GLAST Large Area Telescope: Status Report

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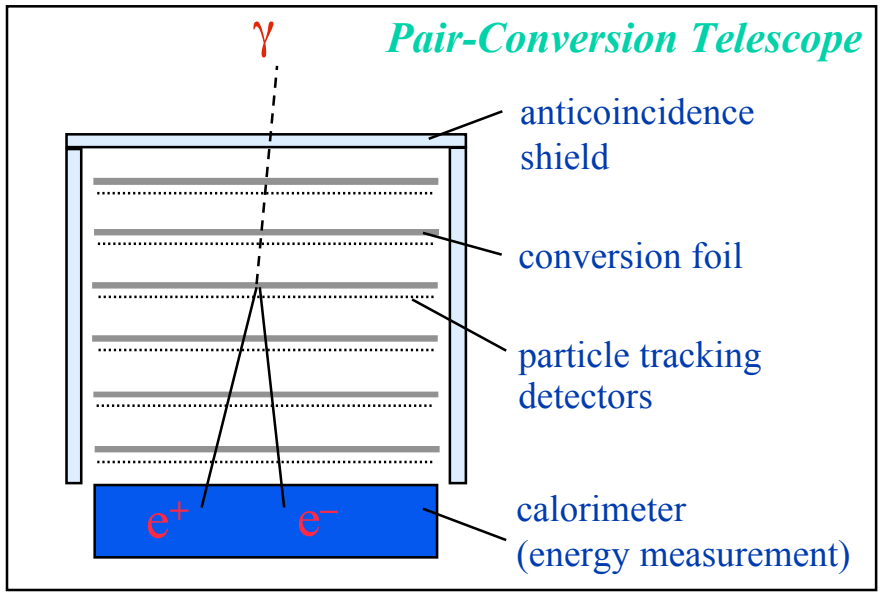
Outline

- **Large Area Telescope (LAT) Overview**
  - Experimental technique
  - Mission constraints on LAT
  - Overview of LAT hardware, performance
  - Triggering and on-board processing
  - Partner contributions (US, France, Italy, Japan, Sweden)
- **Schedule**
- **LAT Development Status**
- **LAT Instrument Operations Center planning**

Experimental Technique

- Instrument must measure the direction, energy, and arrival time of high energy photons (from approximately 20 MeV to greater than 300 GeV):

  - photon interactions with matter in GLAST energy range dominated by pair conversion:
    - ➡ determine photon direction
    - ➡ clear signature for background rejection
  - limitations on angular resolution (PSF)
    - **low E: multiple scattering => many thin layers**
    - **high E: hit precision & lever arm**



Energy loss mechanisms:

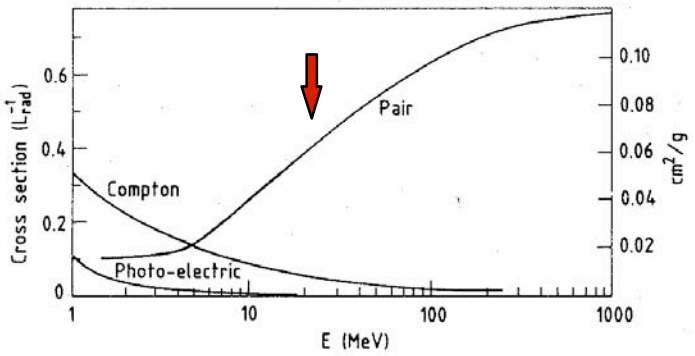


Fig. 2: Photon cross-section σ in lead as a function of photon energy. The intensity of photons can be expressed as $I = I_0 \exp(-\sigma x)$, where x is the path length in radiation lengths. (Review of Particle Properties, April 1980 edition).

- must detect γ-rays with high efficiency and reject the much larger (~10^4:1) flux of background cosmic-rays;
- energy resolution requires calorimeter of sufficient depth to measure buildup of the EM shower. Segmentation useful for resolution and background rejection.

Mission Constraints Relevant to LAT Science Performance

- **Lateral dimension < 1.8m**
  Restricts the geometric area.
- **Mass < 3000 kg**
  Primarily restricts the total depth of the CAL.
- **Power < 650W**
  Primarily restricts the # of readout channels in the TKR (strip pitch, # layers), and restricts onboard CPU.
- **Telemetry bandwidth < 300 kbps orbit average**
  Sets the required level of onboard background rejection and data volume per event.
- **Center-of-gravity constraint** restricts instrument height, but a low aspect ratio is already desirable for science.
- **Launch loads and other environmental constraints.**

Si Tracker

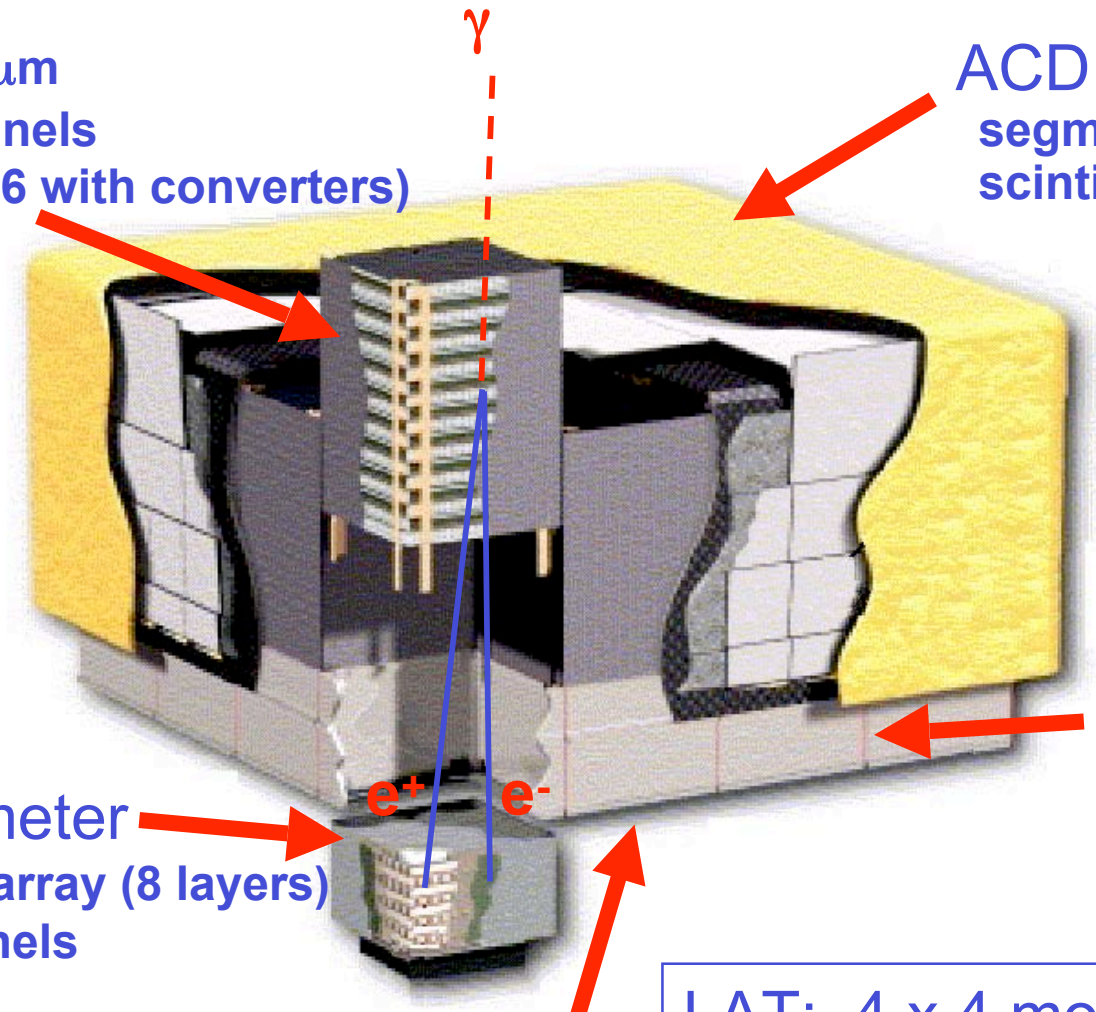
pitch = 228 μm

$8.8\ 10^5$ channels

18 planes (16 with converters)

ACD

segmented scintillator tiles



Grid

mechanical backbone

CsI Calorimeter

hodoscopic array (8 layers)

$6.1\ 10^3$ channels

Data Acquisition

LAT: 4 x 4 modular array

3000 kg, 650 W

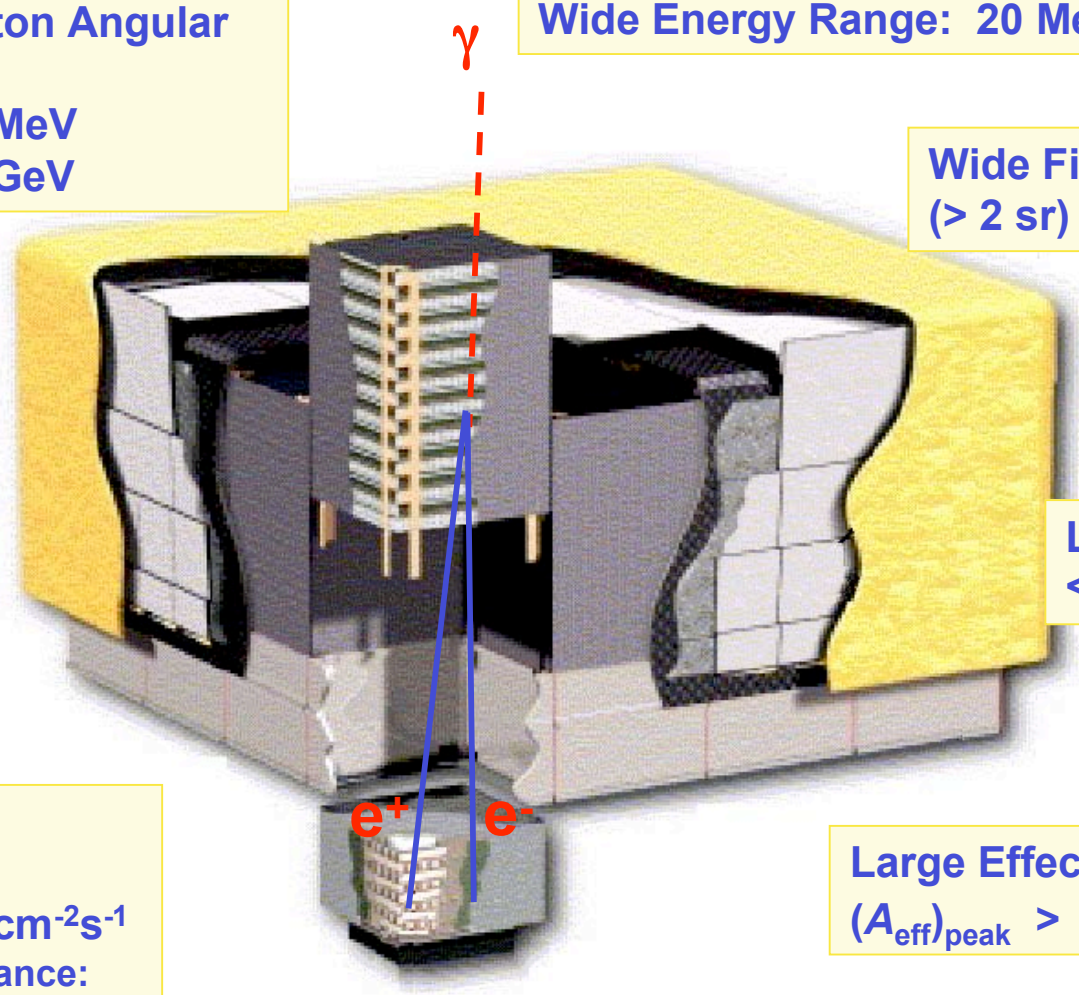
20 MeV – 300 GeV

Single Photon Angular Resolution
3.5° @ 100 MeV
0.15° @ 10 GeV

Wide Energy Range: 20 MeV - >300 GeV

Wide Field of View (> 2 sr)

40 times EGRET's sensitivity and extends energy range to 300 GeV



Low dead time:
< 100 μs/event

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

Source Localization:
0.3' – 1'

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

Good Energy Resolution
$\Delta E/E$ ~ 10%; 100 MeV – 10 GeV
~ < 20%; 10 GeV – 300 GeV

Science Performance Requirements Summary

Parameter	SRD Value	Present Design Value
Peak Effective Area (in range 1-10 GeV)	>8000 cm^2	10,000 cm^2 at 10 GeV
Energy Resolution 100 MeV on-axis	<10%	9%
Energy Resolution 10 GeV on-axis	<10%	8%
Energy Resolution 10-300 GeV on-axis	<20%	<15%
Energy Resolution 10-300 GeV off-axis (>60°)	<6%	<4.5%
PSF 68% 100 MeV on-axis	<3.5°	3.37° (front), 4.64° (total)
PSF 68% 10 GeV on-axis	<0.15°	0.086° (front), 0.115° (total)
PSF 95/68 ratio	<3	2.1 front, 2.6 back (100 MeV)
PSF 55°/normal ratio	<1.7	1.6
Field of View	>2sr	2.4 sr
Background rejection (E>100 MeV)	<10% diffuse	6% diffuse (adjustable)
Point Source Sensitivity(>100MeV)	<6×10^{-9} $cm^{-2}s^{-1}$	3×10^{-9} $cm^{-2}s^{-1}$
Source Location Determination	<0.5 arcmin	<0.4 arcmin (ignoring BACK info)
GRB localization	<10 arcmin	5 arcmin (ignoring BACK info)

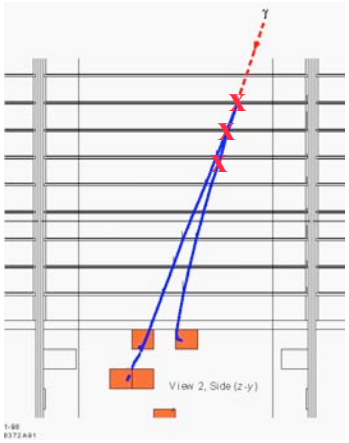
LAT meets all requirements

Instrument Triggering and Onboard Data Flow

Level 1 Trigger

Hardware trigger based on special signals from each tower; initiates readout

Function: • "did anything happen?"
• keep as simple as possible



• **TKR 3 *x*•*y* pair planes in a row**
workhorse γ trigger

OR

• **CAL:**
LO – independent check on TKR trigger.
HI – indicates high energy event ⟶ disengage use of ACD.

Upon a L1T, all towers are read out within 20μs

Instrument Total L1T Rate: <4 kHz>**

**4 kHz orbit average without throttle (1.3 kHz with throttle); peak L1T rate is approximately 12 kHz without throttle and 3.8 kHz with throttle).

On-board Processing

full instrument information available to processors.

Function: reduce data to fit within downlink

Hierarchical filter process: first make the simple selections that require little CPU and data unpacking.

- **subset of full background rejection analysis, with loose cuts**
- **only use quantities that**
  - **¬ are simple and robust**
  - **¬ do not require application of sensor calibration constants**
- **complete event information**
- **signal/bkgd tunable, depending on analysis cuts:**
  γ:cosmic-rays ~ 1:~few

Total L3T Rate: <25-30 Hz>
(average event size: ~8-10 kbits)

On-board science analysis:
transient detection (AGN flares, bursts)

Spacecraft

GLAST LAT Collaboration

United States
- California State University at Sonoma
- University of California at Santa Cruz - Santa Cruz Institute of Particle Physics
- Goddard Space Flight Center – Laboratory for High Energy Astrophysics
- Naval Research Laboratory
- Stanford University – Hansen Experimental Physics Laboratory, Kavli Institute, and SLAC
- Texas A&M University – Kingsville
- University of Washington
- Washington University, St. Louis

France
- CNRS / Institut National de Physique Nucléaire et de Physique des Particules
- Commissariat à l'Energie Atomique / Direction des Sciences de la Matière/ Département d'Astrophysique, de physique des Particules, de physique Nucléaire et de l'Instrumentation Associée

Italy
- Agenzia Spaziale Italiana (ASI), Science Data Center
- Istituto di Astrofisica Spaziale, (IASF, CNR)
- Istituto Nazionale di Fisica Nucleare (INFN)

Japan GLAST Collaboration
- Hiroshima University
- Institute for Space and Astronautical Science
- RIKEN

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

Partner Contributions to LAT

- Precision Si-strip Tracker (TKR)

  - Italy (ASI/INFN): provide Si-strip detectors & test all detectors, assemble & test detector trays, assemble & test TKR modules

  - Japan: provide Si-strip detectors & oversee detector production

  - SU-SLAC & UCSC (USA): provide Si-strip detectors, front-end electronics, cable plant

- Hodoscopic CsI Calorimeter (CAL)

  - IN2P3 (France): mechanical structure; CEA (France): engineering model prototypes of CDEs & test equipment;

  - Sweden: CsI xtals & acceptance testing;

  - NRL (USA): front-end electronics, provide photodiodes, assemble & test CDEs and CAL modules

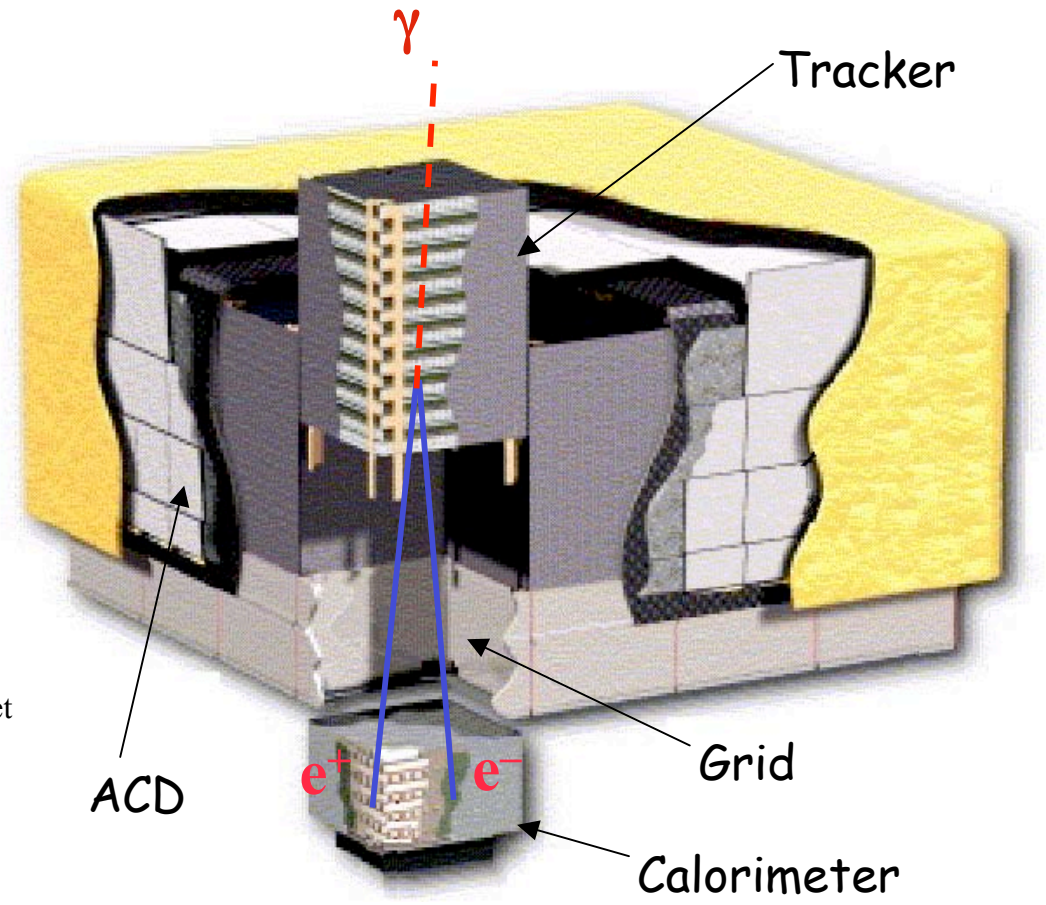
- Segmented Anticoincidence Detector (ACD) including micrometeoriod shield / thermal blanket
  - GSFC (USA)

- Electronics System

  - SU-SLAC & NRL (USA): global electronics and DAQ equipment; flight software

- Mechanical Thermal System

  - SU-SLAC (USA): provide LAT Grid, thermal radiators, heat pipes & ancillaries



- LAT I&T

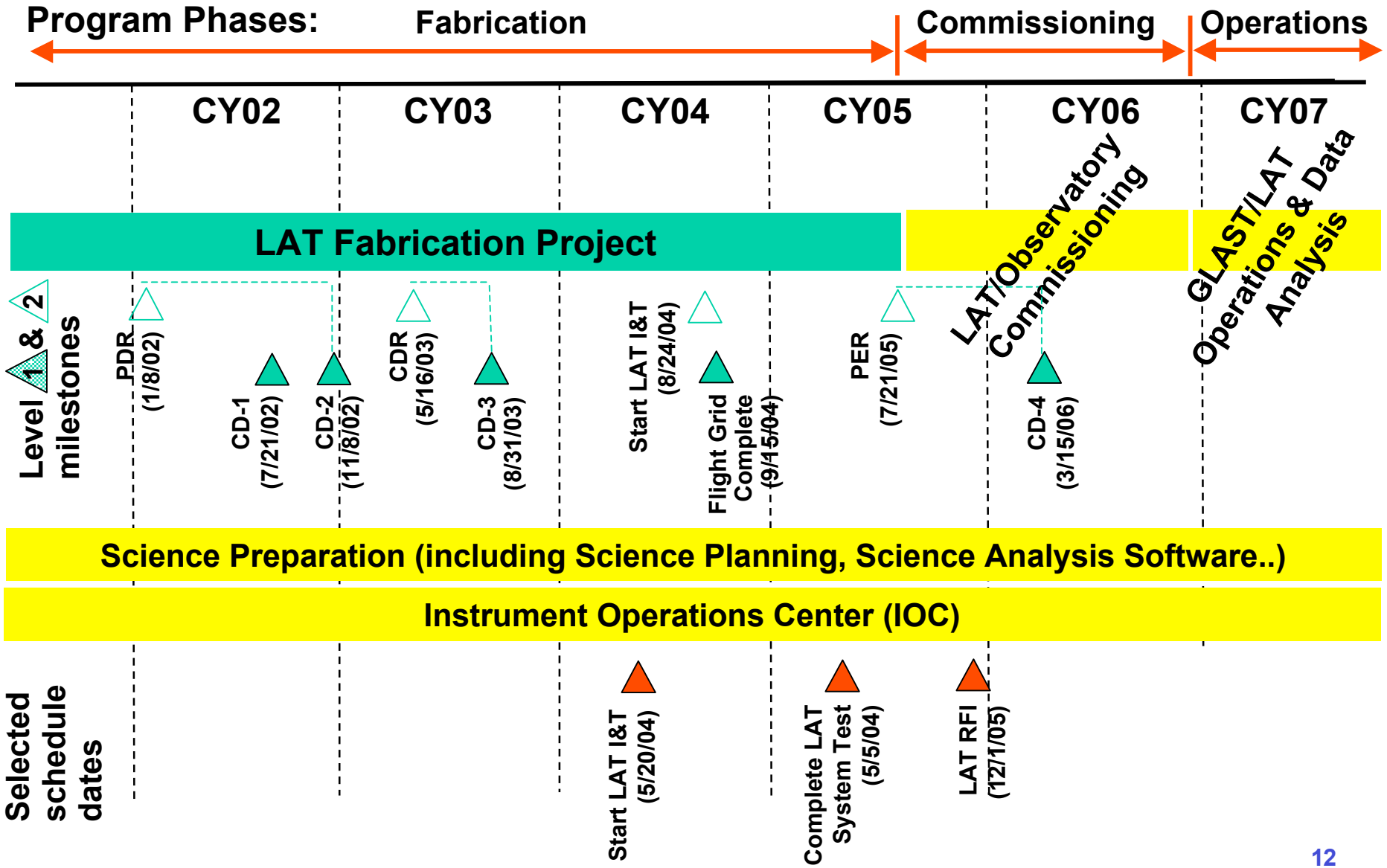
  - SU-SLAC (USA): assembly & test of LAT; provide particle/photon test beams

  - NRL (USA): instrument-level environmental tests

GLAST LAT Status Overview

- Following CNES withdrawal in June '03, LAT Project carried out re-planning:
  - LAT Project presented proposed cost & schedule changes and management changes at DOE-NASA LAT Rebaseline Review held July 31, 2003
  - Rebaseline approved
- LAT is supporting preparations for NASA Mission Confirmation Review
- Collaboration meeting held in Rome, Italy (@ Accademia di Lincei): September 15-17, 2003
  - day 1 & 2: LAT development status; planning for operations phase; kickoff of Data Challenge I
  - day 3: Joint LAT Collaboration – GLAST SWG Science Symposium on Sources of Diffuse High-Energy Radiation
  - (followed by GLAST Mission SWG meeting on September 18)

Elements of GLAST LAT Program

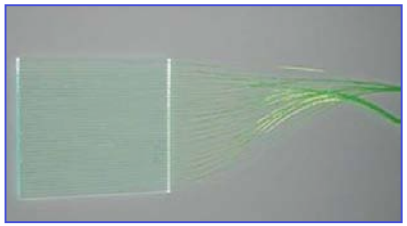


Subsystem Development

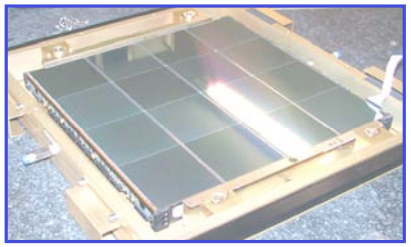
Subsystem development follows systematic progression:

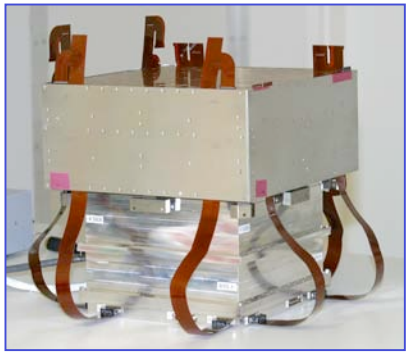
- early test articles (proving concepts of components)
- component beam tests
- single tower balloon flight & beam test
- mechanical prototypes and engineering model (**EM**) now
- qualification units (2 towers)
- flight units (16 towers)

LAT Engineering Model Examples

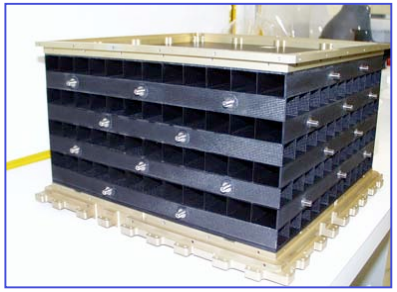


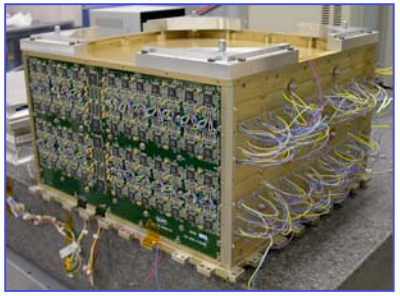
ACD Tile Detector Assembly





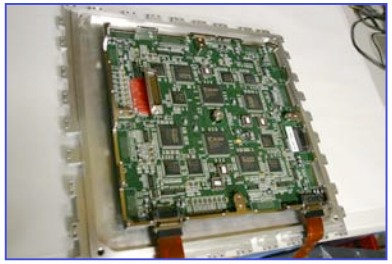
Tracker mini-tower

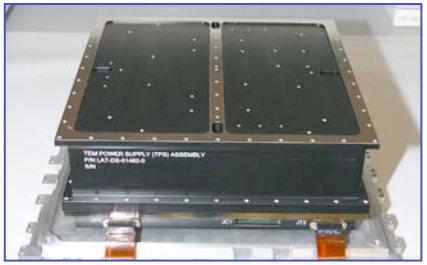




Calorimeter module

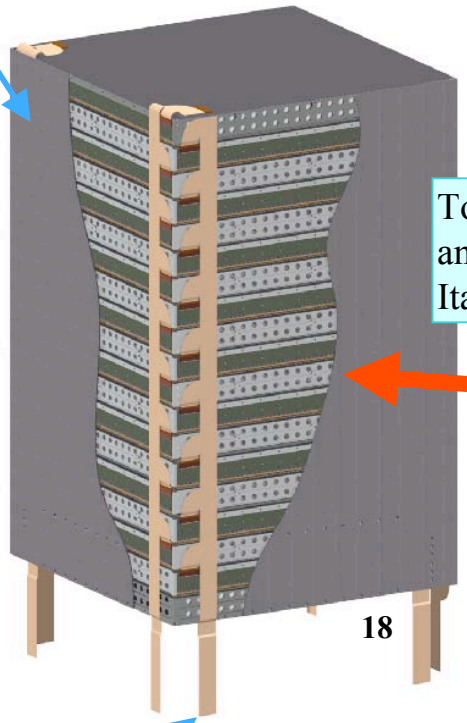
Tower Electronics Module (TEM)





Tracker Components

Tower Structure
Italy, SLAC



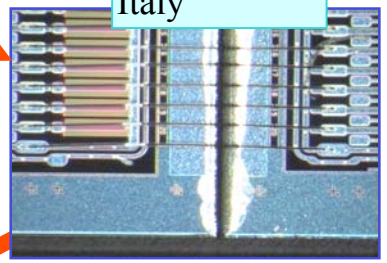
18

Cable Plant
UCSC

SSD Procurement, Testing
Japan, Italy, SLAC

10,368

SSD Ladder
Assembly
Italy



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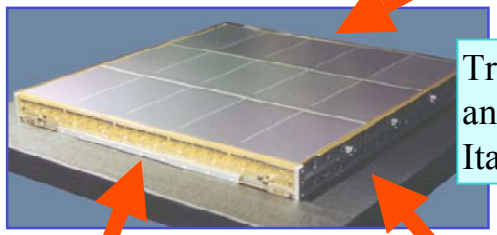
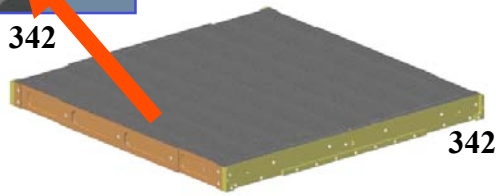
Tower Assembly
and Test
Italy (18)



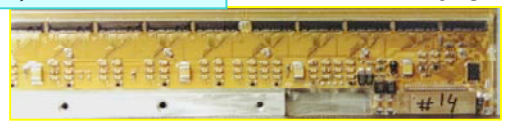
Tray Assembly
and Test
Italy

342



342

Electronics Design,
Fabrication & Test
UCSC, SLAC



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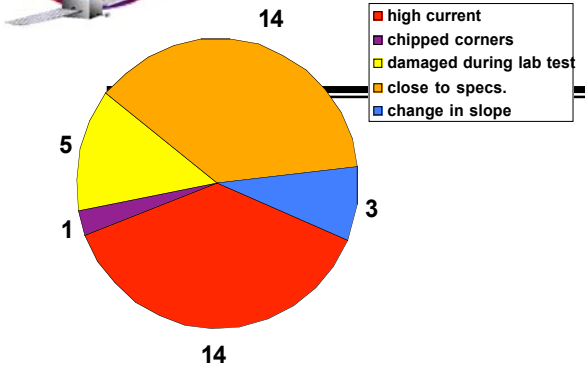
Composite Panel & Converters
Italy, SLAC

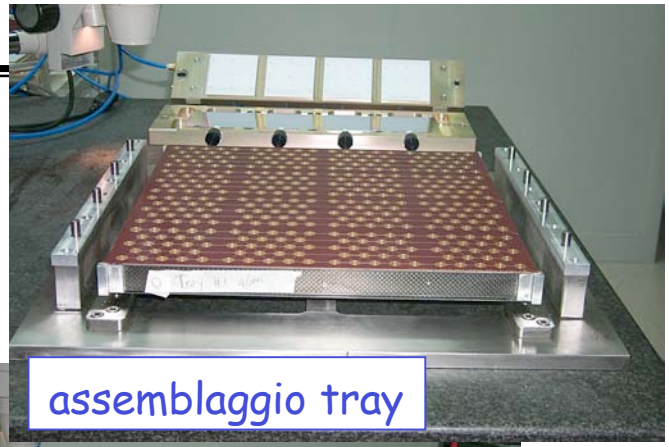
16 flight modules + 2 spares

Hardware Assembly and Test in Italy

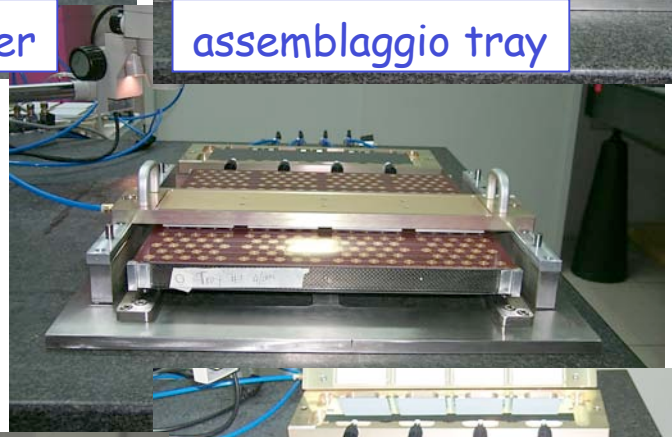


test ottici ed elettrici:
37/3500 ~ 1% SSD rejected

assemblaggio ladder

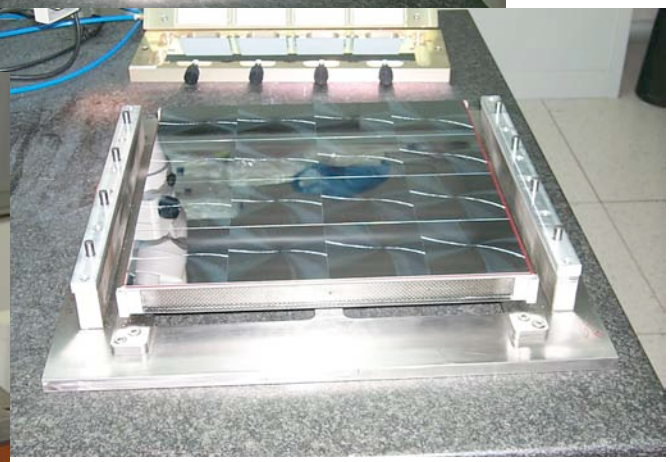


assemblaggio tray

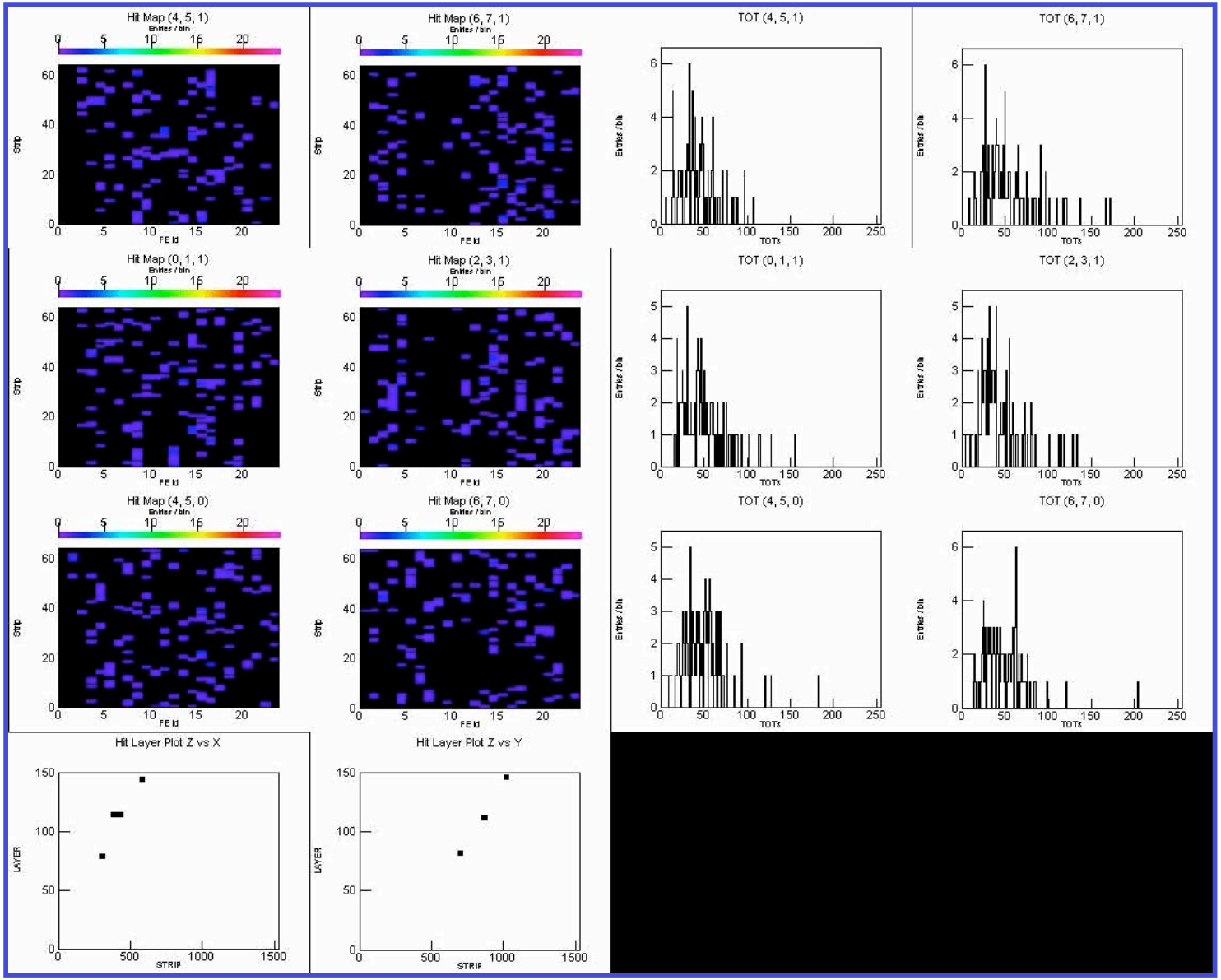


assemblaggio torre

test vibrazionale



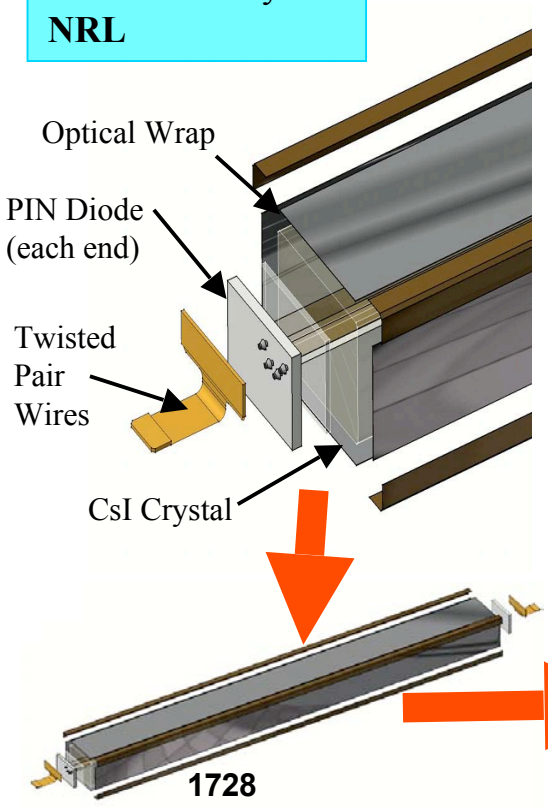
Tracker mini-tower tests at Pisa/SLAC



Calorimeter Production Overview

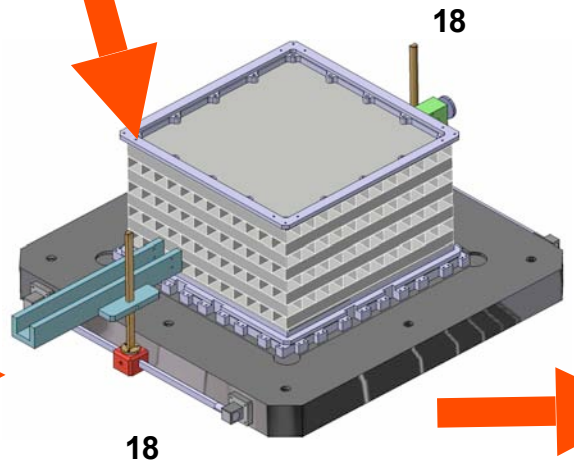
CsI Crystals
Sweden (KTH)

CDE Assembly
NRL



16 flight modules + 2 spares

Mechanical Structure
France (IN2P3/Ecole Polytechnique)

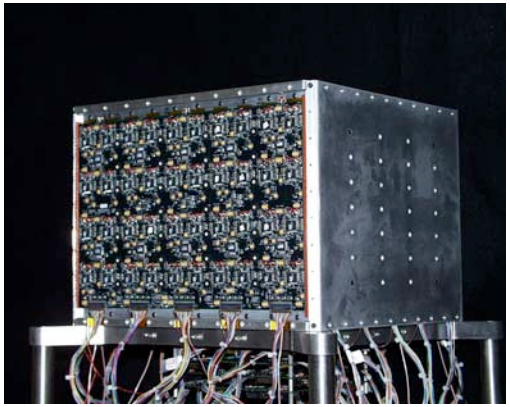


PEM Assembly
NRL

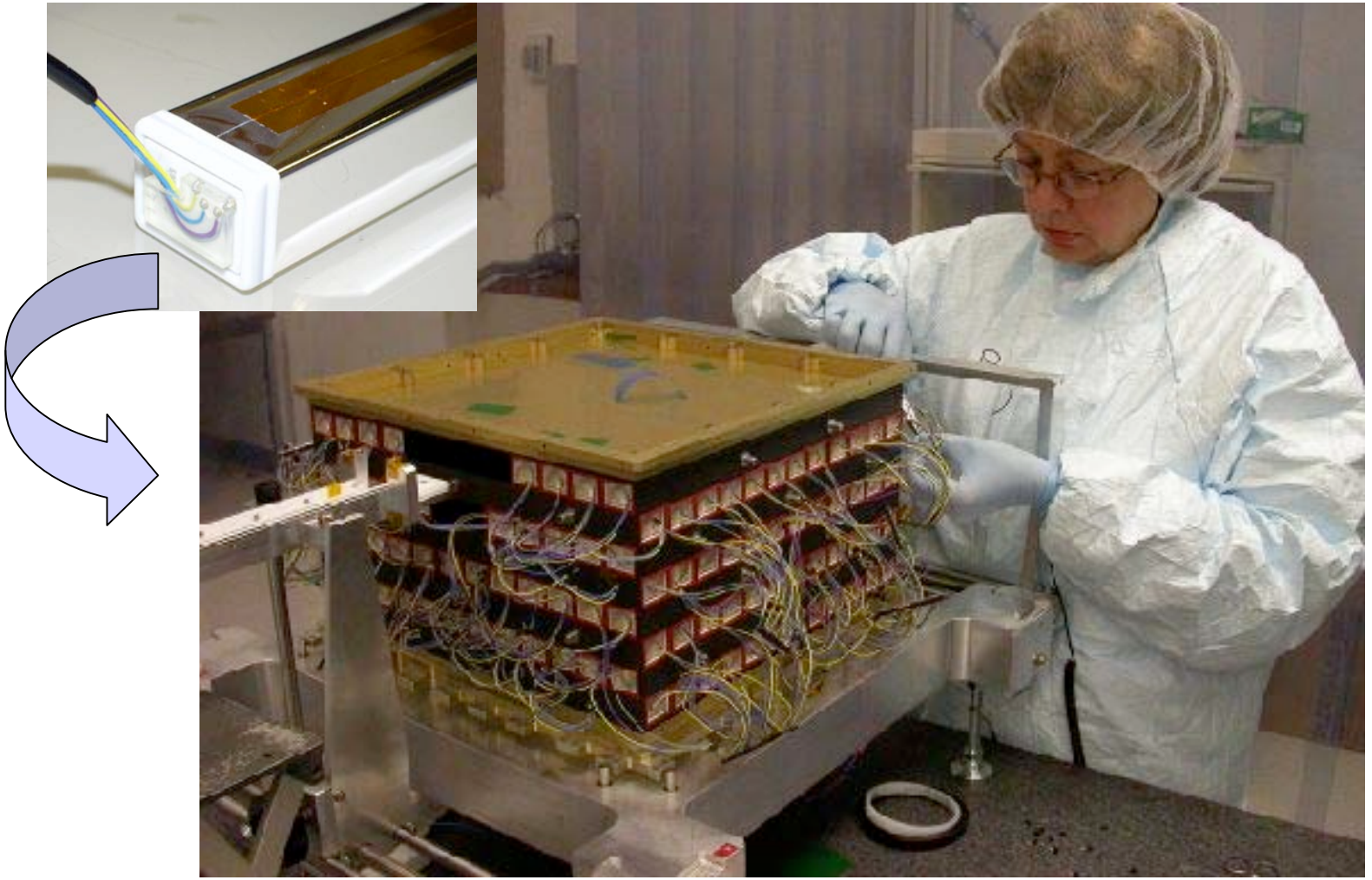
Front-End Electronics
NRL, SLAC

18

Module Assembly
and Test, **NRL+collab**



CAL Engineering Model in Production



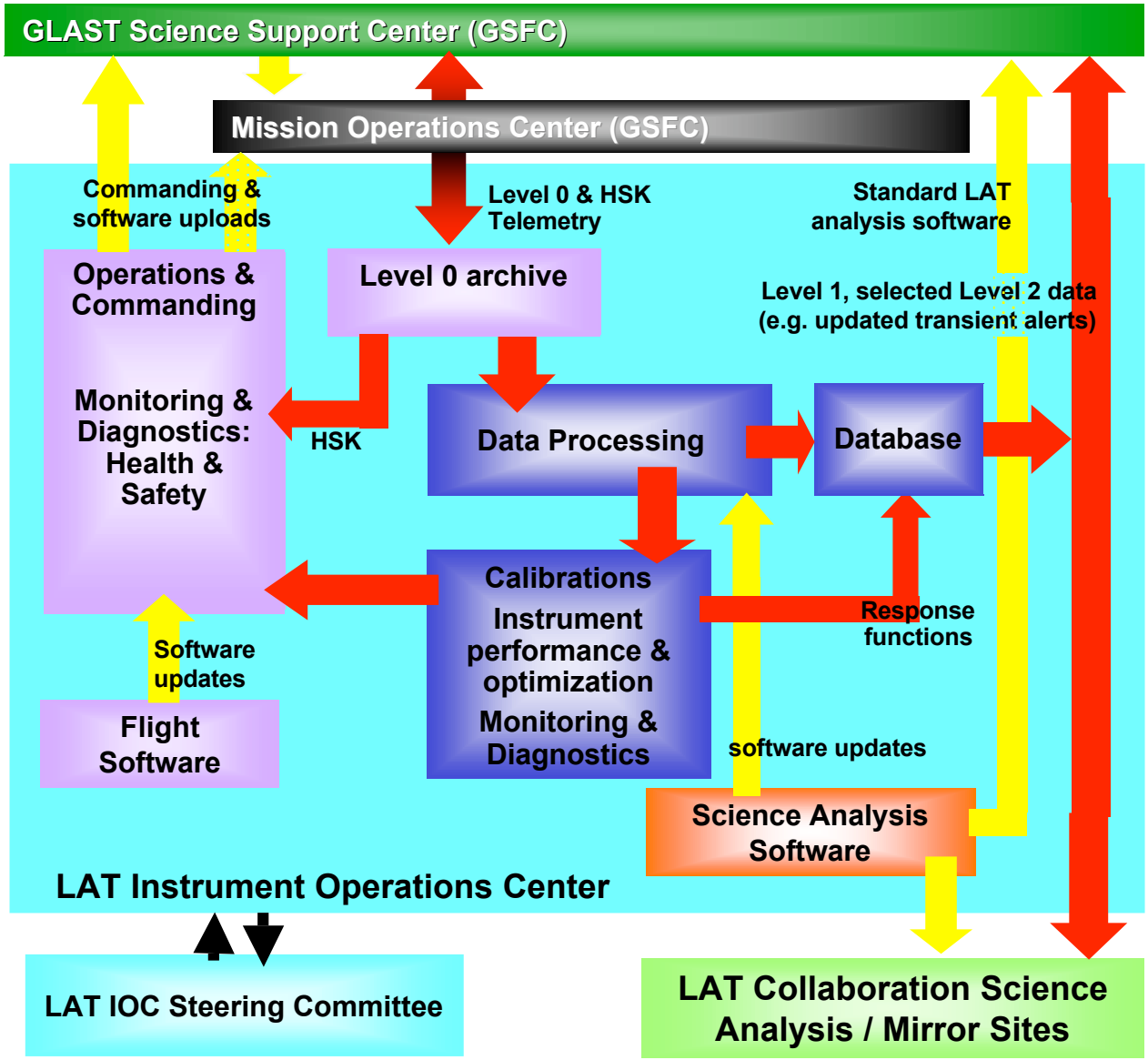
ACD Technical Status

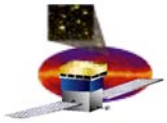
- GSFC, with critical ASIC help from SLAC and collaboration with Washington University on fibers
- Environmental tests of components complete
- First subsystem through its CDR (January)
- Long-lead flight procurements in progress
- Finalizing manufacturing plan
- Closing remaining details of systems environmental requirements
- ACD Electronics Module: EM1 version designed, built, and tested; EM2 version (interfaces, functions, and components as flight-version) in design.

Full-scale mock-up of ACD being used for tile placement and fiber routing

LAT Instrument Operations Center

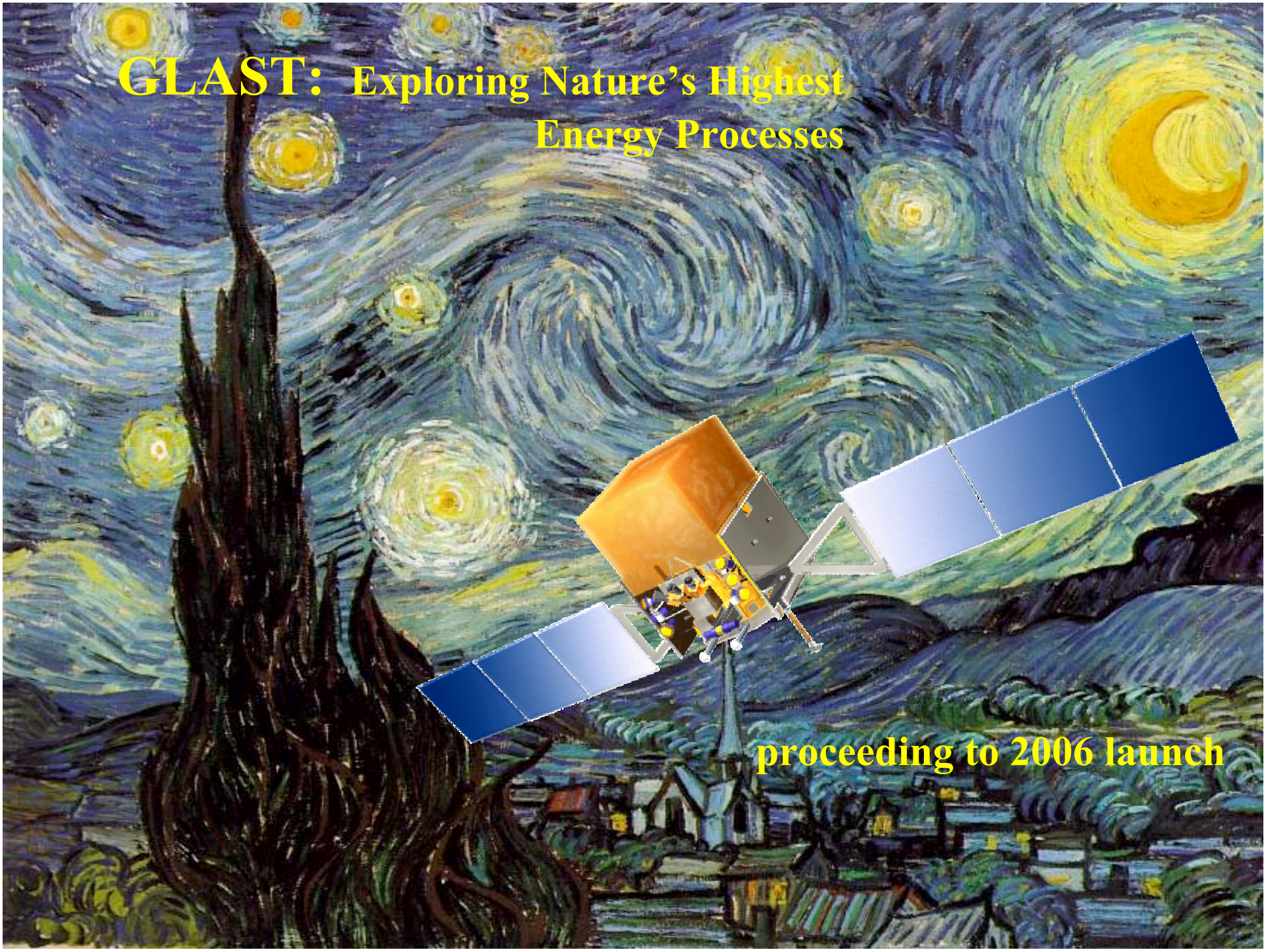
- Receive Level 0 data telemetry packets from MOC
- Perform science data production to generate Level 1 products
- Build and verify commanding plan for LAT instrument
- Support housekeeping monitoring of the instrument for health and safety
- Verify instrument performance and trending
- Archive all Level 0 telemetry packets and Level 1 products
- Develop (with SSC) Standard LAT analysis software
- Support LAT Collaboration science investigation





Science Analysis Software Technical Status

- Key contributions from Italy and France in many areas of SAS, distributed across institutions => frequent meetings via vrvs.
- New version of the simulation and recon packages: GLEAM
  - Geant4 for particle transport
  - revised reconstruction with many improvements underway
- Support for calibrations planning
  - infrastructure under development and testing for EM
  - database implementation underway. TKR hot/dead strip lists being used as first client
- Data processing facility prototyped for use with EM
- Science tools support
  - defining requirements for higher level analysis tools. Reviewed in September 2002.
  - end-to-end testing, "Data Challenges" planned (DC1 underway)


GLAST: Exploring Nature's Highest Energy Processes
proceeding to 2006 launch