GLAST
Mission Formulation

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GLAST Users Group
GSFC, October 22, 2003
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
GLAST: DOE and NASA Partnership

Department of Energy
Office of Science

Understand the nature of matter at the most fundamental level and to explore the evolution and fate of the universe through fundamental interactions of energy, matter, time and space.

NASA - Office of Space Science

Chart the evolution of the universe, from origins to destiny

1. Understand the structure of the universe
2. Explore the ultimate limits of gravity and energy in the universe
3. Learn how galaxies, stars and planets form, interact and evolve

Gamma ray Large Area Space Telescope (GLAST)

An astro-particle physics partnership to explore the high-energy universe

Particle physics

Astronomy/astrophysics
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
- Germany
- USA
- Japan
GLAST Project Organization

Mission Formulation

Original signed

Kevin Grady
GLAST Project Manager

September 9, 2003

Users 2003, October 22
Science Requirements

- **High Energy Gamma Rays: 20 MeV - > 300 GeV**
  - Source location <0.5 arcmin
    - High latitude source of $10^{-7}$ cm$^{-2}$ s$^{-1}$ flux, E$^{-2}$ spectrum,
      - 1 $\sigma$ radius, after 1 yr survey
  - Point source sensitivity < $6 \times 10^{-9}$ cm$^{-2}$ s$^{-1}$
    - High latitude source after 1 yr survey, 5 $\sigma$ detection
  - Background to be < 10% of extragalactic high latitude diffuse emission

- **Conduct broad band study of gamma ray bursts**
  - Determine burst spectra from <10 keV to ~30 GeV
  - Determine burst locations <15 degrees and send to the GRB notification network (GCN) within 7 seconds
Mission Requirements and Observing Plan

• **Spacecraft**
  – Pointing knowledge < 10 arcseconds (1σ)
  – Observatory is designed to “point anywhere, anytime”
    • Operate without pointing at the Earth
    • Reorient quickly and autonomously to follow a transient or respond to a target of opportunity
      – Slew 75 degrees in 10 minutes
  – 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 (subject to Senior Review)**
  – 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
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 (Los Alamos) - transients
  - M. Pohl (Iowa State U.) - diffuse galactic
  - S. Thorsett (UCSC) - pulsars

- Program of Education and Public Outreach continues throughout the mission
• Selected as mission concept study, 1994 (PI: Michelson, Stanford)

• Endorsed by Gamma-Ray Astronomy Program Working Group as highest priority in gamma-ray astronomy, 1996

• Chosen as top priority (with Constellation-X) by Structure and Evolution of the Universe Subcommittee, 1997

• Reviewed by SAGENAP, presented to HEPAP, and approved by DoE, 1998

• **Science Requirements Document**, drafted by Facility Science Team, signed in July 1999.


• **GLAST is the highest-ranked Moderate Size space-based initiative in the National Academy of Sciences 2000 Decadal Survey Report.**
GLAST Instruments

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
### Large Area Telescope Parameters

<table>
<thead>
<tr>
<th></th>
<th>CGRO/EGRET</th>
<th>GLAST/LAT</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Range</td>
<td>20 MeV - 30 GeV</td>
<td>20 MeV - &gt; 300 GeV</td>
<td>10 to 300 GeV</td>
</tr>
<tr>
<td>Energy Resolution (ΔE/E)</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Effective Area (1GeV)</td>
<td>1500 cm²</td>
<td>10,000 cm²</td>
<td>6.6</td>
</tr>
<tr>
<td>Field of View</td>
<td>0.5 sr</td>
<td>2.4 sr</td>
<td></td>
</tr>
<tr>
<td>Angular Resolution</td>
<td>5.8° @ 100 MeV</td>
<td>~ 3.5° @ 100 MeV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5° @ 10 GeV</td>
<td>~ 0.1° @ 10 GeV</td>
<td>Area = 1/2.7</td>
</tr>
<tr>
<td>Sensitivity (&gt; 100 MeV)*</td>
<td>~ 10⁻⁷ cm⁻² s⁻¹</td>
<td>~ 3 × 10⁻⁹ cm⁻² s⁻¹</td>
<td>Area = 1/25</td>
</tr>
<tr>
<td>Deadtime</td>
<td>100 ms</td>
<td>&lt;10 µs</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>1810 kg</td>
<td>3000 kg</td>
<td></td>
</tr>
</tbody>
</table>

* 1 year survey at high latitudes

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**Increased area, field of view, angular resolution, extended energy range and operational efficiency provide a powerful combination!**
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
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 (>100 MeV)

- Map the gamma-ray sky with sensitivity > 30 times that of EGRET without becoming source confusion limited.

Total Mission All-Sky Map (E > 100 MeV)

Virgo region
GLAST Project Master Schedule

- Instrument preliminary Design Reviews completed
- Spacecraft contractor selected: Spectrum-Astro
  - S/C PDR May 2003
- Critical Design Reviews for instruments
  - Held LAT May 2003
  - GBM June 2004
- CDR for Spacecraft scheduled for spring 2004
- Instrument deliveries in 2005
  - GBM fall
  - LAT December
- Launch in Feb 2007
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
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

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**GPS Signals**
- Time: 10 µsec
- Position: <3.3 km

**Commands**
- 2 kbps
- Telemetry: 32 kbps, 2.5 Mbps

**Telemetry**
- 1 kbps
- Alert Messages: 1 kbps

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**Data, Command Loads**
- Schedules

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**Mission Operations Center**

**Science Support Center**

**GBM Instrument Operations Center**

**LAT Instrument Operations Center**

**Archive**

**HEASARC**

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**GRB Coordinates Network**

**TDRSS (SN)**

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

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**DELTA 2920H-10**

**Malindi (GN)**

**Hawaii-USN(GN)**

**White Sands (SN)**

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**X-Band**
- Science Data
- 10 Mbps

**X-Band**
- Science Data
- 10 Mbps

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**Malindi**

**Hawaii-USN(GN)**

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**Heavenly Simulator**

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**Users 2003, October 22**
Summary of Capabilities

- Huge FOV (20% of sky) allows primarily scanning operations
- Opens unexplored region > 10 GeV
- Unprecedented PSF for gamma rays (factor 5 better than EGRET at 10 GeV)
- Expect to find new classes of gamma-ray sources with the improved sensitivity
- No expendables and potential for long mission without degradation
- Large sensitive area (> 6x EGRET) for transients
- Quick reaction to gamma-ray bursts and other transients
## GBM Capabilities

<table>
<thead>
<tr>
<th></th>
<th>BATSE</th>
<th>GBM - Requirement</th>
<th>GBM - Current Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>All sky not occulted by Earth</td>
<td>&gt;8 sr</td>
<td>8.7 sr</td>
</tr>
<tr>
<td>Energy Resolution</td>
<td>&lt;10%</td>
<td>&lt;10% (0.1-1.0 MeV, 1σ on-axis)</td>
<td>7% (100 keV) 5% (1 MeV)</td>
</tr>
<tr>
<td>Deadtime</td>
<td></td>
<td>&lt; 10 μs/event</td>
<td>2.5 μs/event</td>
</tr>
<tr>
<td>Burst Sensitivity - Ground (5σ, 50-300 keV)</td>
<td>0.2 cm^{-2} s^{-1}</td>
<td>&lt;0.5 cm^{-2} s^{-1}</td>
<td>0.45 cm^{-2} s^{-1}</td>
</tr>
<tr>
<td>Burst Sensitivity - On-board (5σ, 50-300 keV, 50% efficiency)</td>
<td></td>
<td>&lt;1.0 cm^{-2} s^{-1}</td>
<td>0.78 cm^{-2} s^{-1}</td>
</tr>
<tr>
<td>GRB Alert Location</td>
<td>~25°</td>
<td>-</td>
<td>&lt;15°</td>
</tr>
<tr>
<td>GRB Final Location</td>
<td>1.7°</td>
<td>-</td>
<td>&lt;1.5°</td>
</tr>
<tr>
<td>GRB Notification Time to Spacecraft</td>
<td>&lt;2s</td>
<td>2s (arbitrarily selectable, trade-off between speed &amp; accuracy)</td>
<td></td>
</tr>
</tbody>
</table>
## LAT Capabilities

<table>
<thead>
<tr>
<th></th>
<th>EGRET</th>
<th>LAT - Requirement</th>
<th>LAT - Current Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Resolution</strong></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><strong>Effective Area</strong></td>
<td>1500 cm²</td>
<td>&gt;8000 cm² (maximum value, 1-10 GeV)</td>
<td>10,000 cm² at 10 GeV</td>
</tr>
<tr>
<td><strong>Point Source Sensitivity</strong></td>
<td>~1 x 10⁻⁷ cm² s⁻³</td>
<td>&lt;6 x 10⁻⁹ cm² s⁻² (at high gal. latitude for 1-year sky survey, for photon index of &lt;2)</td>
<td>3 x 10⁻⁹ cm² s⁻²</td>
</tr>
<tr>
<td><strong>Angular Resolution</strong></td>
<td>5.8° (100 MeV)</td>
<td>&lt;3.5° (100 MeV)</td>
<td>3.4° (100 MeV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;0.15° (&gt;10 GeV)</td>
<td>0.086° (&gt;10 GeV)</td>
</tr>
<tr>
<td><strong>Source Location Determination</strong></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><strong>Field-of-view</strong></td>
<td>0.5 sr</td>
<td>&gt;2 sr</td>
<td>2.4 sr</td>
</tr>
<tr>
<td><strong>Timing Accuracy</strong></td>
<td>100 µs</td>
<td>&lt;10 µs</td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Deadtime</strong></td>
<td>100 ms/event</td>
<td>&lt;100 µs/event</td>
<td>TBD</td>
</tr>
<tr>
<td><strong>GRB Location Accuracy On-Board</strong></td>
<td></td>
<td>&lt;10 arcmin</td>
<td>5 arcmin</td>
</tr>
<tr>
<td><strong>GRB Notification Time to Spacecraft</strong></td>
<td></td>
<td>&lt;5 s</td>
<td>TBD</td>
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