GLAST

The Gamma-ray Large Area Space Telescope

Overview, Instruments, Observing Modes, Data

VLBI in the GLAST Era Workshop
23 April 2007

S. Ritz
GLAST Project Scientist

for the GLAST Mission Team

see http://glast.gsfc.nasa.gov and links therein

GLAST Key Features

- **Huge field of view**
  - **LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.**
- **Huge energy range, including largely unexplored band 10 GeV - 100 GeV**
- **Will transform the HE gamma-ray catalog:**
  - **by > order of magnitude in # point sources**
  - **spatially extended sources**
  - **sub-arcmin localizations (source-dependent)**

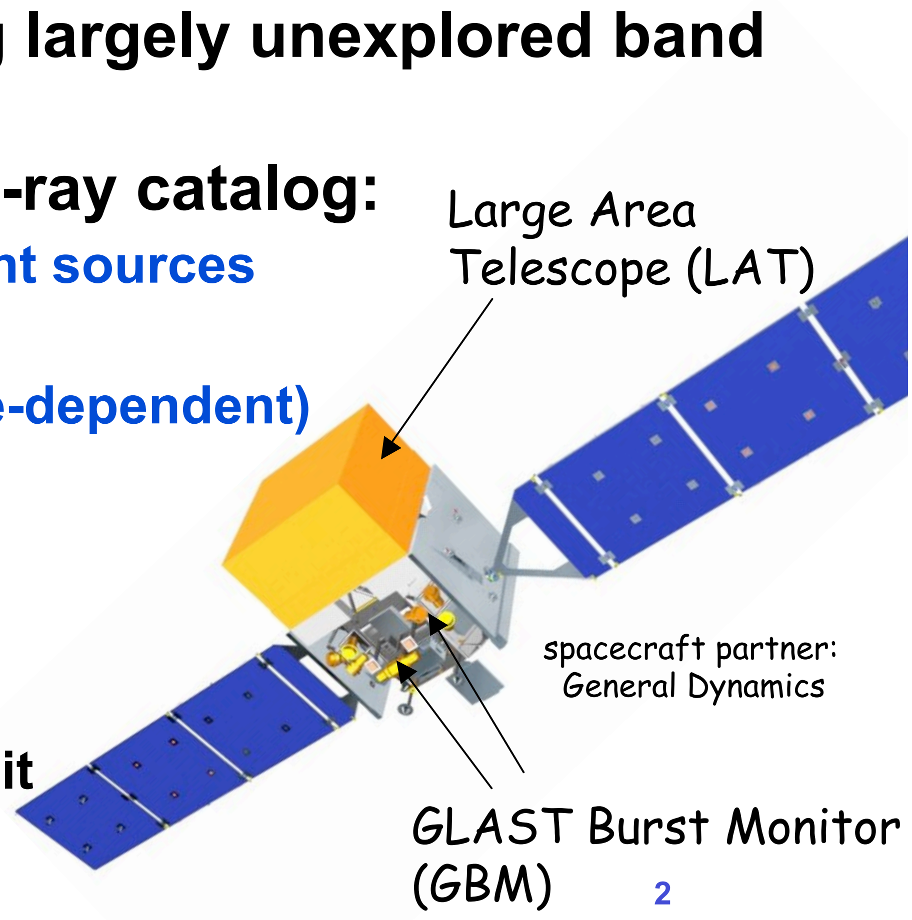
<u>Two GLAST instruments</u>:

LAT: 20 MeV – >300 GeV

GBM: 10 keV – 25 MeV

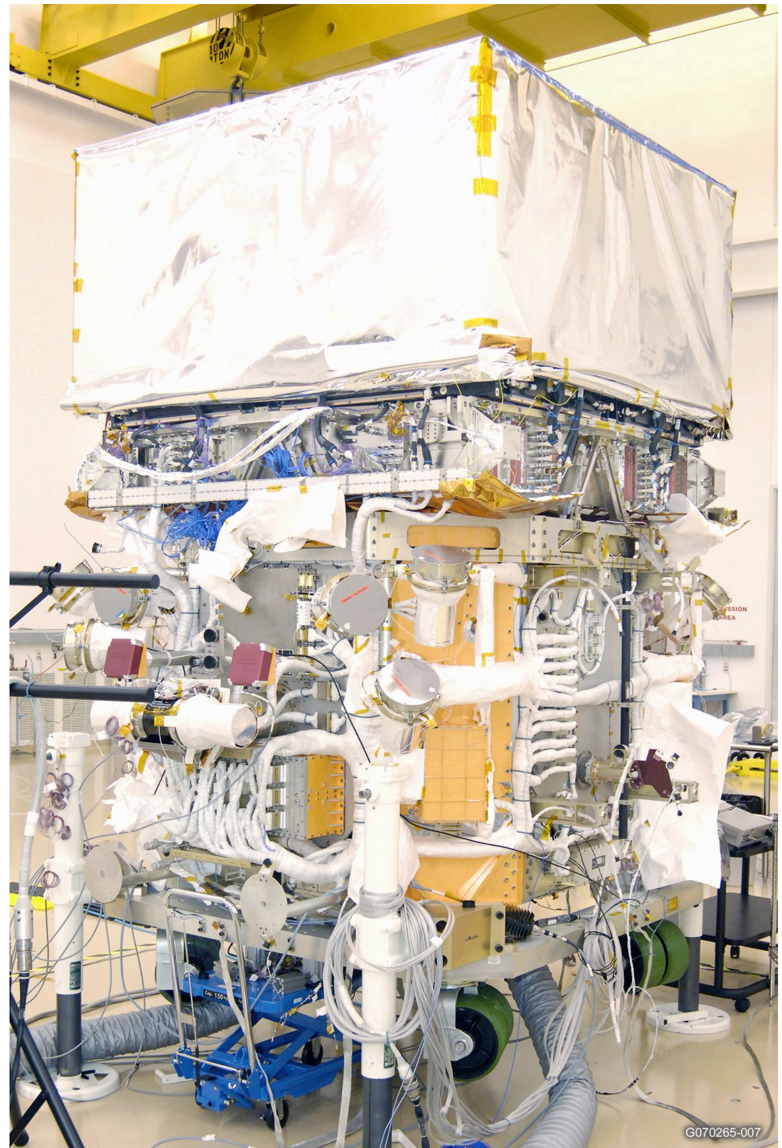
Launch: late 2007. 565 km, circular orbit

5-year mission (10-year goal)



Latest Picture of GLAST Observatory

http://glast.gsfc.nasa.gov/public/resources/images/Observatory_Mar07.jpg



GLAST LAT High Energy Capabilities

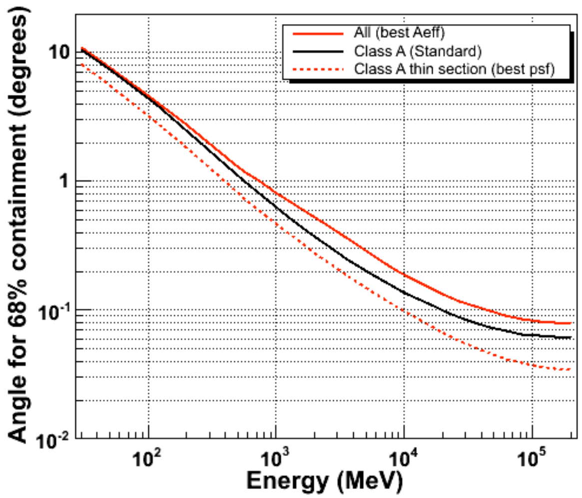
EGRET on GRO firmly established the field of high-energy gamma-ray astrophysics and demonstrated the importance and potential of this energy band.

GLAST is the next great step beyond EGRET, providing a huge leap in capabilities:

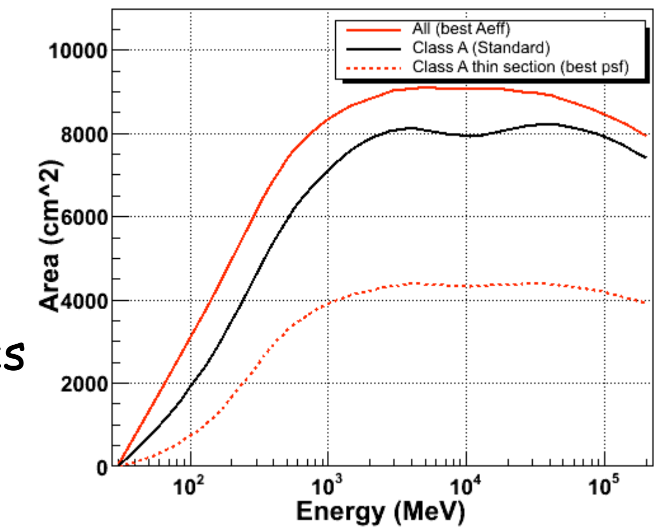
- *Very large FOV (~20% of sky), factor 4 greater than EGRET*
- *Broadband (4 decades in energy, including unexplored region E > 10 GeV)*
- *Unprecedented PSF for gamma rays (factor > 3 better than EGRET for E>1 GeV)*
- *Large effective area (factor > 5 better than EGRET)*
- *Results in factor > 30 improvement in sensitivity*
- *Much smaller deadtime per event (27 microsec, factor 4,000 better than EGRET)*
- *No expendables → long mission without degradation*

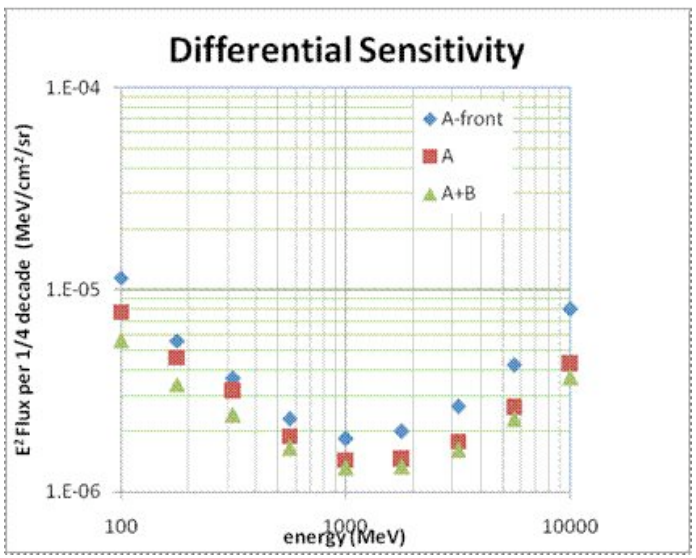
Look for an update soon

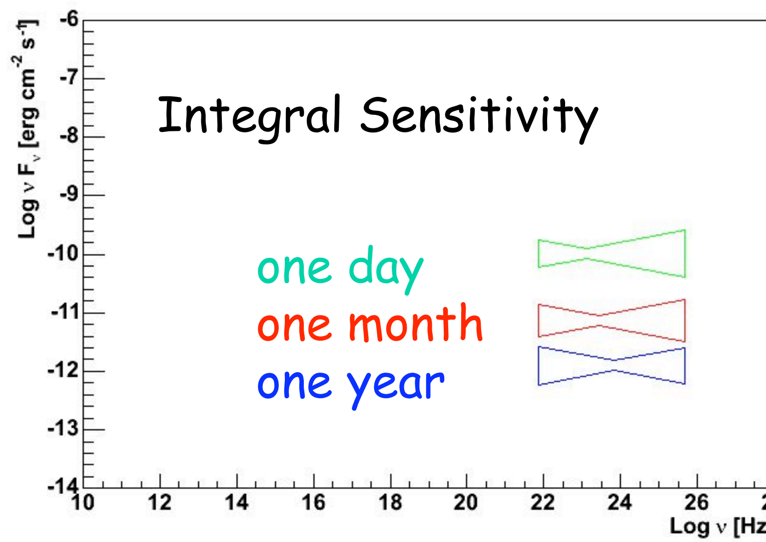
LAT performance summary



⇒ sensitivity depends on source characteristics







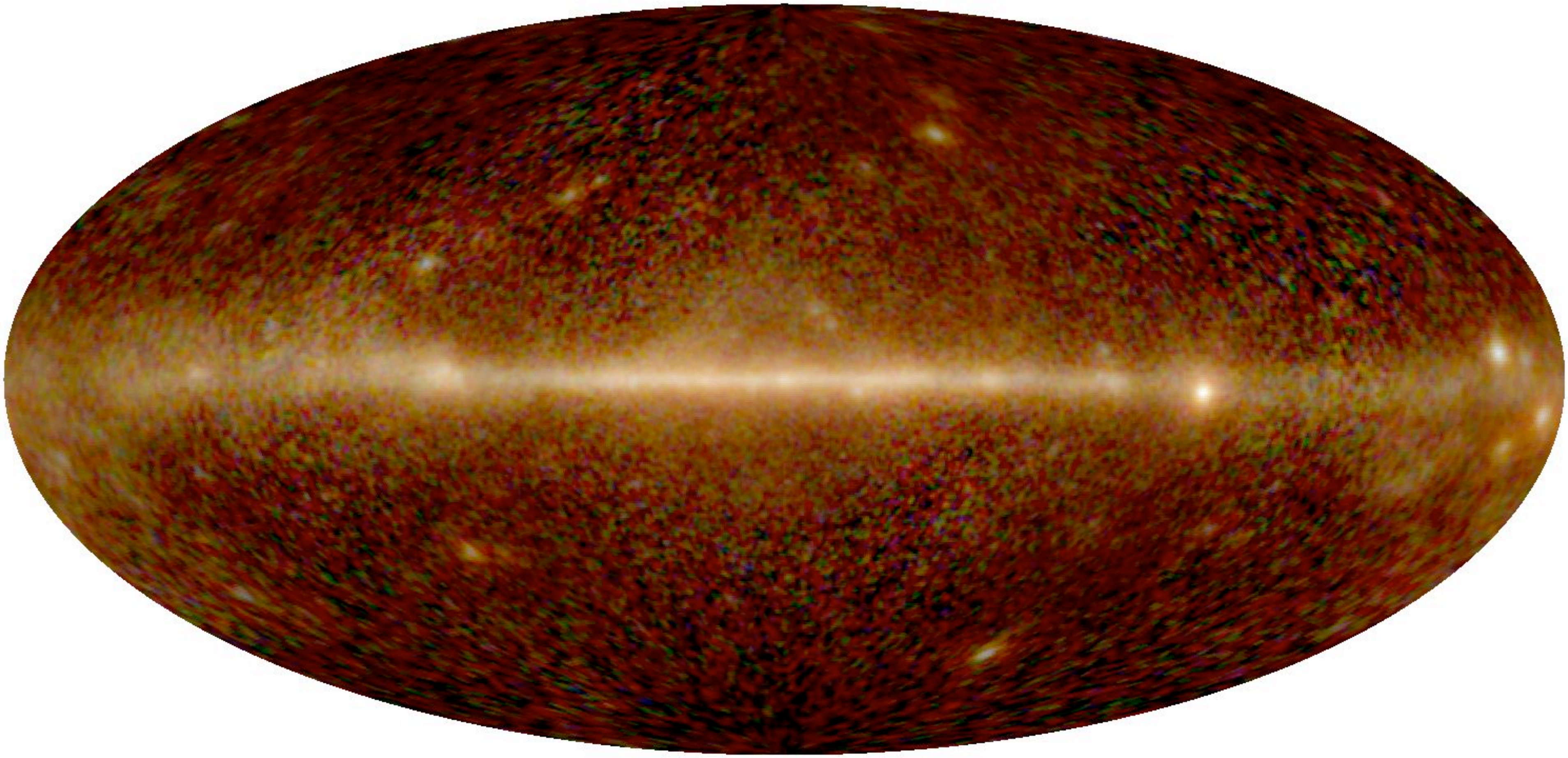
after 1 year, pt src sensitivity <4x10^{-9} cm^{-2}s^{-1} (E>100 MeV)

Leap in Capabilities: Implications

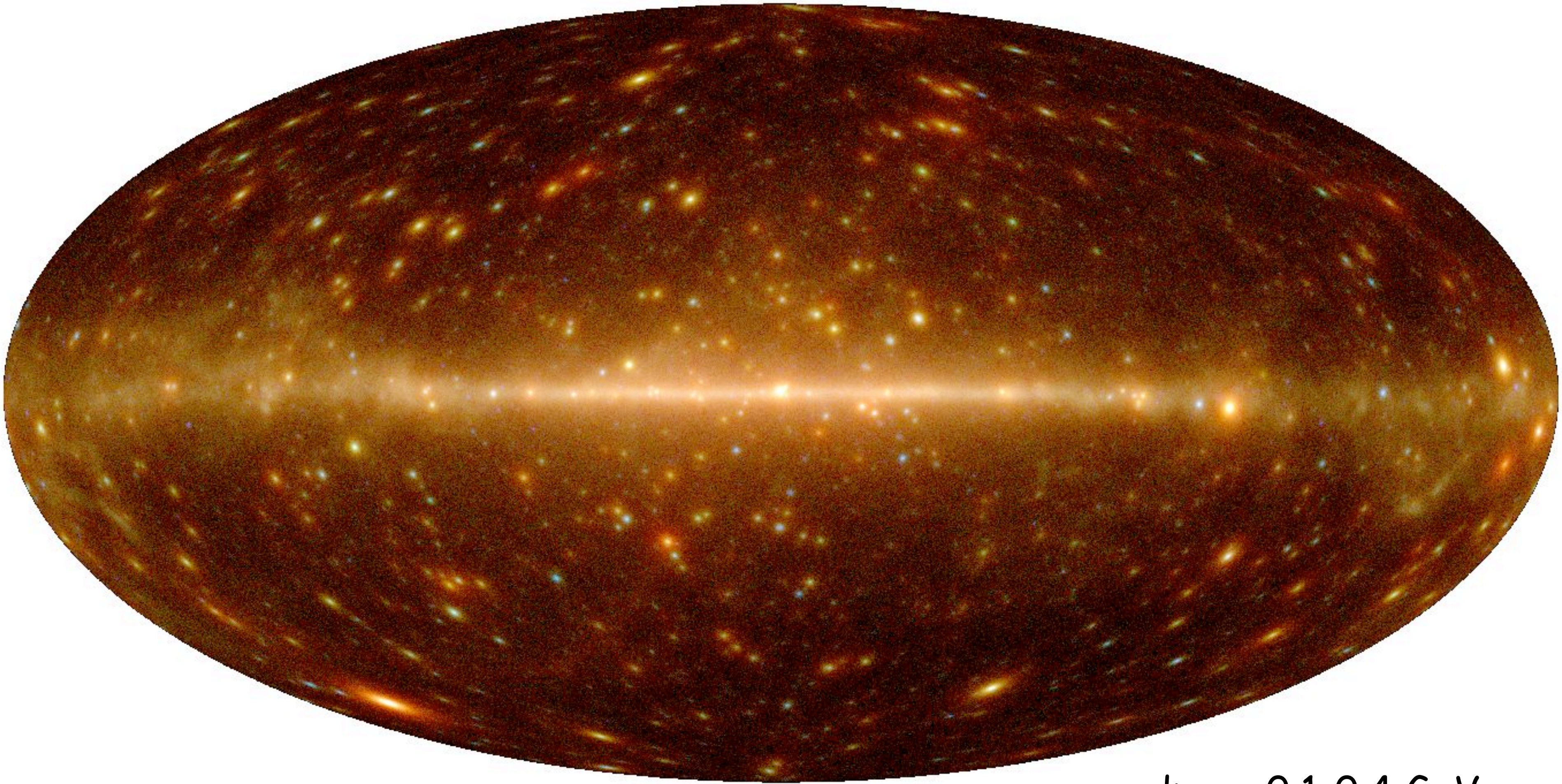
- **Dynamic Range Frontier; Variability Frontier** Whole-sky aperture for transients and variable sources: longterm, evenly sampled lightcurves; dynamic range of emission.
- **Depth Frontier** Deepening exposure over whole mission lifetime.
- **Energy Frontier** Discovering energy budgets and characteristics of wide variety of cosmic accelerator systems on different scales.
  - Getting to know 10 - 100 GeV sky
  - Connecting with TeV facilities: variability, spectral coverage
  - 7 decades of GLAST GRB energy coverage
- **Spatial Frontier** Breaking through to sub-arcmin point-source localizations (source dependent) -- ID the sources; PLUS starting to move beyond point sources: capabilities to resolve spatially (>~0.5° features), spectrally, and temporally.
- **Timing Frontier** Transient and periodic pulse profiles, searches.
- **Measurement Frontier** A rich data set to mine, touching many areas of science. Sources we know (AGN, SNR, XRBs, pulsars, PWN, galaxy clusters, solar flares, moon,…) and those awaiting discovery.

<u>Even greater multiwavelength/multimessenger needs and opportunities</u>

EGRET



GLAST One-year Service Challenge Simulation

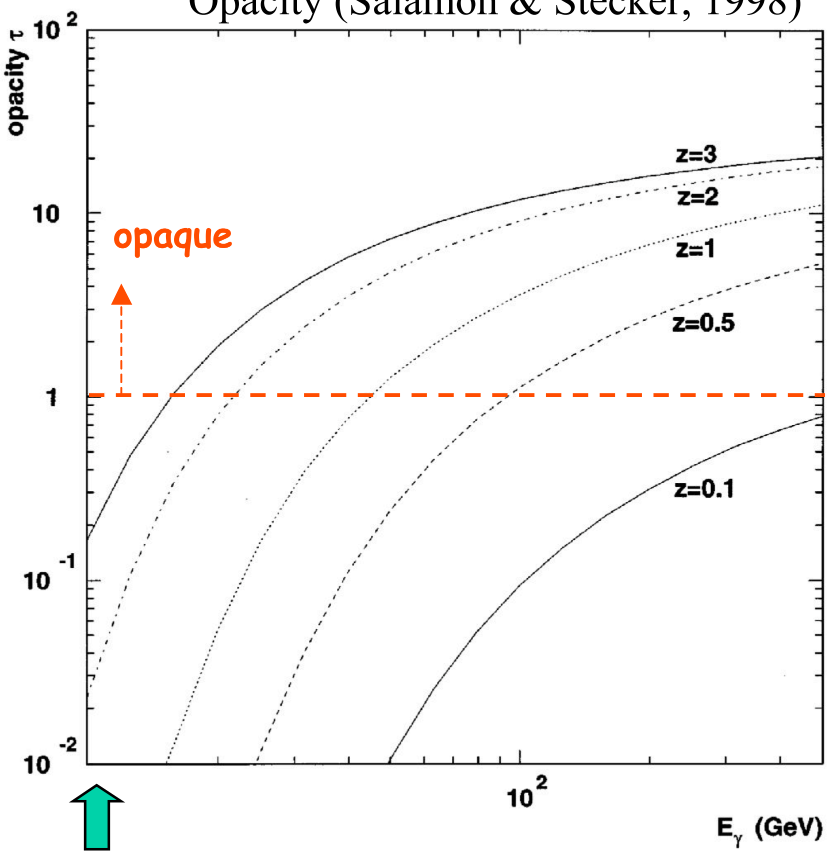


red: 0.1-0.4 GeV
green: 0.4-1.6 GeV
blue: >1.6 GeV

An Important Energy Band

Photons with E>10 GeV are attenuated by the diffuse field of UV-Optical-IR extragalactic background light (EBL)

Opacity (Salamon & Stecker, 1998)



No significant attenuation below ~10 GeV.

only $e^{-\tau}$ of the original source flux reaches us

EBL over cosmological distances is probed by gammas in the 10-100 GeV range. <u>Important science for GLAST!</u>

In contrast, the TeV-IR attenuation results in a flux that may be limited to more local (or much brighter) sources.

A dominant factor in EBL models is the star formation rate -- <u>attenuation measurements can help distinguish models</u>.

GLAST Science

GLAST will have a very broad menu that includes:

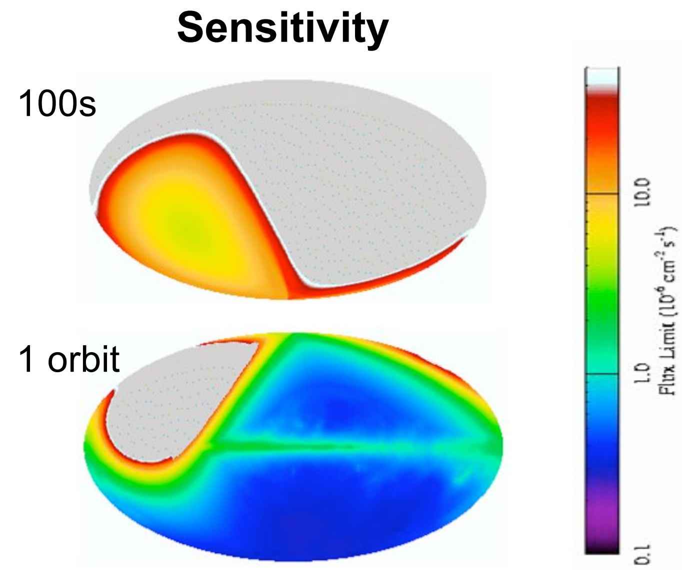
- Systems with supermassive black holes (Active Galactic Nuclei)
- Gamma-ray bursts (GRBs)
- Pulsars
- XRBs, microquasars
- Solar physics
- SNRs, Origin of Cosmic Rays
- Probing the era of galaxy formation, optical-UV background light
- Solving the mystery of the high-energy unidentified sources
- Discovery! New source classes. Particle Dark Matter? Other relics from the Big Bang? Testing Lorentz invariance.

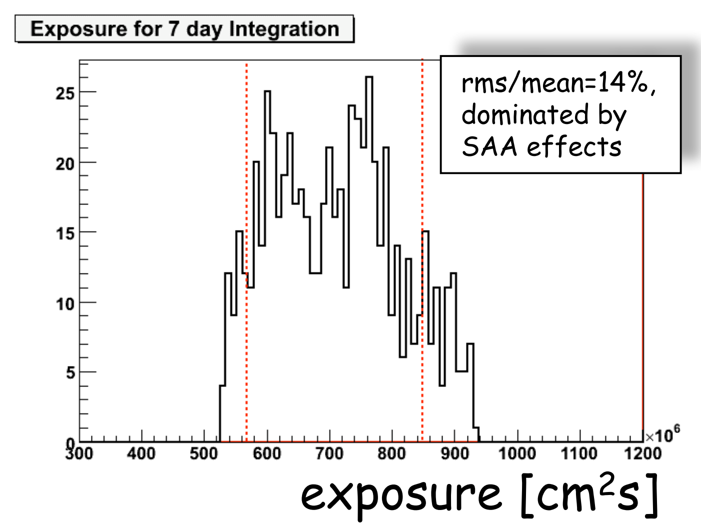
Huge increment in capabilities.

GLAST draws the interest of both the High Energy Particle Physics and High Energy Astrophysics communities.

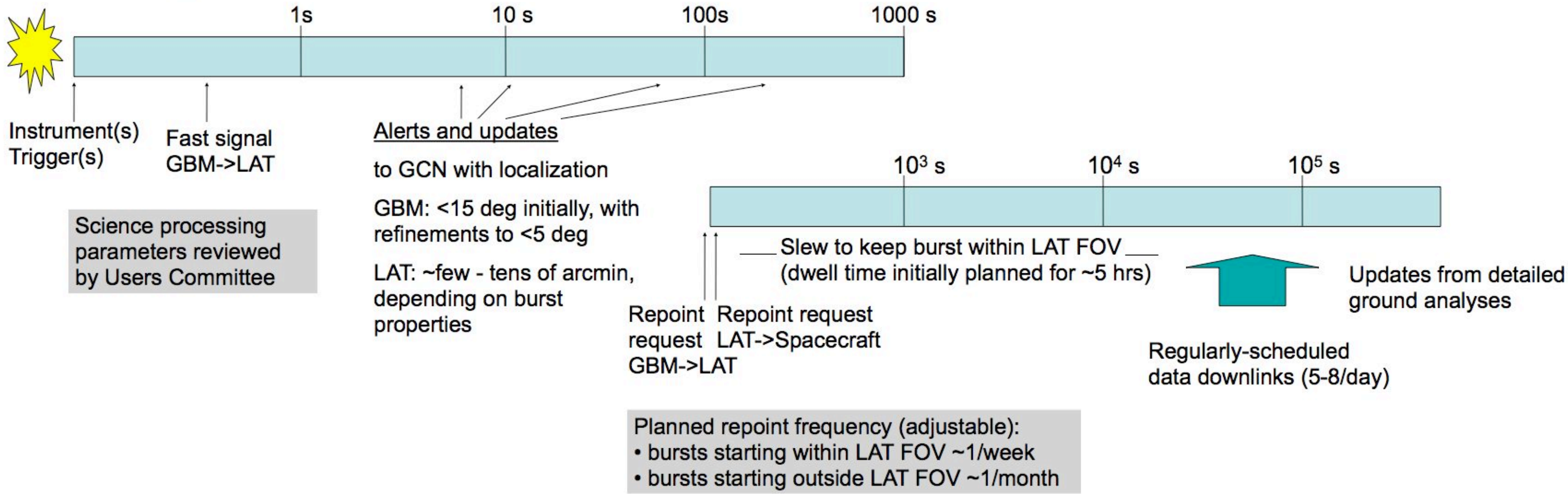
Operating modes

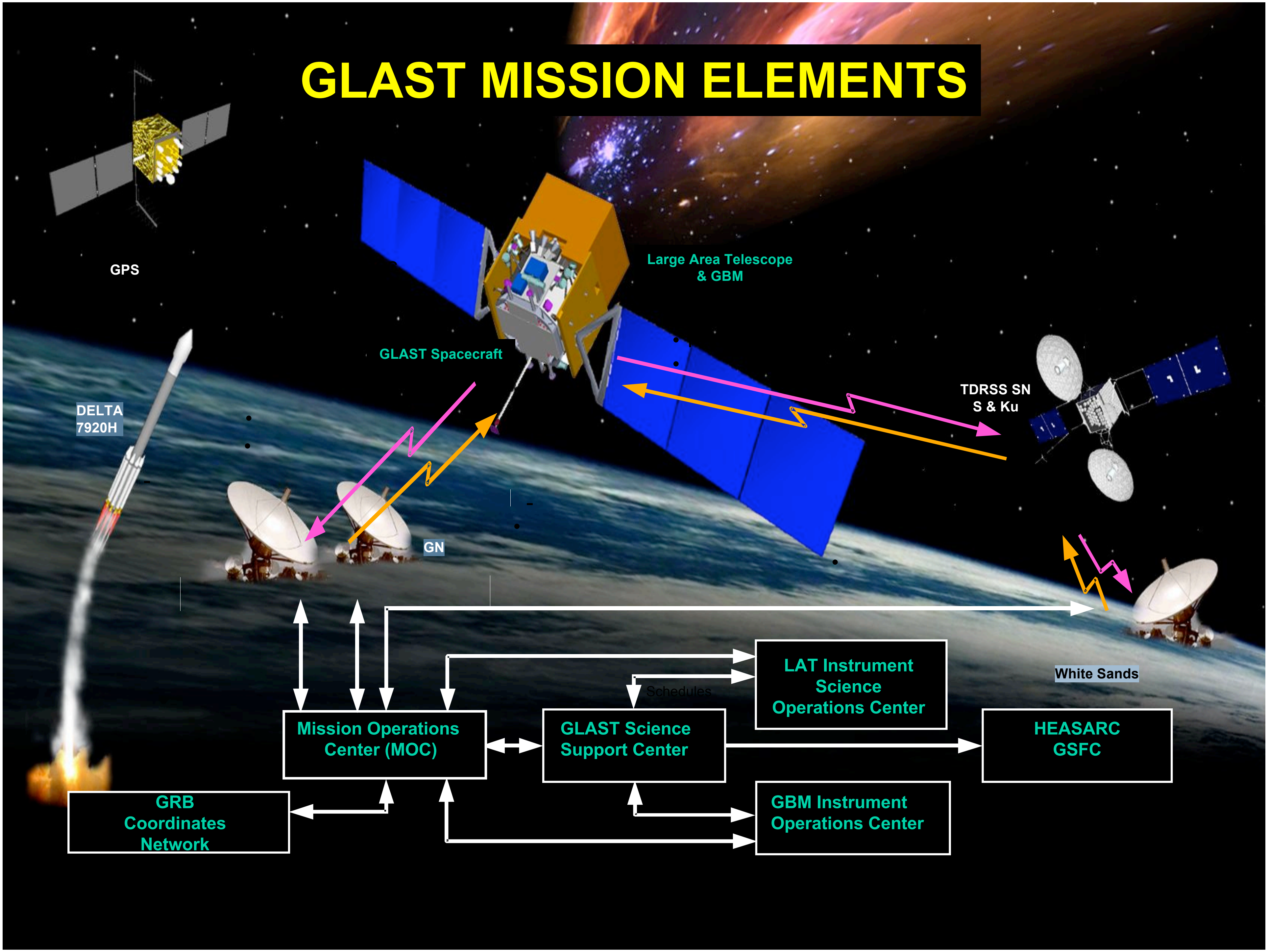
- Primary observing mode is Sky Survey
  - Full sky every 2 orbits (3 hours)
  - Uniform exposure, with each region viewed for ~30 minutes every 2 orbits
  - Best serves majority of science, facilitates multiwavelength observation planning
  - Exposure intervals commensurate with typical instrument integration times for sources
  - EGRET sensitivity reached in ~days
- Pointed observations when appropriate (selected by peer review) with automatic earth avoidance selectable. Target of Opportunity pointing.
- Autonomous repoints for onboard GRB detections in any mode.





Typical GLAST GRB Timeline




GLAST MISSION ELEMENTS
GPS
Large Area Telescope & GBM
GLAST Spacecraft
DELTA 7920H
TDRSS SN S & Ku
GN
White Sands
Schedules
LAT Instrument Science Operations Center
Mission Operations Center (MOC)
GLAST Science Support Center
HEASARC GSFC
GRB Coordinates Network
GBM Instrument Operations Center

GLAST LAT Collaboration

United States
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Ohio State University
- Sonoma State University
- Stanford University (SLAC and HEPL/Physics)
- University of Washington
- Washington University, St. Louis

France
- IN2P3, CEA/Saclay

Italy
- INFN, ASI, INAF

Japanese GLAST Collaboration
- Hiroshima University
- ISAS, RIKEN

Swedish GLAST Collaboration
- Royal Institute of Technology (KTH)
- Stockholm University

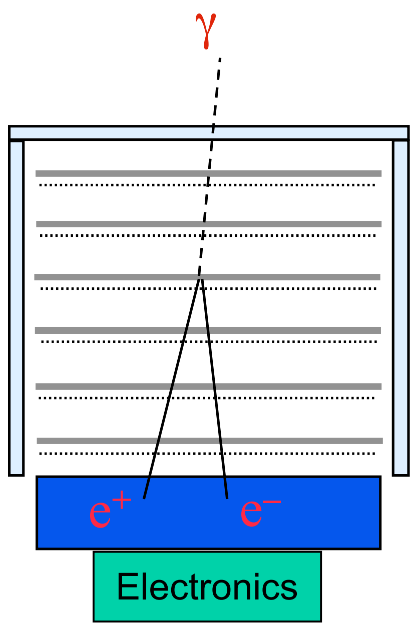
PI: Peter Michelson (Stanford & SLAC)

~230 Members (including ~84 Affiliated Scientists, plus 24 Postdocs, and 36 Graduate Students)

Cooperation between NASA and DOE, with key international contributions from France, Italy, Japan and Sweden.

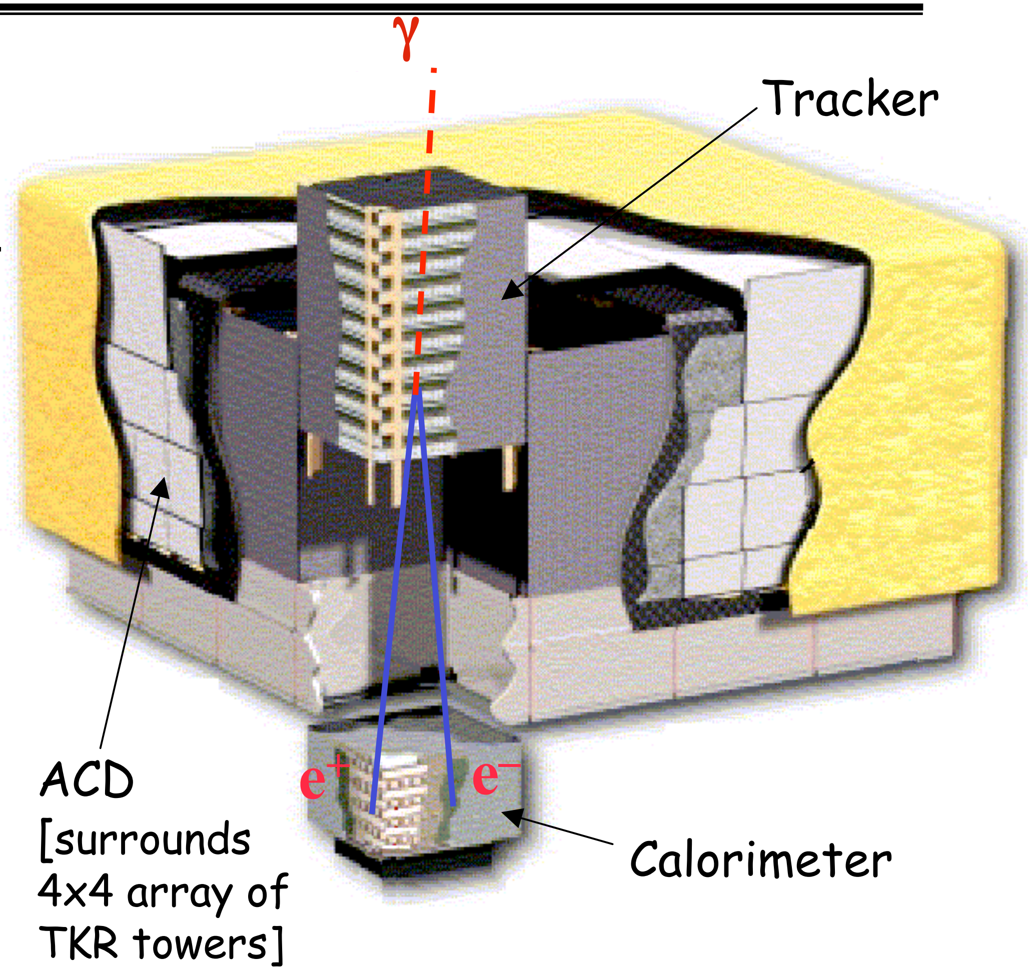
Managed at Stanford Linear Accelerator Center (SLAC).

Pair Conversion Telescope



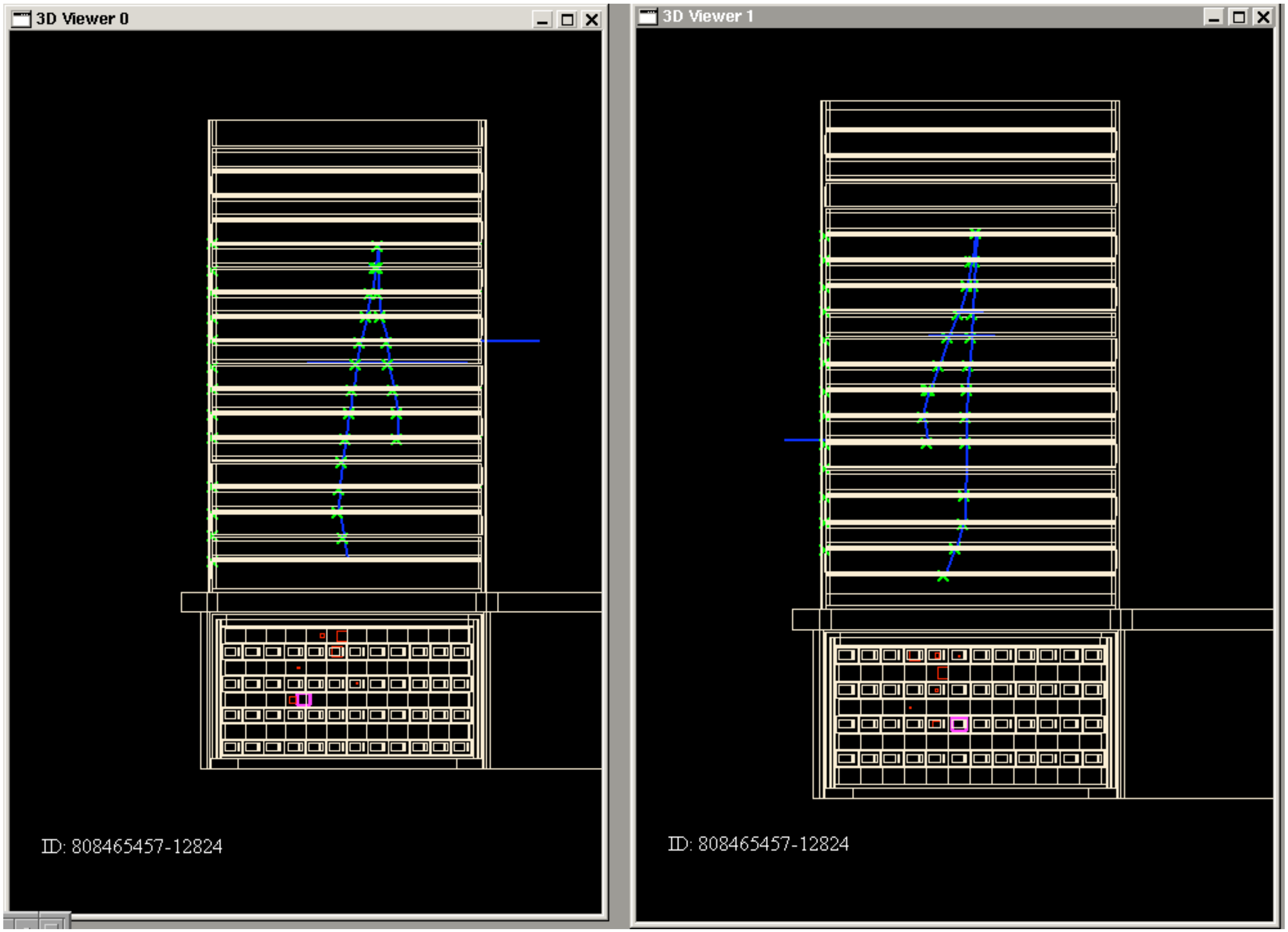
Overview of LAT

- Precision Si-strip Tracker (TKR)
  18 XY tracking planes. Single-sided silicon strip detectors (228 μm pitch) Measure the photon direction; gamma ID.
- Hodoscopic CsI Calorimeter(CAL)
  Array of 1536 CsI(Tl) crystals in 8 layers. Measure the photon energy; image the shower.
- Segmented Anticoincidence Detector (ACD) 89 plastic scintillator tiles. Reject background of charged cosmic rays; segmentation removes self-veto effects at high energy.
- Electronics System Includes flexible, robust hardware trigger and software filters.

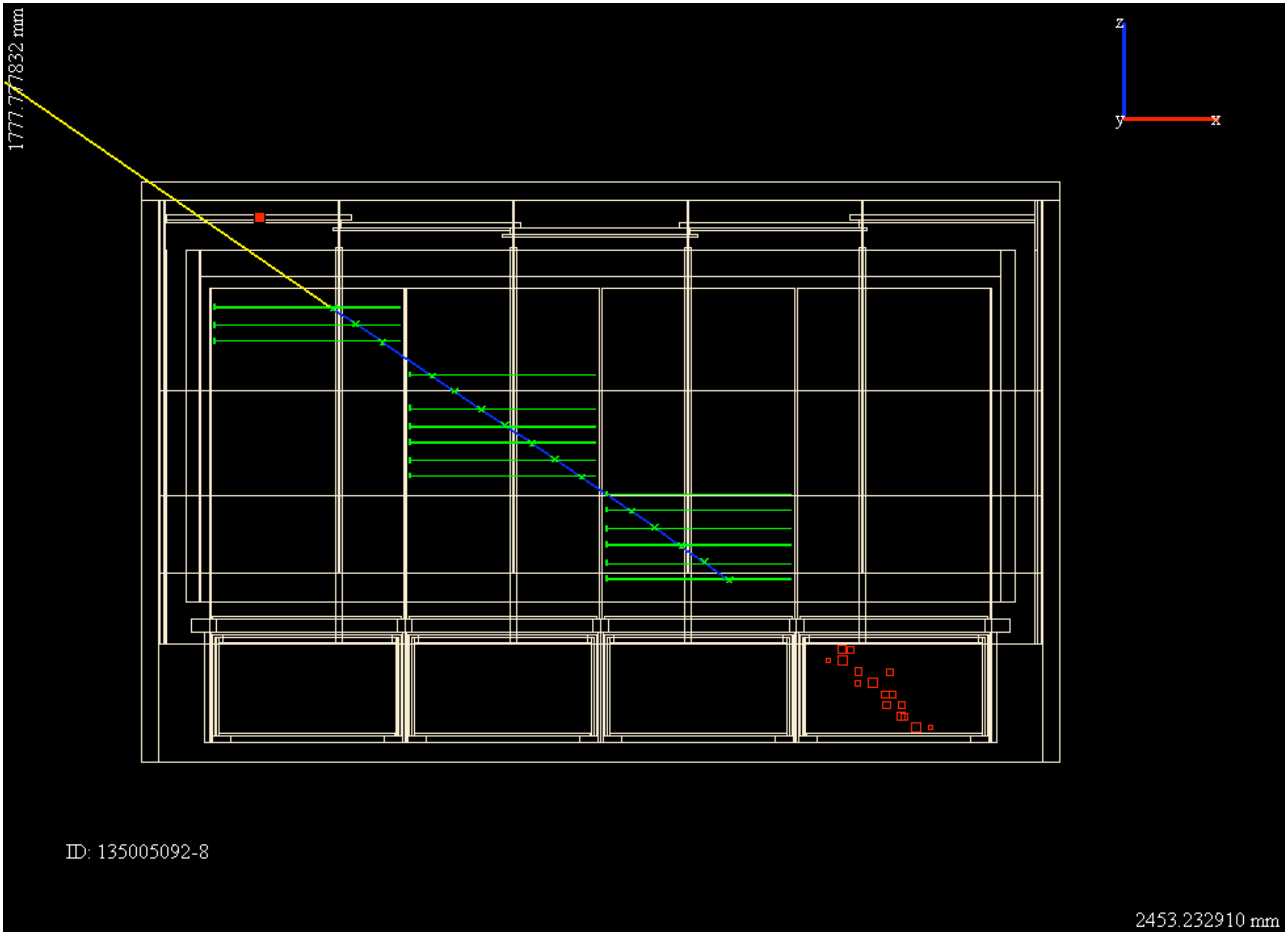


Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.

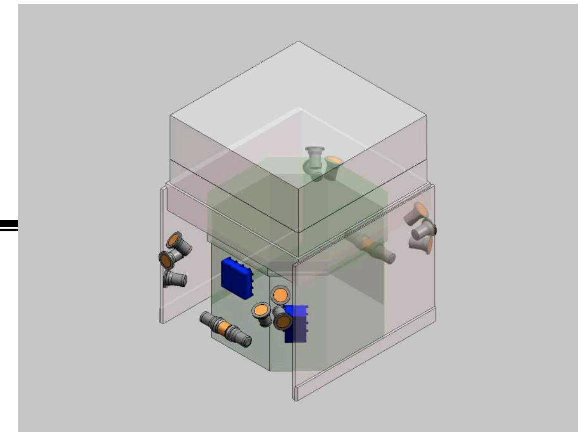
Gamma Candidate in First Integrated Tower!



16 Towers with ACD



GBM Collaboration



National Space Science & Technology Center

University of Alabama in Huntsville	NASA Marshall Space Flight Center	Max-Planck-Institut für extraterrestrische Physik
Michael Briggs William Paciesas Robert Preece Narayana Bhat Marc Kippen (LANL)	Charles Meegan (PI) Gerald Fishman Chryssa Kouveliotou Robert Wilson	Giselher Lichti (Co-PI) Andreas von Keinlin Volker Schönfelder Roland Diehl Jochen Greiner Helmut Steinle

On-board processing, flight software, systems engineering, analysis software, and management

Detectors, power supplies, calibration, and analysis software

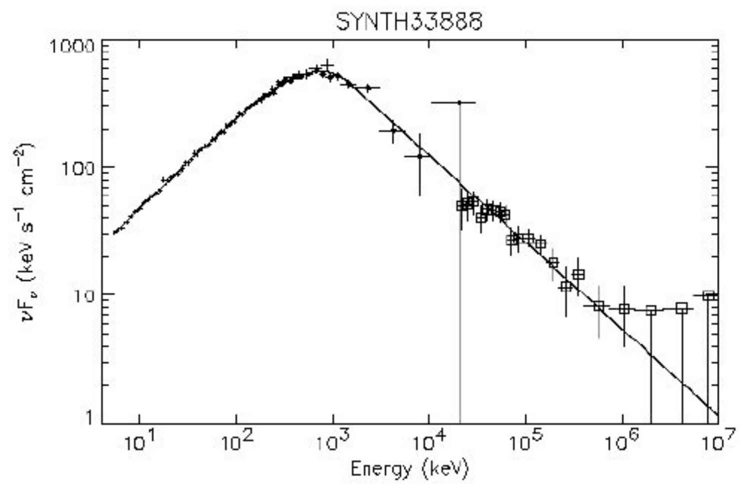
GBM

- **provides spectra for bursts from 10 keV to 30 MeV, connecting frontier LAT high-energy measurements with more familiar energy domain;**

Simulated GBM and LAT response to time-integrated flux from bright GRB 940217

Spectral model parameters from CGRO wide-band fit

1 NaI (14 º) and 1 BGO (30 º)



- **provides wide sky coverage (>8 sr) -- enables autonomous repoint requests for exceptionally bright bursts that occur outside LAT FOV for high-energy afterglow studies (an important question from EGRET);**
- **provides burst alerts to the ground.**

GBM Requirements

Parameter	Level 1 Requirements	Intra-Project Goals	Expected Performance
Energy range	10 keV – 25 MeV	5 keV – 30 MeV	8 keV – 30 MeV (1)
Energy resolution	10% (1σ; 0.1 – 1.0 MeV)	7% (1σ; 0.1 – 1.0 MeV)	<8% at 0.1 Mev (2) <4.5% at 1.0 Mev (3)
Effective area	NaI: >100 cm^2 at 14 keV BGO: >80 cm^2 at 1.8 MeV	NaI: >50 cm^2 at 6 keV BGO: none	NaI: 47.5 – 78 cm^2 at 14 keV BGO: >95 cm^2
On-board GRB locations	(none)	15° accuracy (1σ radius) within 2 seconds	<15°; 1.8 seconds (<8° for S/C <60° zenith)
GRB sensitivity (on ground)	0.5 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.3 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.47 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)
GRB on-board trigger sensitivity	1.0 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.75 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)	0.71 photons cm^{-2} s^{-1} (peak flux, 50–300 keV)
Field of view	>8 steradians	10 steradians	9 steradians

(1) **Supported by measurements of window absorption**
(2) **Measured NaI-system resolution**
(3) **Measured BGO-system resolution**

- **on-ground location accuracy: < ~few degrees**
- **expected burst-detection rate of the GBM:**
  - **~60 bursts/year in 55° FoV of LAT**
  - **~200 GBM-detected bursts/year**

Operations Phases, Guest Observers, Data

- After the initial on-orbit checkout, verification, and calibrations, the first year of science operations will be an all-sky survey.
  - all GBM data released
  - LAT data on flaring sources, transients, and “sources of interest” will be released, with caveats (see following slide)
  - first-year LAT individual photon candidate events initially used for detailed instrument characterization, refinement of the alignment, and key projects (source catalog, diffuse background models, etc.) needed by the community. Individual photon data released at the end of year one. Subsequent photon data released immediately after processing.
  - burst alerts and repoints for bright bursts
  - extraordinary ToO’s supported
  - workshops for guest observers on science tools and mission characteristics for proposal preparation
- Observing plan in subsequent years driven by guest observer proposal selections by peer review -- default is sky survey mode. Data released through the science support center (GSSC).

Year 1 LAT Data Releases

- **Main purpose: trigger MW observations for analysis of year 1 data**
- **Throughout year 1 and beyond, high-level data releases continuously:**
  - **on any flaring source (flux > 2×10^{-6} $cm^{-2}s^{-1}$, E>100 MeV), followed down to factor ~10 lower intensity. Time-binned spectra (or energy-binned light curves) and associated errors.**
  - **on approximately 20 sources of interest, time-binned spectra (or energy-binned light curves) or upper limits. List vetted through Users Committee. Posted on GSSC website.**
  - **information from GRBs detected both onboard and from ground-based analyses. For GBM bursts with no LAT detections, upper limits provided.**
- **At end of year 1, individual photon candidate event info released. All subsequent (year 2 and beyond) individual photon candidate events released immediately after processing.**
- **Approximately six months into year 1 (in advance of Cycle 2 proposals) a preliminary LAT source list of high-confidence sources will be released**
  - **position, avg flux, peak flux, spectral index, associated errors**

Preliminary LAT Year1 Monitored Source Release List

http://glast.gsfc.nasa.gov/ssc/data/policy/LAT_Monitored_Sources.html

discussing adding 5 more:
BL LAC
OJ 287
0235+163
0716+714
1510-089

Source Type	Source Name	EGRET Name	Average or Min. Flux (10^{-8} γ $cm^{-2}s^{-1}$)	Galactic Lattitude	Redshift	TeV Source
Blazar	0208-512	3EGJ0210-5055	85.5 ± 4.5	-61.9	1.003	
	PKS 0528+134	3EGJ0530+1323	93.5 ± 3.6	-11.1	2.060	
	0827+243	3EGJ0829+2413	24.9 ± 3.9	31.7	2.046	
	Mrk 421	3EGJ1104+3809	13.9 ± 1.8	65.0	0.031	Yes
	W Com 1219+285	3EGJ1222+2841	11.5 ± 1.8	83.5	0.102	
	3C 273	3EGJ1229+0210	15.4 ± 1.8	64.5	0.158	
	3C 279	3EGJ1255-0549	74.2 ± 2.8	57.0	0.538	
	1406-076	3EGJ1409-0745	27.4 ± 2.8	50.3	1.494	
	H 1426+428	NA		64.9	0.129	Yes
	PKS 1622-297	3EGJ1625-2955	47.4 ± 3.7	13.4	0.815	
	1633+383	3EGJ1635+3813	58.4 ± 5.2	42.3	1.814	
	Mrk 501	NA		38.9	0.033	Yes
	1730-130 NRAO 530	3EGJ1733-1313	36.1 ± 3.4	10.6	0.902	
	1ES 1959+650	NA		17.7	0.048	Yes
	PKS 2155-304	3EG2158-3023	13.2 ± 3.2	-52.2	0.116	Yes
	3C 454.3	3EGJ2254+1601	53.7 ± 4.0	-38.3	0.859	
	1ES 2344+514	NA		-9.9	0.044	Yes
HMXB	LSI+61 303 2CG135+01	3EGJ0241+6103	69.3 ± 6.1	1.0		Yes
any source (except Crab, Vela, and Geminga pulsars)			monitor if flux exceeds 2×10^{-6} $cm^{-2}s^{-1}$ then reported down to 2×10^{-7} $cm^{-2}s^{-1}$			

GI Opportunities

- Annual cycles; typical range $50-$100k/investigation
- Cycle 1:
  - expect to fund ~50 investigations for
    - analyses of released data
    - GLAST-related MW observations
      - NRAO MOU announcement soon
    - GLAST-related theory
    - GLAST-relevant data analysis methodology
- Cycle 2 and onward:
  - expect to fund ~100 investigations for all of the above plus detailed analyses of LAT photon candidate event lists.
  - may propose pointed observations, as well as ensured sky-survey periods (expect <20% time on pointed observations)
- Tentative Schedule for Cycle 1 (2007)
  - NRA in ROSES released, proposals due in September, Cycle 1 funding starts in early 2008. See http://glast.gsfc.nasa.gov/ssc/.

Cycle 1

- NRA in ROSES released
  - See *http://glast.gsfc.nasa.gov/ssc/*
- Notice of intent (optional):
  - due 13 July
  - http://glast.gsfc.nasa.gov/ssc/proposals/cycle1/noi
- **Proposals due 7 September**
- Two-stage proposal process: first science evaluation, then budget
  - first stage proposal must contain a stated budget maximum
- Two proposal classes:
  - (1) Regular proposals with research plans that can be completed in one year (anticipate funding ~40)
  - (2) Large proposals whose research plans are more expansive and may take up to three years to complete (anticipate funding ~4)
  - Page limit for the central Science-Technical-Management section of Phase 1 proposals is 4 pages for Regular proposals and 6 pages for Large proposals.

GLAST Fellows Program Plan

- Similar to other observatory Fellows programs
- Tentative schedule:
  - first call for proposals Fall 2007, selections announced early 2008, start in September 2008
- Three new Fellows selected each year, for three-year periods

GLAST Science Support Center (GSSC)

- Supports guest investigator program
- Provides training workshops
- Provides data, software, documentation, workbooks to community
- Archives to HEASARC
- Joint software development with Instrument Teams, utilizing HEA standards
- Located at Goddard

see http://glast.gsfc.nasa.gov/ssc/

and help desk

http://glast.gsfc.nasa.gov/ssc/help/

GLAST Users Committee (GUC)

- Advises GLAST Project and NASA HQ on NASA-funded Guest Investigator Program and Policies
- Meeting at Goddard in November, featuring a beta-test of the science tools.
- First-year source list vetting.
- See *http://glast.gsfc.nasa.gov/ssc/resources/guc/*

GLAST Users Committee Members

- Josh Grindlay (Chair)
- Matthew Baring
- Roger Brissenden
- Wim Hermsen
- Buell Januzzi
- Don Kniffen
- Henric Krawczynski
- Reshmi Mukherjee
- Luigi Piro
- Jim Ulvestad
- Ann Wehrle

Plus

- David Band
- Neil Gehrels
- Rick Harnden
- Julie McEnery
- Chip Meegan
- Peter Michelson
- Steve Ritz
- Rita Sambruna
- Chris Shrader
- Kathy Turner
- Lynn Cominsky

http://glast.gsfc.nasa.gov/ssc/resources/guc/

SWG Activities

- **Membership includes international representatives from LAT and GBM, along with four Interdisciplinary Scientists (IDS)**
  - **Chuck Dermer, Brenda Dingus, Martin Pohl, Steve Thorsett**

- **SWG scientific review of the expected performance (LAT, GBM, Observatory) relative to the Science Requirements. See**

  http://glast.gsfc.nasa.gov/science/swg/feb07/

MW Info and Coordination

- **Multiwavelength observations are key to many science topics for GLAST.**
  - **GLAST welcomes collaborative efforts from observers at all wavelengths**
    - **For campaigners' information and coordination, see** *http://glast.gsfc.nasa.gov/science/multi*
    - **To be added to the Gamma Ray Multiwavelength Information mailing list, contact Dave Thompson,** *djt@egret.gsfc.nasa.gov*

- **GI Program will support correlative observations and analysis**
  - **See** *http://glast.gsfc.nasa.gov/ssc/proposals*

Summary

- **All the parts of GLAST are coming together:**
  - **the instruments are beautiful!**
  - **observatory integration is nearing completion; environmental testing about to start**
- **Preparation for science and operations in full swing**
  - **good connections among all the elements**
  - **MW observations are key to many science topics for GLAST. See *http://glast.gsfc.nasa.gov/science/multi/***
- **Looking forward to launch at end of this year.**
- **Guest Investigator Program starting soon, with many opportunities for GIs. Join the fun!**

Started monthly GLAST news email. Sign up by sending email to
majordomo@athena.gsfc.nasa.gov
(you can leave the subject line blank)

In the body of the message, please write the following:

subscribe glastnews your-email-address