GLAST Large Area Telescope:  
Introduction and Project Overview  
WBS 4.1

Peter F. Michelson  
Department of Physics & SLAC  
Stanford University, Stanford CA  
Principal Investigator & Spokesperson  

peterm@stanford.edu
GLAST Mission

GLAST measures the direction, energy & arrival time of celestial gamma rays

- LAT measures gamma-rays in the energy range ~20 MeV - >300 GeV

- GBM provides correlative observations of transient events in the energy range ~20 keV – 20 MeV
Outline

- Agenda – Day 1
- GLAST Science Opportunities
- GLAST Mission Overview
- Large Area Telescope (LAT) Overview
- LAT Project Organization and Status
- Issues & Summary
## LAT Instrument Team Presentations: Day 1

<table>
<thead>
<tr>
<th>WBS #</th>
<th>Description</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Introduction &amp; Overview</td>
<td>P. Michelson</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Project Organization &amp; Mgt</td>
<td>W. Althouse</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Science Req. &amp; Inst. Design</td>
<td>S. Ritz</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Balloon Flight Results</td>
<td>T. Kamae</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Systems Engineering Overview</td>
<td>T. Thurston</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Performance &amp; Safety Assurance</td>
<td>D. Marsh</td>
</tr>
<tr>
<td>4.1.4</td>
<td>Tracker</td>
<td>R. Johnson</td>
</tr>
<tr>
<td>4.1.5</td>
<td>Calorimeter</td>
<td>N. Johnson</td>
</tr>
<tr>
<td>4.1.6</td>
<td>Anti-Coincidence Detector</td>
<td>D. Thompson</td>
</tr>
<tr>
<td>4.1.7</td>
<td>Electronics &amp; Flight Software</td>
<td>G. Haller / J. J. Russell</td>
</tr>
<tr>
<td>4.1.8</td>
<td>Mechanical Systems</td>
<td>M. Nordby</td>
</tr>
<tr>
<td>4.1.9</td>
<td>Instrument Integration &amp; Testing</td>
<td>E. Bloom</td>
</tr>
<tr>
<td>4.1.B</td>
<td>Instrument Operations Center</td>
<td>S. Williams</td>
</tr>
<tr>
<td>4.1.D</td>
<td>Science Analysis Software</td>
<td>R. Dubois</td>
</tr>
</tbody>
</table>
GLAST Science Opportunities
GLAST Science Opportunities

- Active Galactic Nuclei
- Isotropic Diffuse Background Radiation
- Cosmic Ray Production:
  - Identify sites and mechanisms
- Endpoints of Stellar Evolution
  - Neutron Stars/Pulsars
  - Black Holes
- Unidentified Gamma-ray Sources
- Dark Matter
- Solar Physics
- Gamma-Ray Bursts
- DISCOVERY!
Scientific Heritage: CGRO-EGRET

EGRET All-Sky Map (E > 100MeV)
3rd EGRET Source Catalog

- 271 sources
- 172 sources are unidentified

![Diagram of EGRET Source Catalog with various markers for different types of sources.](image-url)
LAT Source Catalogs

**LAT Catalog:** ~10,000 sources (survey)
GRB, AGN, 3EG + Gal. plane & halo sources

**Catalog strategy**
- precise interstellar emission model
- new statistical analyses including variability and spectral signatures
  ⇒ distinguish unresolved gas clumps
  ⇒ flux histories
- cross references with astronomical catalogs

**Transients or Flares**
- rapid alert for GRBs (~12 s to the ground)
- sky survey data analyzed on a daily basis
- timely IAU circulars and WWW announcements
  ⇒ GRB catalog
GLAST probes the Optical-UV EBL

large effective area, broad energy range

- Important advances made by GLAST:
  1) Detect thousands of blazars; measure spectra of several hundred above 10 GeV: instead of peculiarities of individual sources, look for systematic effects vs. redshift.
  2) key energy range for cosmological distances: (TeV-IR more local due to opacity).
- Effect is dependent on details of EBL model
LAT Science capabilities - resolution

Source identification requires a multiwavelength approach
- localization
- variability

Source localization (68% radius)

\[ \gamma \text{ bursts} \quad 1 \text{ to tens of arcmin} \]

\textbf{Unidentified EGRET sources} 0.3’ to 1’

Evidence for at least 2 unidentified Galactic populations:
- variable Galactic halo population
- persistent Gould Belt population
LAT Science capabilities - resolution

Extended sources spatially & spectrally resolved

**Supernova Remnants** ⇒ cosmic-ray & plerion acceleration

**Interstellar emission** up to TeV, $\Delta E/E \Rightarrow \pi^0$ decay emission
⇒ cosmic-ray propagation pc → kpc

**Nearby galaxies & Galaxy clusters**
⇒ cosmic-ray production & halos
Science capabilities – transient sensitivity

EGRET Fluxes

- GRB940217 (100 sec)
- PKS 1622-287 flare
- 3C279 flare
- Vela Pulsar
- Crab Pulsar
- 3EG 2020+40 (SNR γ Cygni?)
- 3EG 1835+59
- 3C279 lowest 5σ detection
- 3EG 1911-2000 (AGN)
- Mrk 421
- Weakest 5σ EGRET source

all 3EG sources + 80 new in 2 days
~200 γ bursts per year
AGN flares > few min

*zenith-pointed, ^“rocking” all-sky scan

Document: LAT-PR-00403
Section 1.0 Introduction and Overview
Good particle physics candidate for galactic halo dark matter is the LSP in R-parity conserving SUSY.

If true, there may well be observable Galactic halo annihilations.

Example: X is LSP from Standard SUSY: annihilations to jets produce an extra component of multi-GeV $\gamma$ flux that follows halo density peaking at $\sim 0.1 \, M_\chi$ or lines at $M_\chi$. Background is galactic diffuse $\gamma$-rays from CR interaction with gas.

Although calculations for $\gamma$-rays are less uncertain than for other signals (antiprotons, positrons), a null result will not likely constrain SUSY parameter space. If SUSY is discovered at accelerators, GLAST may be able to determine its cosmological significance quickly.

Just an example of what might be waiting for us to find.
GLAST Mission Overview
Gamma-ray Large Area Space Telescope

GLAST Mission
- high-energy gamma-ray observatory; 2 instruments
  - Large Area Telescope (LAT)
  - Gamma-ray Burst Monitor (GBM)
- launch (Sept 2005): Delta 2 class
- orbit: 550 km, 28.5° inclination
- mission operations
- science
  - LAT Collaboration
  - GBM Collaboration
  - Guest Observers
- lifetime: 5 years (minimum)

GLAST Observatory
- spacecraft
- LAT
- GBM

Mission Ops Center
- Observatory safety
- Spacecraft health
- Commanding
- Mission scheduling
- Level 0 processing
- GBM data handling

Science Support Center
- Science scheduling
- Archiving
- Guest Observer Support
- Standard product processing

GBM Inst. Ops. Center
- Instrument performance
- Standard product processing

LAT Inst. Ops. Center
- LAT data handling
- Instrument performance
- Level 1 data processing; selected higher level processing
- Support LAT Collaboration Science Investigation

Gamma-ray Large Area Space Telescope

Document: LAT-PR-00403 Section 1.0 Introduction and Overview 16
GLAST Mission Overview

GLAST Mission

- Mission Management (NASA) 1.0
- Science 3.0
- Spacecraft 5.0
- Launch Vehicle 7.0
- Education & Public Outreach 9.0

- Mission Systems Engineering 2.0
- Instruments 4.0
- Mission Support I&T 6.0
- Mission Operations 8.0

- LAT Instrument Project .1
- GBM Instrument Project .2
<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992 – 1996</td>
<td>Various funding sources including DOE and NASA to Stanford-SLAC collaboration (including SLAC, NRL, GSFC, Internationals) to study instrument concept and technologies.</td>
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</tbody>
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| 1997 | Mission endorsed by NASA Space Science Advisory Committee and highest priority of SEU Subcommittee.  
Presented to HEPAP, Jan 1997  
NASA HQ requests GSFC to lead an effort better defining GLAST Mission in terms of technical requirements, scope, and cost. |
| 1998 | NASA Research Announcement (NRA) issued 1/98 for GLAST instrument technology development; two (2) instrument teams selected and under contract.  
Submitted proposal for LAT Investigation to DOE, February; reviewed by SAGENAP - April  
Mission Concept Review - September. |
| 2000 | LAT selected – February |
### Project History (2 of 2)

<table>
<thead>
<tr>
<th>2000: (continued)</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Selection of GBM, Dr. Charles Meegan, MSFC, P.I. - March.</td>
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<td>GLAST Mission Independent Assessment - April thru October</td>
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<td>Spacecraft Accommodation Studies with Lockheed Martin, TRW, and Orbital Sciences Corp. - May thru August.</td>
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<td><strong>NRC Decadal Astronomy &amp; Astrophysics Review ranks GLAST highest priority “moderate size” space mission for next decade</strong> - September.</td>
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<td>System Requirements Review (SRR) for Mission and LAT - September 27 &amp; 28.</td>
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<td>Verbal agreement with ASI for use of Malindi ground station.</td>
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<td>2001:</td>
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<td></td>
<td>Began second spacecraft studies with LM and TRW – April; Spectrum Astro joined study – August</td>
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<td></td>
<td>LAT Collaboration Meeting at Stanford University - August</td>
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<td><strong>LAT Balloon Flight successful</strong> - August.</td>
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</table>
GLAST scheduled for launch in March 2006
Large Area Telescope (LAT) Overview
GLAST LAT Overview: Performance

Instrument performance meets or exceeds all requirements in 433-SRD-0001

- Single Photon Angular Resolution
  - $3.5^\circ$ @ 100 MeV
  - $0.15^\circ$ @ 10 GeV

- Point Source Sensitivity:
  - $< 6 \times 10^{-9}$ ph cm$^{-2}$s$^{-1}$
  - (est. performance: $< 3 \times 10^{-9}$ ph cm$^{-2}$s$^{-1}$)

  **40 times EGRET’s sensitivity**

- Source Localization:
  - $0.3^\prime$ – $1^\prime$ (unid EGRET)

- Wide Energy Range: 20 MeV - >300 GeV

- Wide Field of View
  - (> 2 sr)

- Local dead time:
  - $< 100 \mu$s/event

- Large Effective Area
  - $(A_{\text{eff}})_{\text{peak}} > 8,000$ cm$^2$

- Good Energy Resolution
  - $\Delta E/E \sim 10\%$; 100 MeV – 10 GeV
  - $\sim < 20\%$; 10 GeV – 300 GeV
GLAST LAT Overview: Design

**Si Tracker**
- Pitch = 228 µm
- 8.8 $10^5$ channels
- 12 layers × 2.8% $X_0$
- + 4 layers × 18% $X_0$
- + 2 layers

**CsI Calorimeter**
- Hodoscopic array
- 8.4 $X_0$, 8 × 12 bars
- 2.0 × 2.7 × 33.6 cm
- ⇒ cosmic-ray rejection
- ⇒ shower leakage correction

**Grid (}& Thermal Radiators)**
- 3000 kg, 650 W (allocation)
- 1.8 m × 1.8 m × 1.0 m
- 20 MeV – 300 GeV

**ACD**
- Segmented scintillator tiles
- 0.9997 efficiency
- ⇒ minimize self-veto

**Data Acquisition**
- Flight Hardware & Spares
  - 16 Tracker Flight Modules + 2 spares
  - 16 Calorimeter Modules + 2 spares
  - 1 Flight Anticoincidence Detector
  - Data Acquisition Electronics + Flight Software
Summary of Key Developments that enable the LAT

- **Tracker**
  - Low-power front-end electronics (500 µW/ch -> <200 µW/ch)
  - High reliability SSDs (~0.01% bad channels)
  - Cost reduction of SSDs (~$200/cm² (1980’s) -> ~$7/cm²)
  - Carbon fiber technology: mechanical strength, thermal conduction

- **ACD**
  - Wavelength shifting fiber readout (Fermilab development)

- **Calorimeter**
  - Carbon fiber technology
  - Reliable mounting of PIN diodes to CsI xtals

- **Analysis/Design**
  - Reliable, verified instrument simulation programs (C++, OO technology)
LAT Project Organization and Status
Relations between LAT Organizations

- MoAs between Stanford University-SLAC and collaborating institution regarding participation in LAT Project
  - Ratify flight proposal and define technical role
  - Establish management policies and areas of responsibility
  - Establish responsibilities & membership of collaboration committees
  - Identify Key Personnel
  - Includes: Statement of Work, general conditions concerning cross-waiver of liability, data & intellectual property, international exchange of information & materials
- Signatories:
  - Stanford University: PI & SLAC Director;
  - collaborating institutions: responsible institutional management authorities, lead scientist(s), subsystem manager
## Status of LAT Cost Estimate

- At 8/14/01 LAT Quarterly Review, identified total estimated LAT pre-launch cost and funding profile (FY 02/03) as issues
- With subsystem managers, developed plan to mitigate cost issues
  - status of cost estimate updated and cost reduction options identified and prioritized (based on risk)
  - No science de-scope necessary

<table>
<thead>
<tr>
<th></th>
<th>8/14/01</th>
<th>12/18/01</th>
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<tbody>
<tr>
<td>Estimated DOE/NASA Project Cost (escalated $M, no contingency)</td>
<td>100.2</td>
<td>94.4</td>
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<tr>
<td>Pre-launch Project Funding ($ M) TOTAL</td>
<td>116.1</td>
<td>115.8</td>
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<tr>
<td>Contingency</td>
<td>$16.0 M</td>
<td>$21.4 M</td>
</tr>
<tr>
<td></td>
<td>20%*</td>
<td>28%*</td>
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* Note: contingency calculation excludes FY00/01 cost (incurred), E/PO and Japanese “loan”
### Status of Agreements concerning LAT

<table>
<thead>
<tr>
<th>Agreement</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Energy – NASA</td>
<td>pending signature</td>
</tr>
<tr>
<td>NASA – CNES Agreement</td>
<td>pending, draft exists; requires NASA/DOE Agreement</td>
</tr>
<tr>
<td>NASA – ASI Agreement</td>
<td>pending, draft exists; requires NASA/DOE Agreement</td>
</tr>
<tr>
<td>NASA – Japan</td>
<td>draft in process</td>
</tr>
<tr>
<td>NASA – Sweden</td>
<td>draft in process</td>
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</tbody>
</table>
## Status of LAT MoAs

<table>
<thead>
<tr>
<th>MoAs between SU-SLAC and:</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC/LHEA</td>
<td>√ signed</td>
</tr>
<tr>
<td>NRL</td>
<td>Requires IPO action</td>
</tr>
<tr>
<td>UCSC/SCIPP</td>
<td>√ signed</td>
</tr>
<tr>
<td>U Wash</td>
<td>√ signed</td>
</tr>
<tr>
<td>Royal Inst. Of Technology &amp; Stockholm Univ., Sweden; NRL</td>
<td>√ signed</td>
</tr>
<tr>
<td>Hiroshima Univ., ISAS &amp; RIKEN, Japan; UCSC/SCIPP</td>
<td>√ signed</td>
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</tbody>
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Status of LAT MoAs

- **CEA/DAPNIA & IN2P3, France; NRL** Pending NASA/CNES LoA
  - Draft MoA exists and LAT-internal issues resolved;
  - MoA requires NASA-CNES LoA;
  - CNES review: took place on November 6; raised management issues concerning division of responsibilities for work in France;
  - LAT IPO worked with CNES, IN2P3, and CEA/DAPNIA management to resolve issues. French hardware contributions managed under 2 labs:
    - CEA/DAPNIA: Crystal Detector Elements (CDEs)
    - IN2P3/Ecole Polytechnique: mechanical structure;
    - CAL I&T now entirely in U.S. with participation from collaborating entities;

- **INFN, ASI, Italy** Pending final approval from ASI
  - MoA reviewed and approved by joint INFN-ASI committee on Nov 23;
  - Presented at December INFN Council meeting; will be signed by INFN President;
  - ASI Scientific Director forwarding MoA to President for final ASI approval
Issues & Summary
Key International Agreements and MoAs with Foreign Partners not yet completed

- But, technical work is proceeding according to current plan
- Signing of DOE–NASA Implementing Agreement should clear way for NASA Headquarters to place high priority on finalizing and signing of International Agreements with CNES and ASI
Summary

- GLAST Science Opportunities
  - Science is exciting!
  - LAT Collaboration meeting at SU (Aug 1-2, 2001), attended by more than 100 collaboration members, began science planning to achieve/enhance science objectives of GLAST; next collaboration meeting planned for Spring 2002

- Large Area Telescope (LAT)
  - Instrument based on proven technologies – design and technology under development since 1992
  - Technical performance of instrument design concept successfully demonstrated with balloon flight – August 2001

- LAT Project Organization and Status
  - LAT team has evolved from a collection of scientists with a common interest (1992) to an organized project team (now)