GLAST Large Area Telescope:

Balloon Flight Results
WBS 4.1.E

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On behalf of
LAT Balloon Flight Team
GSFC, SU-SLAC, SU-HEPL, Hiroshima, NRL, UCSC, Pisa
led by D. Thompson, G. Godfrey, S. Williams
Balloon Flight Results

Outline

- Rationale and Goals
- Preparation
- Balloon Flight and Operations
- Instrument Performance
- Results vs. Simulation
- Conclusions
Rationale: Why a Balloon Flight?

NASA Announcement of Opportunity: "The LAT proposer must also demonstrate by a balloon flight of a representative model of the flight instrument or by some other effective means the ability of the proposed instrument to reject adequately the harsh background of a realistic space environment. ... A software simulation is not deemed adequate for this purpose."

Planning the balloon flight: Identify specific goals that were practical to achieve with limited resources (time, money, and people), using the previously-tested Beam Test Engineering Model (BTEM) as a starting point.

Fig.1: Beam Test Engineering Model ('99) (BTEM), a prototype GLAST/LAT tower. The black box to the right is the anticoincidence detector (ACD), which surrounds the tracker (TKR). The aluminum-covered block in the middle is the calorimeter (CAL). Readout electronics were housed in the crates to the left.
Goals of the Balloon Flight

- Validate the basic LAT design at the single tower level.
- Show the ability to take data in the high isotropic background flux of energetic particles in the balloon environment.
- Record all or partial particle incidences in an unbiased way that can be used as a background event data base.
- Find an efficient data analysis chain that meets the requirement for the future LAT Instrument Operations Center.
Preparation: What Was Needed for this Balloon Flight?

- A detector similar and functionally equivalent to one LAT tower. **BTEM**
- Rework on Tower Electronics Module. **Stanford U**
- Rework on Tracker. **UCSC**
- Rework on Calorimeter. **NRL**
- Rework on ACD. **GSFC**
- External Gamma Target (XGT). **Hiroshima, SLAC**
- On-board software. **SLAC, SU, NRL**
- Pressure vessel to keep ~1 atm air for cooling, high voltage, and hard drives. **SLAC, GSFC**
- Mechanical structure to support the instrument through launch, flight, and recovery. **GSFC, SLAC**
- Power, commanding, and telemetry. **NSBF, SU, SLAC, NRL**
- Real-time commanding and data displays. **SU, SLAC, NRL**
- Data analysis tools. **SLAC, GSFC, UW, Pisa**
- Modeling of the instrument response. **Hiroshima, SLAC, KTH**
Preparation: BFEM Integration

New Cooler

View of XGT

Installing the BFEM in Pressure Vessel
Balloon Flight Operations Team at Palestine, Texas

Balloon Team at Palestine Texas
Flight and Operation: Launch on August 4, 2001

The balloon reached an altitude of 38 km and gave a float time of 3 hours.

First results (real-time data): trigger rate as a function of atmospheric depth. The trigger rate never exceeded 1.5 KHz, well below the BFEM capability of 6 KHz.
Flight and Operation: Onboard DAQ and Ground Electronics Worked

Realtime event display
Instrument Performance: All Subsystems Performed Properly

External Targets (4 plastic scint) to test direction determination and measure interaction rate.

ACD (13 scint. tiles) to detect charged particles and heavy ions (Z>=2).

CAL (CsI logs) To image EM energy deposition.

Tracker (26 layers of SSD) to measure charged tracks 200um and reconstruct gamma ray direction.

4.5 million L1T recorded on-board and 345k events down linked.
Instrument Performance: All Subsystems Performed Properly

Level-1 Trigger Rate (L1T)

<table>
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<tr>
<th></th>
<th>Level Flight Data</th>
<th>Simulation (Geant4)</th>
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<tbody>
<tr>
<td><strong>Cosmic-Ray Fluxes Model</strong></td>
<td></td>
<td>(Cosmic-Ray Fluxes Model)</td>
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<tr>
<td>All</td>
<td>500/sec</td>
<td>504/sec</td>
</tr>
<tr>
<td>“Charged”</td>
<td>444/sec</td>
<td>447/sec</td>
</tr>
<tr>
<td>“Neutral”</td>
<td>56/sec</td>
<td>57/sec</td>
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</table>

Number of Events Recorded

<table>
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<tr>
<th></th>
<th>Events through Downlink</th>
<th>Events in Hard Disk</th>
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</thead>
<tbody>
<tr>
<td>Before Launch</td>
<td>30.5k</td>
<td>-</td>
</tr>
<tr>
<td>Ascending</td>
<td>109k</td>
<td>1.4M</td>
</tr>
<tr>
<td>Level Flight</td>
<td>105k</td>
<td>-</td>
</tr>
</tbody>
</table>
Instrument Performance: ACD Threshold and Efficiency

Anti-Coincidence Detector

Pulse height distr. for stiff charged particles shows clean separation of the peak from noise.

Scinti. Eff. ~ 99.95% or better*

(* One track passed thru the bent part of a tile.)
Instrument Performance: CAL’s Energy Measurement & Imaging

Calorimeter
Pulse height distr. for stiff charged particles shows a single-charge peak and a peak due to alpha particles.

Alpha particles are seen.

Imaging capability demonstrated
Instrument Performance: Tracker & XGT Association

Cosmic ray interaction in 4 External Targets (plastic scintillators)

Gamma ray produced in XGT (20 identified)

Hadrons produced in XGT (416 recorded)
Instrument Performance: Mechanical Stability Demonstrated

Launch

Landing

Recovery

Temperature [°C] and Pressure [psi]

Time [min]
Results: Reconstruction of Events

Charged particle event: The track passes through the ACD (top), the tracker, and the calorimeter. Note: Tracker has no Si strips in the upper right corner.

Gamma-ray event: Two tracks are seen in the tracker and calorimeter. Pattern recognition of an inverted “V” will allow us to selected gamma-rays from cosmic-ray background.

“Interaction” event: Particle and gamma-ray splashes deposit energy in ACD, Tracker, and Calorimeter.
Simulation: Background and Instrument Model

Primary protons passing into the Earth’s magnetic field and secondary protons produced by hadronic int. in the atmosphere

Gammas prod. by cosmic-rays interacting in the atmosphere
Results vs Simulation: Charged Particles Flux & Angular Distribution

Model fluxes and angular distributions: protons, muons, and electrons

Data

\[ \text{Cos}(\text{Theta}) \text{ for protons} \]

Simulation prediction

- Protons
- Muons
- E-/e+
- \( \gamma \)

Cosine of cosmic-ray direction

90 deg.  Downward
Results vs Simulation: “Charged” Particle Distribution

“Charged” particle hit distribution: model fluxes and angular distributions

Data

Simulation prediction

Tracker layer number

Calorimeter side

Top of Tracker

Counts/s

0 5 10 15 20 25
Results vs Simulation: “Neutral” Particle Distribution

“Neutral” particle hit distribution: gammas and under-the-ACD electrons

![Graph showing the comparison between simulation prediction and data for the hit distribution of gammas and under-the-ACD electrons. The x-axis represents the tracker layer number, ranging from 0 to 25, and the y-axis represents the counts per second, ranging from 0 to 60. The graph includes lines indicating simulation prediction and data.]
Conclusions

**Goals of the balloon flight were achieved.**

- BFEM successfully collected data using a simple **three-in-a-row trigger** at a rate that causes little concern when extrapolated to the full flight unit LAT.
- **Mechanical robustness of the Tracker design around Silicon Strip Detectors** has been verified.
- **Power of segmented Calorimeter design** has been demonstrated in identifying gamma rays in charged cosmic ray background.
- **Efficiency of ~99.97% for ACD** is shown to be achievable.
- Through the data analysis, we gained confidence in our ability to **simulate the instrument and the cosmic ray background.**
- Balloon flight offered a first opportunity for the LAT team to go through procedures and to face issues typical to a flight program.
- Lessons learned drawn from BFEM experiences will be fed back to the LAT team.
- The data are being used to try out the **background filter algorithms and reconstruction programs**

**Balloon Experiment has served many purposes and was a success.**