least three I&T team members (logistics person, LAT DAQ expert, EGSE expert) will accompany the LAT on the flight. Their tasks will be to protect the health of the LAT, monitor the LAT environment, perform the specified LAT tests and data taking, monitor the flight path and altitude of the aircraft, and make any unanticipated decisions.

6.3.3. LAT tests to be performed on the airplane

As stated in Section 1., the purpose of the airplane test is to record ~orbital rate cosmic rays with the flight DAQ and onboard software filter. Compared to the orbital DAQ, the only difference will be
that the ready-to-be-downlinked data will flow to an EGSE hard disk rather than to the spacecraft solid state recorder.

The aircraft will be in one of three states:

1. Sitting on the ground, climbing, or descending,
2. Level flight for ~2 hours at a “middle altitude” of ~25,000 feet (TBD) chosen so that the L1T trigger rate from cosmics is equal to that in orbit,
3. Level flight for ~2 hours at a “top altitude” of ~35,000 feet [TBD] where the L1T trigger rate from cosmics is ~2 times larger.

The LAT data taking modes will be the same as those available in orbit. These will be:

1. **Standard Trigger Mode**: This is the workhorse 3-in-a-row tracker layers with the standard software filter for gammas. This should include the standard trickle rate of raw events, heavy ion ACD triggers for calibrating the calorimeter, and high energy calorimeter triggers.

2. **Throttled Trigger Modes**: These modes (~2 TBD) are where the event rate to disk has been reduced by more stringent hardware or software requirements. For example, these modes might include:
   - a calorimeter energy requirement in coincidence with 3-in-a-row,
   - a hardware ACD veto of L1T,

3. **Damaged Trigger Modes**: These modes (~2 TBD) test some part of the LAT failing. For example, these modes might include:
   - turn off one ACD tile
   - turn off one tower

4. **Wide Open Trigger Mode**: This is the 3 in-a-row tracker layers with no software filtering.

The total flight time in a passenger jet is 5 hrs between San Jose and Baltimore (2457 miles).

Data taking will be broken up by the EGSE into 10 minute runs (TBD) or 1 Gbyte file length, whichever comes first. Data runs will be recorded continuously from before take off until after landing of the aircraft. Only one trigger configuration should be used per run and an attempt should be made to have only one aircraft state (eg: climbing/descending, mid-altitude level, top-altitude level) in each run. All the data taking modes should be cycled through when in level flight. The “Standard Trigger” should be used when changing altitudes. Therefore, during each 2 hours of level flight each of the 6 trigger modes would be run twice.

Sufficient information should be displayed by the online EGSE to know that the LAT is functioning. In particular, the EGSE should display the L1T deadtime, and should display the event rate being recorded to disk from both the software filter and the various trickle sources individually. In addition, there should be an event display that samples the events going to disk.

If the LAT performance fails to meet certain proscribed levels (TBD) during the flight, the onboard I&T personnel will be authorized by the test procedure (TBD) to perform additional tests (TBD) that will aid in understanding and debugging the problem.

### 6.4. Trucking from the arrival Airport to the Thermal-Vac facility

The trucking requirements are the same as for trucking to the airport in section 6.2.
7. **Airplane Cost Estimates**

Requests for Information were made to eight airlines regarding the cost of shipping an 8500 lb container with dimensions 90”L x 90”W x 76”H from the San Francisco Bay Area to the Washington, DC area in July, 2004 on a direct non-stop flight. Our requirements for having a gas bottle for dry nitrogen flow or electric dehumidifier, airplane power for operating the instrument, and personnel to accompany the instrument and record data were explained.

Table 2. Airlines from which LAT shipping costs were requested.

<table>
<thead>
<tr>
<th>Airline</th>
<th>Telephone response from airline</th>
<th>Response to RFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Airlines</td>
<td>No cargo only aircraft. Our container is too large to fit in bottom cargo compartments. Person can’t be in the cargo compartment when in motion.</td>
<td></td>
</tr>
<tr>
<td>Continental Airlines</td>
<td>No cargo only aircraft. Our container is too large to fit in bottom cargo compartments. Person can’t be in the cargo compartment when in motion.</td>
<td></td>
</tr>
<tr>
<td>Delta Airlines</td>
<td>No cargo only aircraft. Our container is too large to fit in bottom cargo compartments. Person can’t be in the cargo compartment when in motion.</td>
<td></td>
</tr>
<tr>
<td>Emery Worldwide</td>
<td>RFI sent.</td>
<td>No. Emery leases all their aircraft. This use not consistent with their lease agreement, and Emery does not want the hassle of renegotiation.</td>
</tr>
<tr>
<td>Federal Express</td>
<td>RFI sent.</td>
<td>Yes. Must charter an entire aircraft. $82 K Carvair prop plane (~25,000 foot ceiling) (cargo door 64” high) $100 K Jet, 17,500 lb max, 3 GLAST people max, one fuel stop on the way, 24 VDC 16 kw, 1 month lead time, N2 okay if it is documented to meet IATA rules.</td>
</tr>
<tr>
<td>Leading Edge Air Logistics</td>
<td>RFI sent.</td>
<td></td>
</tr>
<tr>
<td>National Air Cargo</td>
<td>RFI sent. Charter broker.</td>
<td>Must charter a 747 for a one way non-stop flight for $150,000.</td>
</tr>
<tr>
<td>Northwest Airlines</td>
<td>RFI sent.</td>
<td>No cargo only aircraft. Our container is too large to fit in bottom cargo compartments. Person can’t be in the cargo compartment when in motion. No N₂ bottle.</td>
</tr>
<tr>
<td>United Airlines</td>
<td>No cargo only aircraft. Our container is too large to fit in bottom cargo compartments. Person can’t be in the cargo compartment when in motion.</td>
<td></td>
</tr>
<tr>
<td>US Airways</td>
<td>RFI sent.</td>
<td>No response.</td>
</tr>
</tbody>
</table>
8. **Impact on Other Subsystems**

The only subsystem impact external to Integrate and Test is that the **Electronics Subsystem** will now have to supply power conversion from the aircraft power to the power required by the EGSE, liquid chiller, air dehumidifier, and the 28 VDC required by the LAT.

The remaining impacts are internal to the **Integrate and Test** subsystem. The LAT airplane test has an impact on the maximum data rate that the EGSE is required to record. The LAT has already been designed to handle in-orbit cosmic ray rates. Event data is designed to flow from the LAT via a 30 Mbit/sec cable to the satellite’s solid state recorder. For ground testing, the **Flight Software Subsystem** will receive this 30 Mbit/sec cable into a card in a crate external to the LAT. A CPU in this crate may write the events to disk or send them out on an Ethernet cable. Before the LAT airplane test, the EGSE only had to handle the ground cosmic ray rate (~300 Hz for accumulating $10^8$ cosmics for the LAT survey of detector locations). Now, for the “Wide Open Trigger Mode”, the EGSE should be able to record the maximum data rate that the LAT is capable of sending over the 30 Mbit/sec cable. Most of the time during the flight the other trigger modes will be used for which the data rate will be much less.

The EGSE must also be packaged to be mounted and used while in flight on the aircraft. The EGSE will probably be fixed to the outside of the LAT Transport Box.

If there were no SLAC thermal test, there would be an additional impact on the **Integrate and Test** MGSE since the LAT must be operated while inside the Transport Box. However, it is planned to take data while thermal cycling the LAT within the Transport Box at SLAC. Thus, the additional MGSE of the liquid chiller, power penetrations, and data line penetrations of the Transport Box will already have been provided.

An additional effort from **Integrate and Test** will be necessary to analyze the airplane cosmic data and quantify the LAT’s performance at the high cosmic rates.