GLAST
Progress and Plans as of March 2003

Jonathan Ormes, Project Scientist,
on behalf of the GLAST team
and the Large Area Telescope Collaboration

Presented at the High Energy Astrophysics Divisional Meeting
Mt. Tremblant, March 23-25, 2330
GLAST is an International Mission

NASA - DoE Partnership on LAT
LAT is being built by an international team
  Si Tracker: Stanford, UCSC, Japan, Italy
  CsI Calorimeter: NRL, France, Sweden
  Anticoincidence: GSFC
  Data Acquisition System: Stanford, NRL
GBM is being built by US and Germany
  Detectors: MPE

Sweden  Italy  France  USA  Japan

Germany
Mission Objectives

- Understand the mechanisms of particle acceleration in astrophysical environments such as active galactic nuclei, pulsars and supernova remnants
- Determine the high energy behavior of gamma-ray bursts and other transients
- Resolve and identify point sources with known objects
- Probe dark matter and the extra-galactic background light in the early universe
Large Area Telescope (LAT)
PI: Peter Michelson
Stanford University

GLAST Burst Monitor (GBM)
PI: Charles Meegan
Marshall Space Flight Center

Photon Direction:
Si SSD Tracker

Background rejection:
Anti-coincidence Detectors

Energy:
Calorimeter

1.8 m
GLAST Burst Monitoring

- LAT and GBM work synergistically to make new GRB observations

- GBM provides low-energy context measurements with high time resolution
  - Broad-band spectral sensitivity
  - Contemporaneous low-energy & high-energy measurements
  - Continuity with current GRB knowledge-base (GRO-BATSE)

- Provides rapid GRB timing & location triggers w/FoV > LAT FoV
  - Improved sensitivity and response time for weak bursts
  - Follow particularly interesting bursts for afterglow observations
  - Provide rapid locations for ground/space follow-up
# GBM Capabilities

<table>
<thead>
<tr>
<th></th>
<th>BATSE</th>
<th>GBM - Requirement</th>
<th>GBM - Current Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field of View</strong></td>
<td>All sky not occulted by Earth</td>
<td>&gt;8 sr</td>
<td>8.7 sr</td>
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<tr>
<td><strong>Energy Resolution</strong></td>
<td>&lt;10%</td>
<td>&lt;10% (0.1-1.0 MeV, 1% on-axis)</td>
<td>7% (100 keV) 5% (1 MeV)</td>
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<td>&lt; 10 ms/event</td>
<td>2.5 ms/event</td>
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<td><strong>Burst Sensitivity - Ground (5%, 50-300 keV)</strong></td>
<td>0.2 cm$^{-2}$ s$^{-1}$</td>
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<tr>
<td><strong>Burst Sensitivity - On-board (5%, 50-300 keV, 50% efficiency)</strong></td>
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<td>&lt;1.0 cm$^{-2}$ s$^{-1}$</td>
<td>0.78 cm$^{-2}$ s$^{-1}$</td>
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<td><strong>GRB Alert Location</strong></td>
<td>~25°</td>
<td>-</td>
<td>&lt;15°</td>
</tr>
<tr>
<td><strong>GRB Final Location</strong></td>
<td>1.7°</td>
<td>-</td>
<td>&lt;1.5°</td>
</tr>
<tr>
<td><strong>GRB Notification Time to Spacecraft</strong></td>
<td></td>
<td>&lt;2s</td>
<td>2s (arbitrarily selectable, trade-off between speed &amp; accuracy)</td>
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Burst Alerts

GBM
- Trigger
- Quick Test?
- Classification, Location, Hardness, Initial Flux
- Flux, Fluence, Hardness (Running Updates)
- Parameters
- Science Repoint Candidate

S/C
- Begin R/T downlink
- Continue R/T, 5 - 10 min.
- parameters

LAT
- Mode Change ?
- LAT information + GBM Information Packet
- Repoint request
- S/C Repoint Decision

Parameters
Mission Repointing Plan for Bursts

Summary of plan
- Detection a sufficiently significant burst
- Interrupt the scanning operation
- Remain pointed at the burst region for 5 hours (TBR).

There are two cases:

1. **The burst occurs within the LAT FOV.**
   - For moderately bright bursts.
   - Set threshold to occur approximately once per week.

2. **The burst occurs outside the LAT FOV.**
   - For exceptionally bright bursts.
   - Set threshold to occur a few times per year.

Reevaluate strategy based on what has been learned about delayed high-energy emissions.
- the brightness criterion
- the stare time
**Tracker: 18 xy planes**

- **Si-strips**: fine pitch: 228 µm, high efficiency
  - 12 x 0.03 $X_0$ front-end □ reduce multiple scattering
  - 4 x 0.18 $X_0$ back-end □ increase sensitivity > 1 GeV
  - 2 blank planes to locate calorimeter entry location

**Calorimeter: 1536 CsI(Tl) crystals in 8 layers**

- **CsI**: wide energy range 0.1-100 GeV
  - hodoscopic □ cosmic-ray rejection
  - □ shower leakage correction
  - 8.5 $X_0$ □ shower max contained < 100 GeV

**Anti-Coincidence Detector**

- segmented [89 tiles] plastic scintillator
  - □ minimize self-veto
  - > 0.9997 efficiency & redundant readout

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**LAT Instrument**

16 [4x4] towers □ modularity
- height/width = 0.4
- □ large field-of-view

TKR
ACD
1.8 m

CAL
<table>
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<tr>
<th>Lat Capabilities</th>
<th>EGRET</th>
<th>LAT - Requirement</th>
<th>LAT - Current Design</th>
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<tr>
<td>Energy Resolution</td>
<td>10 %</td>
<td>&lt;10%, 0.1–100 GeV (1σ, on-axis)</td>
<td>~9%, 0.1–100 GeV</td>
</tr>
<tr>
<td>Effective Area</td>
<td>1500 cm²</td>
<td>&gt;8000 cm² (maximum value, 1-10GeV)</td>
<td>10,000 cm² at 10 GeV</td>
</tr>
<tr>
<td>Point Source Sensitivity (5σ, &gt;100 MeV)</td>
<td>~1 ¥ 10^-7 cm² s⁻¹</td>
<td>&lt;6 ¥ 10^-9 cm² s⁻² (at high gal. latitude for 1-year sky survy, for photon index of -2)</td>
<td>3 ¥ 10^-9 cm² s⁻²</td>
</tr>
<tr>
<td>Angular Resolution</td>
<td>5.8° (100 MeV)</td>
<td>&lt;3.5° (100 MeV)</td>
<td>3.4° (100 MeV)</td>
</tr>
<tr>
<td>Source Location Determination</td>
<td>15 arcmin</td>
<td>&lt;0.5 arcmin (1σ radius, flux 10^-7 cm⁻² s⁻¹ at 100 MeV, high gal latitude)</td>
<td>0.4 arcmin</td>
</tr>
<tr>
<td>Field-of-view</td>
<td>0.5 sr</td>
<td>&gt;2 sr</td>
<td>2.4 sr</td>
</tr>
<tr>
<td>Timing Accuracy</td>
<td>100 ms</td>
<td>&lt;10 ms</td>
<td>TBD</td>
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<tr>
<td>Deadtime</td>
<td>100 ms/event</td>
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<tr>
<td>GRB Location Accuracy On-Board</td>
<td>&lt;10 arcmin</td>
<td>5 arcmin</td>
<td></td>
</tr>
<tr>
<td>GRB Notification Time to Spacecraft</td>
<td>&lt;5 s</td>
<td>TBD</td>
<td></td>
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</table>
200 \( \square \) bursts per year
- prompt emission sampled to > 20 \( \mu \)s

AGN flares > 2 month
- time profile + \( \square \)E/E \( \square \) physics of jets and acceleration

\( \square \) bursts delayed emission

all 3EG sources + 80 new in 2 days
- periodicity searches (pulsars & X-ray binaries)
- pulsar beam & emission vs. luminosity, age, B

\( 10^4 \) sources in 1-yr survey
- AGN: logN-logS, duty cycle, emission vs. type, redshift, aspect angle
- extragalactic background light (\( \square \) + IR-opt)
- new \( \square \) sources (\( \mu \)QSO, external galaxies, clusters)

LAT 1yr 2.3 \( 10^{-9} \) cm\(^2\) s\(^{-1}\)
GLAST

Science Topics

• Active Galactic Nuclei
• Isotropic Diffuse Background Radiation
• Cosmic Ray Production:
  – Molecular Clouds
  – Supernova Remnants
  – Normal Galaxies
• Endpoints of Stellar Evolution
  – Neutron Stars/Pulsars
  – Black Holes
• Unidentified Gamma-ray Sources
• Dark Matter
• Solar Physics
• Gamma-Ray Bursts
From EGRET to GLAST

- ○ = EGRET blazars seen sometimes
- ● = EGRET blazars seen always
- ✶ = EGRET unidentified high-latitude variables
- □ = Simulated GLAST 20✓ AGN detections
• EGRET detected ~ 70-90 AGN. Extrapolating, GLAST should expect to see dramatically more — many thousands.

• The GLAST energy range is broad, overlapping those of ground-based experiments for good multiwavelength coverage.

• The wide field of view will allow GLAST to monitor AGN for time variability on many scales.

Joining the unique capabilities of GLAST with other detectors will provide a powerful tool.
• GLAST combined with TeV observatories will probe the complex spectra of blazars
For SNR candidates, the LAT sensitivity and resolution will allow mapping to separate extended emission from the SNR from possible pulsar components.

Energy spectra for the two emission components may also differ.

Resolved images will allow observations at other wavelengths to concentrate on promising directions.

(a) Observed (EGRET) and (b) simulated LAT (1-yr sky survey) intensity in the vicinity of _-Cygni for energies >1 GeV. The coordinates and scale are the same as in the images of _-Cygni in the box at left. The dashed circle indicates the radio position of the shell and the asterisk the pulsar candidate proposed by Brazier et al. (1996).
EGRET to GLAST: galactic diffuse gamma rays
Searching for dark matter

- The lightest super-symmetric particle is a leading candidate for non-baryonic CDM
- It is neutral (hence neutralino) and stable if R-parity is not violated
- It self-annihilates in two ways:
  - $\bar{c}c \rightarrow \bar{q}q$ where $E_{\gamma} = M_{\bar{c}} c^2$
  - $\bar{c}c \rightarrow \bar{q}q$ where $E_{\gamma} = M_{\bar{c}} c^2 (1 - M_Z^2 / 4 M_{\bar{c}}^2)$
- Gamma-ray lines possible
  - 30 GeV - 10 TeV

![Diagram showing gamma-ray lines](image)
Mission Requirements and Observing Plan

• **Spacecraft**
  - Pointing knowledge $< 10$ arcseconds (1 $\square$)
  - Observatory is designed to “point anywhere, anytime”
    • Operate without pointing at the Earth
    • Reorient quickly and autonomously to follow a transient
  - 3 normal operational modes
    • Scan (baseline)
    • Inertial pointing
    • Scan pointing - takes advantage of the wide field of view to optimize time on sky

• **Mission Lifetime 5 years, Goal 10 years**
  - Observatory checkout 30-60 days
  - First year is scanning to make all sky survey
    • Planned observations subject to interruption for extraordinary transients
  - Second year and beyond - operational mode driven by competitive proposals
GLAST Project Master Schedule

- Instrument preliminary Design Reviews completed
- Spacecraft contractor selected: Spectrum-Astro
  - S/C PDR March 2003
  - S/C CDR fall 2003
- Critical Design Reviews for instruments will be April or May this year
- Instrument deliveries in 2005
  - GBM spring
  - LAT summer
- Launch in 2006
  - September ("God willin’ and the creek don’t rise.")
Guest Investigator Program

• GI program starts during the survey
  – 10-15 GIs
• Will grow to ~100 Guest Investigations funded by NASA each year.
• GLAST Fellows program

• Continue Interdisciplinary Scientist (IDS) Program
  C. Dermer (NRL) - non-thermal universe
  B. Dingus (Wisconsin) - transients
  M. Pohl (Ruhr U.) - diffuse galactic
  S. Thorsett (UCSC) - pulsars

• Program of Education and Public Outreach continues throughout the mission
Transient policy

- The GLAST instrument teams have the duty to release data on transient gamma ray sources to the community as soon as practical. The decisions on which data are to be released will be based on advice from scientists analyzing the data and an evaluation of the scientific interest that the data might generate. They will follow the general guidelines suggested below:

  1) Gamma-ray bursts: All data on gamma-ray bursts that trigger either the LAT or GBM will be released. The prompt data release will include direction, fluence estimate and other key information about the burst immediately on discovery. Individual photon data and technical information for their analysis will be released as soon as practical.

  2) Blazars and some other sources of high interest: 10-20 pre-selected sources from the 3rd EGRET catalog will be monitored continuously and the fluxes and spectral characteristics will be posted on a publicly accessible web site. Another 10-20 scientifically interesting sources will be added to this list during the survey. The list will include some known or newly discovered AGN selected to be of special interest by the TeV and other communities as well as galactic sources of special interest discovered during the survey.

  3) New transients: The community will be notified when a newly discovered source goes above an adjustable flux level of about \((2-5) \times 10^{-6}\) photons \((> 100\, \text{MeV})\) per cm\(^2\) s for the first time; the flux level is to be adjusted to set the release rate to about 1-2 per week. A source exhibiting unusual behavior that is detectable on sub-day timescales, such as a spectral state change or a large flux derivative while the source is at elevated flux levels, will also trigger an alert to the community.
Multi-wavelength campaigns

- Science requires broad band (radio to gamma-rays) study of these celestial sources. Therefore, following the survey, the observing program will be determined entirely by the astronomical and high energy physics communities based on proposals submitted.
  - LAT and GBM team members can compete, but cannot win additional funding.
  - Non-US investigators may apply
  - Selection is based on peer reviewed proposals.

- The community will interface to the GLAST data through the GLAST Science Support Center.
  - SSC mirror sites in Italy (LAT and GBM may have others)
Gamma-ray science requires multi-wavelength approach

In the MeV range and above, sources are non-thermal
produced by interactions of energetic particles

- Nature rarely produces mono-energetic particle beams. Broad range of particle energies leads to a broad range of photon energies.
  - Example: $\gamma$ production
- Charged particles rarely interact by only one process. Different processes radiate in different energy bands.
  - Example: synchrotron-Compton processes
- High-energy particles, as they lose energy, can radiate in lower-energy bands.
  - Contrast: non-thermal X-ray source can have high-energy cutoff

Due to variability on short time scales, AGN require simultaneous multiwavelength observations for maximum scientific return.

For other science, the time scale for variability is long (e.g. SNR, plereons); therefore simultaneity is not critical for multiwavelength observations.

For transients or other variable unidentified gamma-ray sources, having simultaneous observations may be the only viable means of positive identification.
Data release policies

- All-sky survey during the first year.
  - LAT team to produce a point source catalog and an all sky map; formal release 90 days following completion of the survey.
- Transient source locations are made public immediately with photon data (light curves, improved positions, etc.) to follow as practical.
  - During first year photon data to include warning that the data may be unverified and uncalibrated
  - Best efforts to release preliminary catalogs in time for AOs
    - The first 3 months of observations will be delivered at 6 months
    - The full 12 months of observations will be delivered 1 month after the end of the sky survey
- Guest investigators may propose for source studies, associated theory or key projects
  - Data from these sources of interest are made available immediately to the GIs.
- Following the survey, it is being proposed that all GLAST data will be made public immediately.
  - Comments on this policy may be sent to Jonathan.F.Ormes@nasa.gov or Donald.A.Kniffen@nasa.gov
  - We plan to conduct workshops on how to propose for and how to the use the tools to analyze the GLAST data
The LAT FOV is huge:

For the purposes of setting slew requirements define

- **LAT FOV**: anything within ±55° (0.96 radian) (TBR) of normal incidence is within the LAT FOV.
- **“Pointing”**: the target is within ±30° (0.52 radian) (TBR) of normal incidence. Individual targets may have a different criterion, depending on their characteristics.

What does “pointing” mean?

\[
FOM = \frac{\sqrt{A_{\text{eff}}}}{\theta_{\text{in}}}\]

PSF also degrades off axis.
Earth Avoidance for Pointed Observations

Before Occultation
- Earth’s disk is approaching from the left
- FOV is losing inertial target

After Occultation
- Earth’s disk is receding to the right
- FOV is picking up inertial target
Scan Pointed Observations

One day observation trade 20% exposure on source for sky coverage
GLAST Mission Overview

GLAST Science
- Study Cosmos in Energy Range from 10 keV-300 GeV
- Factor of 40 More Sensitivity
- Full Sky Coverage in 3 Hours
- Gamma-Ray Burst Alerts

GPS Signals Provide
- Time 10 µsec
- Position <3.3 km

Commands 2 kbps
Telemetry 32 kbps
2.5 Mbps

Alert Messages 1 kbps

Telemetry 1 kbps

X-Band
- Science Data
- 10 Mbps

S-Band
- Commands 4 kbps
- SW Uploads 4 kbps
- TOO 250 bps

Mission Operations Center
Science Support Center
LAT Instrument Operations Center
Archive
HEASARC

GRB Coordinates Network
Data, Command Loads
Schedules

Alerts

Data, Command Loads
Schedules

GBM Instrument Operations Center