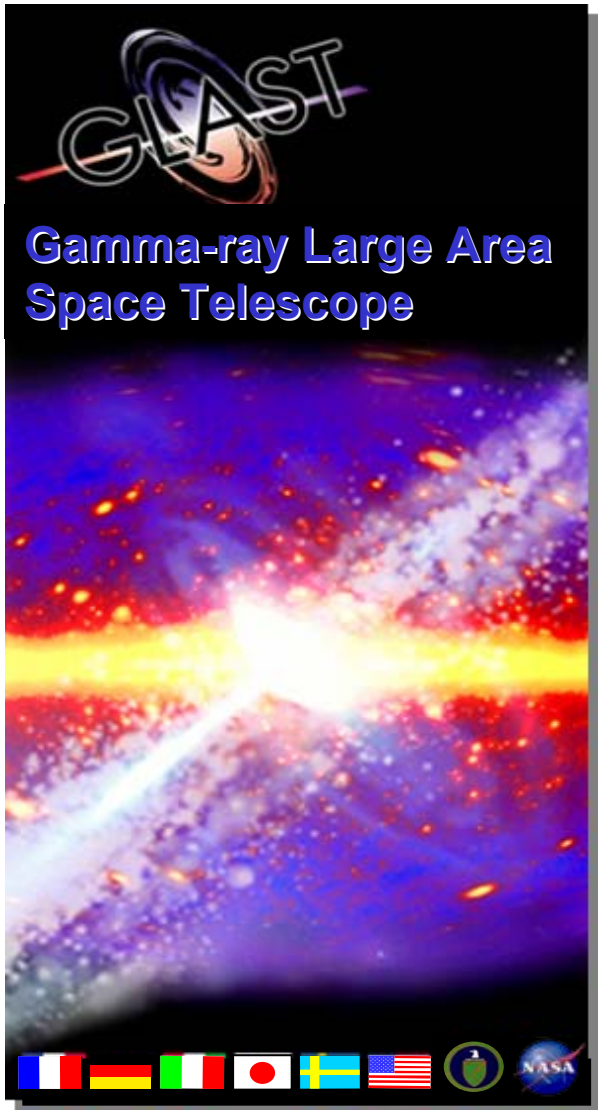


GLAST Large Area Telescope

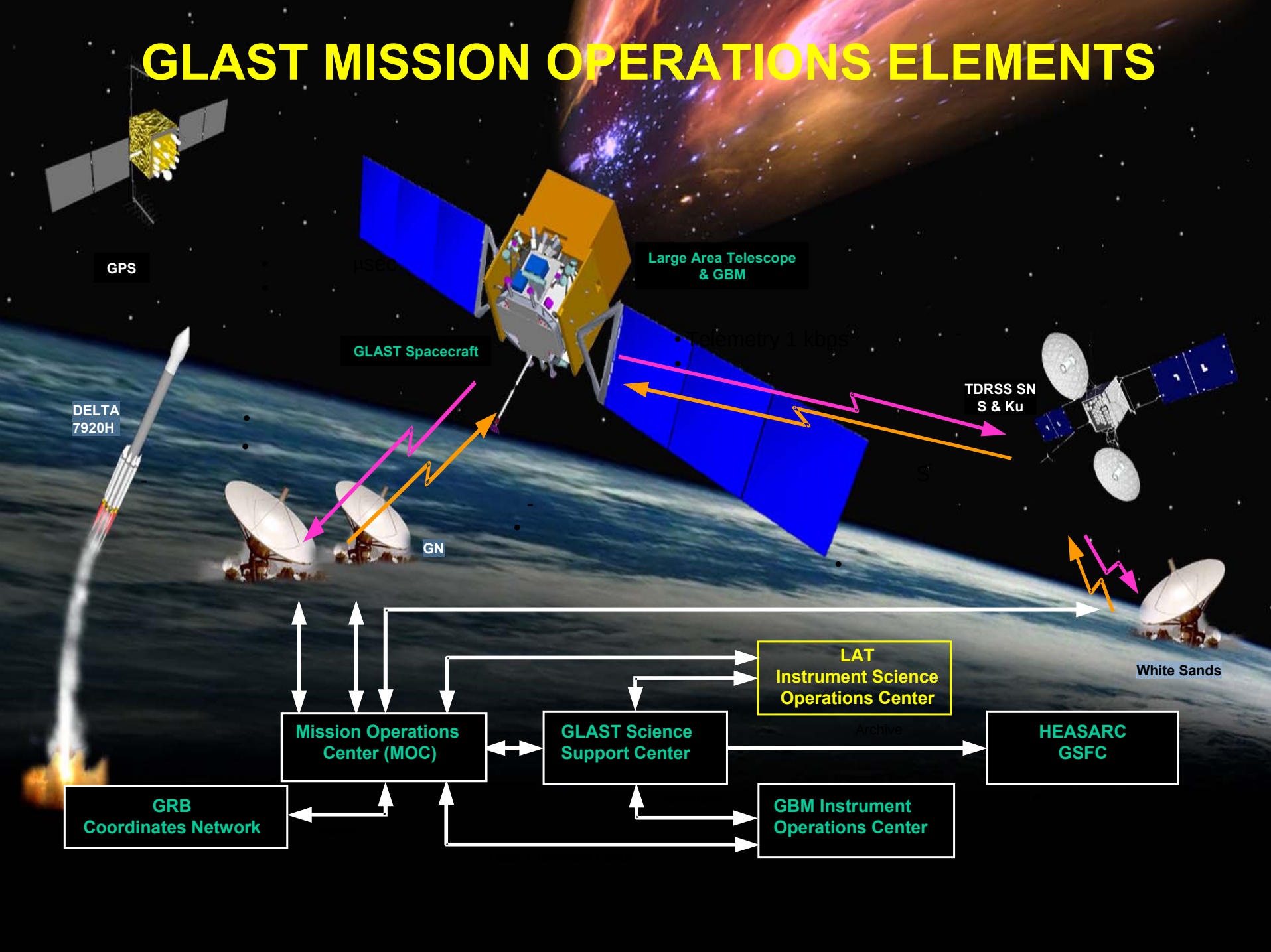
Instrument Science Operations Center Overview

Rob Cameron
Stanford Linear Accelerator Center
rac@slac.stanford.edu
650-926-2989

Outline

- GLAST Mission Operations Overview
- ISOC and the LAT Collaboration
- ISOC Organization and Functions
  - Flight Operations Concept
  - Online Operations, Flight Software
  - Science Operations and Instrument Monitoring
  - Offline Processing
- The LAT Operations Facility at SLAC
- The Road to Launch

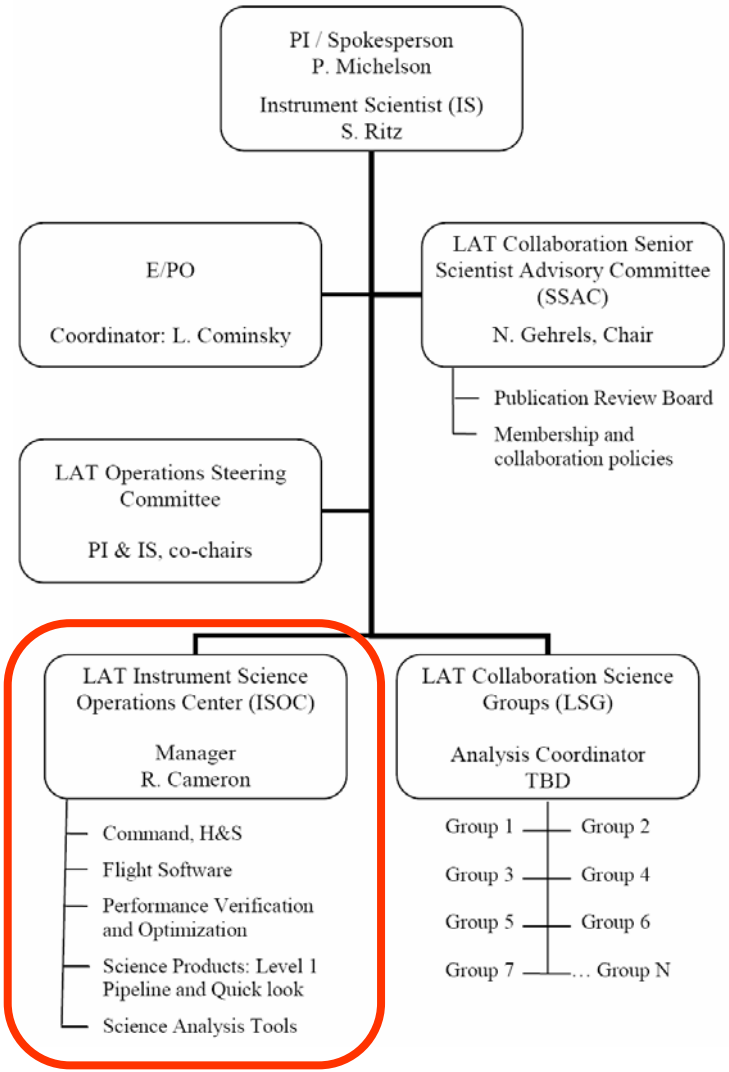
GLAST MISSION OPERATIONS ELEMENTS



LAT ISOC Activities

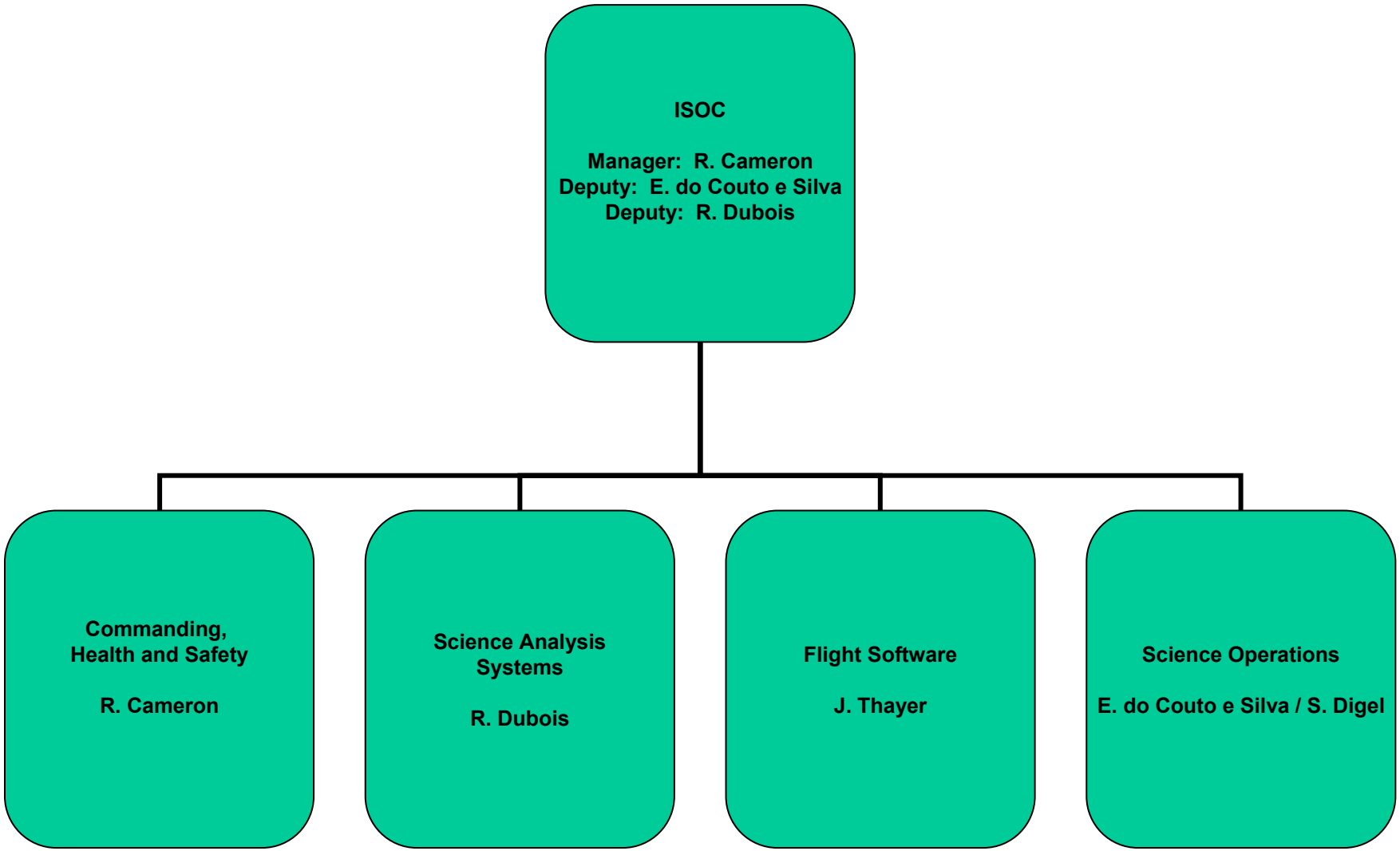
- The LAT ISOC is organized to:
  - Safely operate the instrument
  - Generate reconstructed LAT events and automated science products
- Main Functions:
  - LAT command planning and construction
  - Instrument health and safety monitoring
  - Maintain and modify LAT FSW and the LAT Testbed
  - LAT performance verification and optimization
  - Process and archive LAT data
  - Maintain and optimize the software that produces science data
- Incorporates online and offline operations activities for the LAT
  - Extends existing pre-launch activities into on-orbit operations
- Supports the GLAST mission and the LAT collaboration

The ISOC in the LAT Collaboration



- The ISOC is the core of the LAT support activities at SLAC after the GLAST project delivers the instrument
- ISOC provides LAT data to the collaboration during the first year of the mission, and beyond
- ISOC has close connections to LAT Science Groups
  - e.g. Working with Calibration and Analysis Methods Group to incorporate improvements to event reconstruction into ISOC processing and products
- ISOC has broad involvement in the LAT collaboration
  - e.g. instrument performance analysis and tool development by the collaboration are coordinated through the ISOC

ISOC Organization



ISOC Team Activities and Responsibilities

Commanding, Health and Safety

- LAT mission planning support
- Generate and validate LAT commands
- Pass LAT commands to the GSSC
- Verify correct commands execution
- Receive Level 0 data from the MOC
- Log and archive commands and Level 0 data
- Monitor LAT health and safety
- Maintain continuous knowledge of the configuration of the LAT

Flight Software

- Develop, test, and maintain LAT on-board flight software
- Develop and maintain software tools for the development, testing, and documentation of the operational LAT flight software
- Maintain the LAT Configuration
- Maintain the Dataflow lab and LAT testbed
- Maintain and develop documentation
- Interface with other ISOC groups to troubleshoot issues on orbit

Science Operations

- Characterize, monitor and optimize LAT Performance at all levels
  - individual LAT detectors
  - LAT as an integrated particle physics instrument
  - LAT as a high energy gamma ray detector
- Maintain LAT calibration
- Investigate any instrument anomalies
- Coordinate LAT operations duty scientist program
- Level1 product generation
- Automated science processing & alerts
  - Monitoring of selected celestial sources
  - Detection and monitoring of GRBs and flaring sources

Science Analysis Systems

- Support software development environment and tools
- Supports ISOC and the LAT collaboration
- Instrument data processing: reconstruction, calibration and simulation
- High level science tools & automated science
- Automated processing pipeline machinery
- Moving towards providing all software development for the LAT ground systems
- Acquire and coordinate most LAT compute resources at SLAC: bulk CPU and disk usage
- Database and web development
  - System tests, Data Monitoring
  - Tools used in ISOC day-to-day handling of downlinks

ISOC Operations Concept

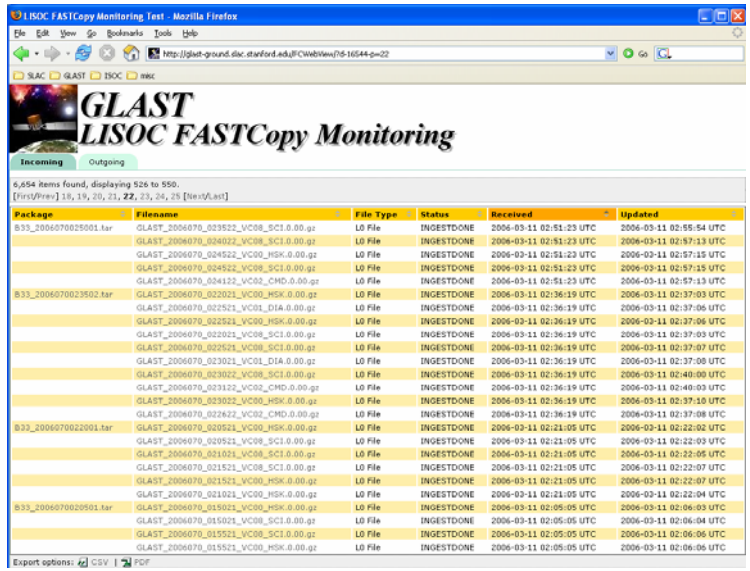
- Continuous data taking by the LAT on orbit
  - Data taking runs controlled by time-tagged LAT commands stored on-board GLAST
  - Interrupted by SAA passages, infrequent calibrations, etc.
- Data downlinked from GLAST through MOC to ISOC ~8x per day
- During contacts with GLAST
  - Real-time housekeeping telemetry flows to ISOC
  - Any needed real-time commanding of LAT, performed by MOC under ISOC direction
- Combination of manual and automated activities at ISOC
  - Manual: mission planning support, command load preparation
  - Automated: Health and safety monitoring
  - Automated: Receipt, processing, archiving of Level 0 (raw event) data; production and archiving of Level 1 (reconstructed events) and selected Level 2 (science) data
- MOC staff supports weekday, day-time operations during normal mission
  - ISOC supporting operator coverage
    - 5 am to 2 pm to cover MOC shift times on East Coast
    - 9 am to 6 pm to cover ISOC activity at SLAC
  - On-call support by ISOC operations staff for anomalies and real-time commanding
- Scientists from LAT collaboration will also provide 24 hour support for monitoring science data
- Weekly cycle for GLAST & LAT mission planning during normal mission
- Simple anomaly response requirements for GLAST Flight Ops Team at MOC
  - Notify the ISOC
  - Follow defined contingency procedures

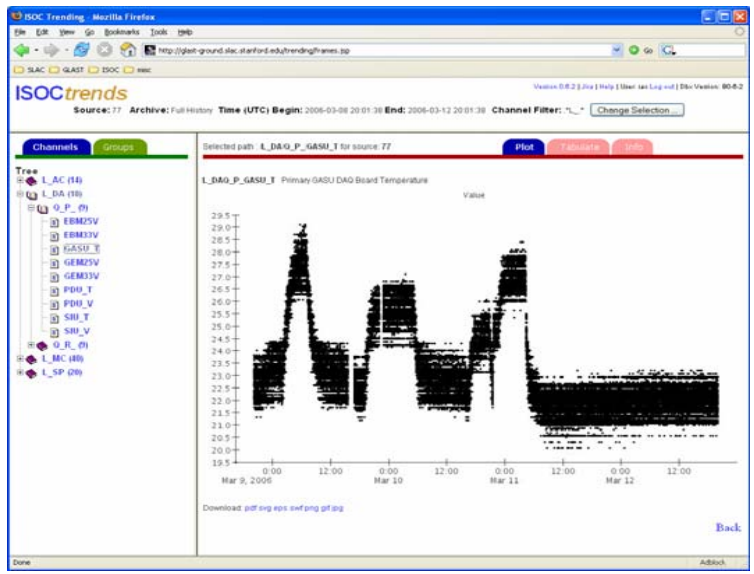
Pre-launch Activity

ISOC infrastructure has supported LAT Integration and Test activity

- Offline processing pipeline
- Data transport from test env. to SLAC
- Level 0 data ingest and archive

- Same infrastructure used for
  - I&T at SLAC
  - LAT Environmental test at NRL
  - Observatory I&T at SASS
  - Pre-launch support at KSC
  - Beam test at CERN
  - Flight Operations



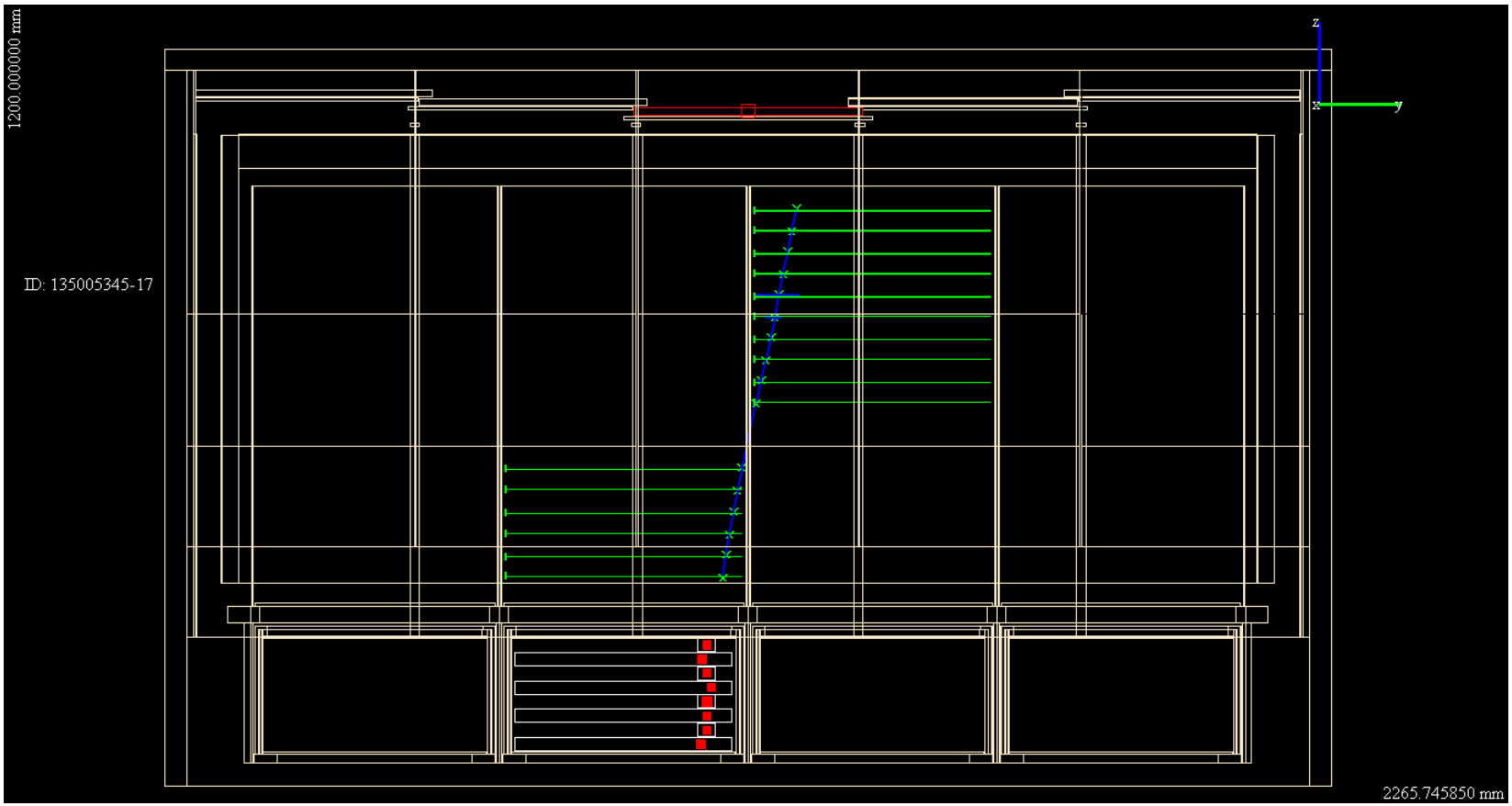


LAT Online Operations with Flight Software

- LAT is now being operated through Flight Software control
  - ~1000 hours of operation by FSW since April
  - 300 million triggers have been logged since running with FSW
- New online testing framework deployed for use with FSW
  - LAT Instrument CheckOut System (LICOS)
  - Significant inheritance from previous non-FSW system: LAT Test Executive (LATTE)
- The same LICOS-based LAT testing environment and procedures used at SLAC are in use at NRL for LAT environmental testing, and are planned for use at Spectrum Astro during Observatory I&T
- FSW is an integral part of the LAT data acquisition (DAQ) subsystem and is developed and managed as part of the DAQ subsystem
  - > 3 million configuration bits to configure system and to take event data properly
  - Configuration of the LAT is identified through on-board files
- On-board FSW file system is managed within online test framework using FMX file management database
  - FSW file system databases are mirrored between SLAC and LAT Test Ground Support Equipment (at NRL or Spectrum Astro)

Muons

- During ground testing, measurements of cosmic ray secondaries provide data to analyze and monitor detector performance and verify science data integrity.



Science Operations: Level1 Data Run Reports

SVAC Report

v3r4p9

PS file PDF file

Author:
{automatically generated}

Purpose

This report is used in offline data analyses to identify apparent problems in cosmic ray muon and VDG data. **Warning! Results from other tests (such as charge injection) should be interpreted with care.**

Software Version

- EngineeringModel: **v5r070305p4**
- TestReport: **v3r4p9**

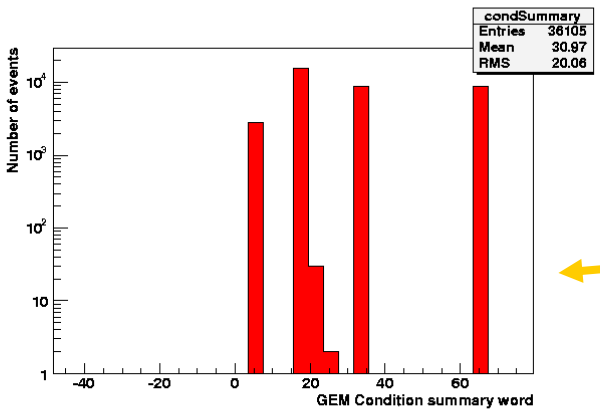
Summary

In the digi file */nfs/farm/g/glast/u25/Integration/rootData/600001188/v5r070305p4/grRoot/digiReport-v3r4p9_600001188_digi_DIGI.*root

- There are **36105** triggers. There should be 36107 events recorded in the eLog database since LATTE adds two additional events in the process which are not triggered events.
- There are **37** bad events
- There are **0** events with Trigger Parity errors
- There are **0** events with Packet errors
- There are **37** events with TEM errors
- There are **0** events with ACD Odd Parity errors

Trigger

GEM condition summary word. The word is deduced by combining bit patterns from the table shown below. For example, an event with both the TKR trigger bit and the CAL low trigger bit set in GEM has the condition summary word of $2^2 + 2^1 = 6$



GEM Condition summary word

Trigger bit	0	1	2	3	4	5	6	7
Summary	ROI	TKR	CAL Low	CAL High	CNO	Periodic	Solicited	External
Number of events	4083	4298	2819	2	15691	8898	8727	0

Muon run report from LAT I&T. To be adapted for charge injection tests and on-orbit operations and to include Level2 data

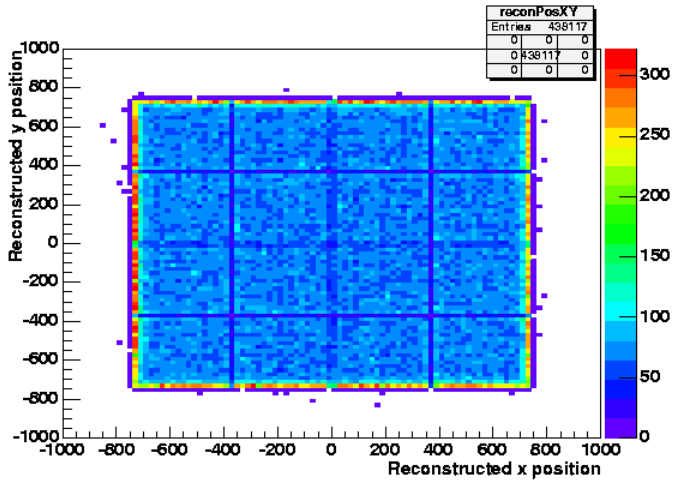
Software versions

Summary results for run and location of archived data

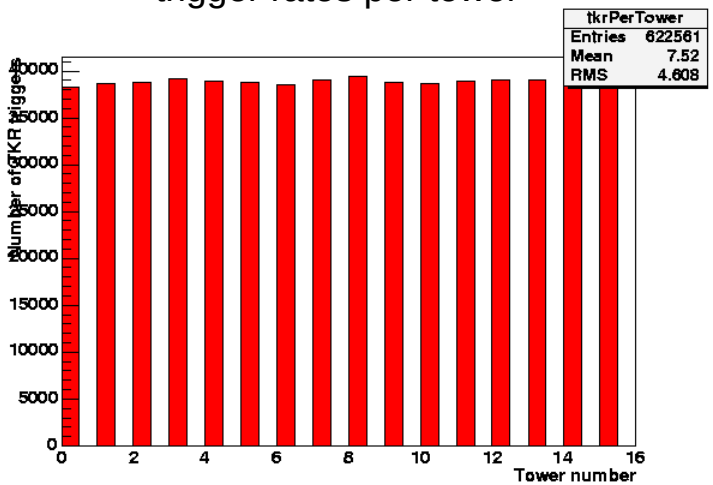
Graphical and Tabular Summaries Of Level1 Data and Instrument Performance for Run

Science Operations: Instrument Monitoring

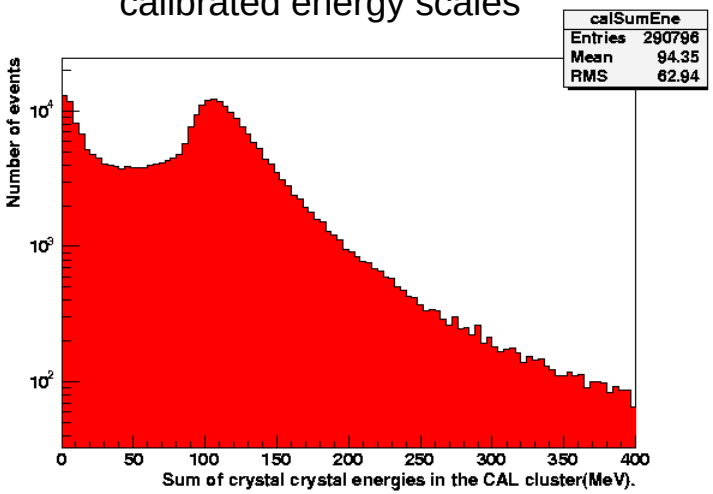
reconstructed track positions



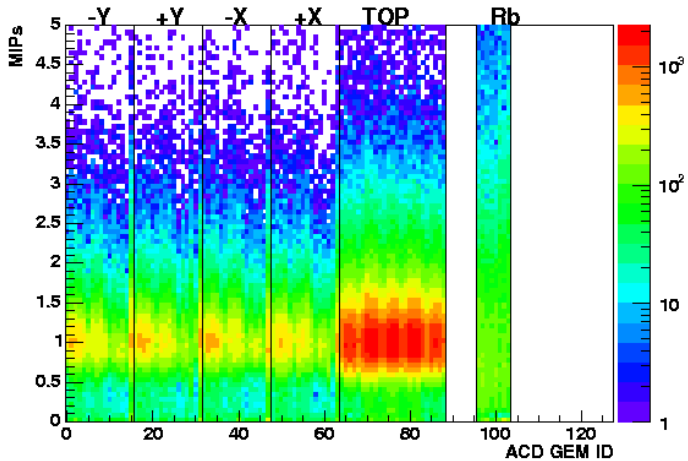
trigger rates per tower



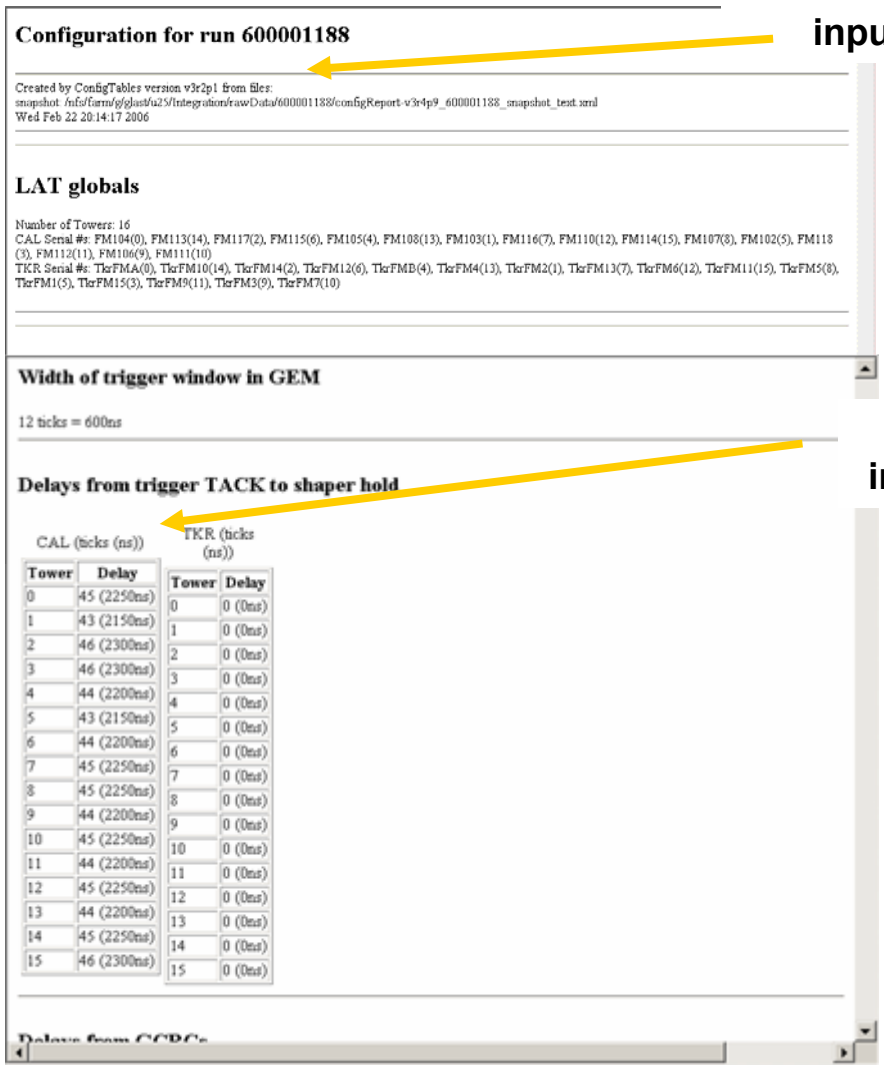
calibrated energy scales



ACD geometry and functionality



LAT Configuration Reports



Configuration for run 600001188

Created by ConfigTables version v3r2p1 from files:
snapshot /nfs/farm/g/glast/u25/Integration/rawData/600001188/configReport-v3r4p9_600001188_snapshot_test.xml
Wed Feb 22 20:14:17 2006

LAT globals

Number of Towers: 16
CAL Serial #s: FM104(0), FM113(14), FM117(2), FM115(6), FM105(4), FM108(13), FM103(1), FM116(7), FM110(12), FM114(15), FM107(8), FM102(5), FM118 (3), FM112(11), FM106(9), FM111(10)
TKR Serial #s: TkrFMA(0), TkrFM10(14), TkrFM14(2), TkrFM12(6), TkrFMB(4), TkrFM4(13), TkrFM2(1), TkrFM13(7), TkrFM6(12), TkrFM11(15), TkrFM5(8), TkrFM1(5), TkrFM15(3), TkrFM9(11), TkrFM3(9), TkrFM7(10)

Width of trigger window in GEM

12 ticks = 600ns

Delays from trigger TACK to shaper hold

CAL (ticks (ns))

Tower	Delay
0	45 (2250ns)
1	43 (2150ns)
2	46 (2300ns)
3	46 (2300ns)
4	44 (2200ns)
5	43 (2150ns)
6	44 (2200ns)
7	45 (2250ns)
8	45 (2250ns)
9	44 (2200ns)
10	45 (2250ns)
11	44 (2200ns)
12	45 (2250ns)
13	44 (2200ns)
14	45 (2250ns)
15	46 (2300ns)

TKR (ticks (ns))

Tower	Delay
0	0 (0ns)
1	0 (0ns)
2	0 (0ns)
3	0 (0ns)
4	0 (0ns)
5	0 (0ns)
6	0 (0ns)
7	0 (0ns)
8	0 (0ns)
9	0 (0ns)
10	0 (0ns)
11	0 (0ns)
12	0 (0ns)
13	0 (0ns)
14	0 (0ns)
15	0 (0ns)

Delays from GCRCs

input configuration file

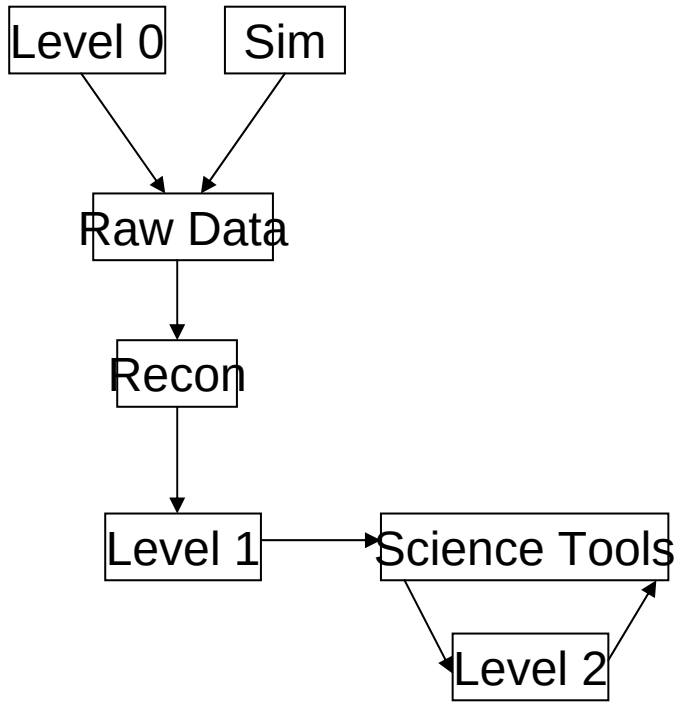
LAT configuration controlled and tracked by a database system for on-orbit operations

Values of timing registers in raw value and engineering units

Calibration and other operational settings are not shown but are also present

Offline Operations

- **Key activities**
  - **Science data processing**
  - **Event reconstruction**
  - **Automated science processing**
  - **Serving data to the LAT collaboration**
- **Uses SLAC SCS computer farm**
- **Flexible implementation**
  - **Pipelined data processing**
- **Supports LAT I&T, used for data challenges and beam tests**



More details given in presentation by R. Dubois

Reconstruction: interpret LAT readout and estimate directions and energies; flag background

Simulation: full modeling of e/γ/p interactions and readout in the LAT

LAT Science Data Processing

- LAT science data processing uses SLAC SCCS computer farm
- Resource requirements:
- Assume equal MC to data
- Need to filter background in early processing stages
- Use ~ 50TB of disk storage per year
  - More for first year of mission, to avoid background filtering?
- Need ~80 2006-era CPUs to turn around one downlink (≡ 3 hrs data) in one hour
  - Aiming for 350-400 GLAST CPUs, based on DC2 experience. Will also use SLAC general queues for noticeable periods
- From background runs produced for DC2
  - Expect ~450 Hz avg rate for events passing on-board filter
- LAT data rate = 1.2 Mb/sec = 5 TB/yr
- Assume all downlinked events kept
  - ~1% good celestial photons
  - Must process all events to make selections

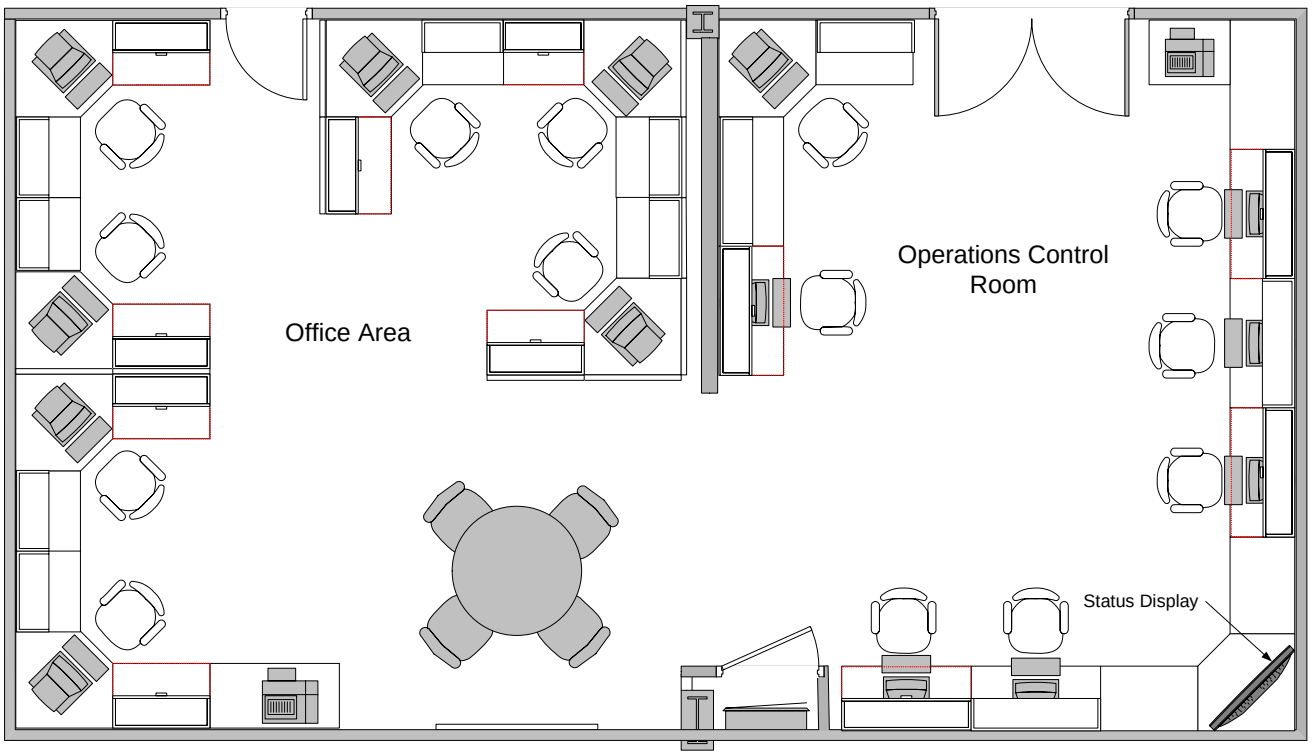
	Recon CPU	Merit size	MC size	Digi size	Recon size
Per event	0.06 sec	0.5 kB	28 kB	1.5 kB	8.6 kB
Per day	650 hrs	19GB	1100GB	58 GB	333GB
Per year		7 TB	252 TB	21 TB	121 TB

LAT Operations Facility

- LAT Operations Facility located in SLAC Building 84, Central Lab Annex
  - Operations Control Room
    - Dedicated work area for LAT flight operations activity
    - Being built and configured in 2006, to support pre-launch operations testing
  - Dataflow Lab
    - Existing Dataflow Lab houses LAT testbed and other test stands
    - Lab area will be expanded in 2006/2007, to accommodate existing equipment plus flight spares and EGSE inherited from LAT Integration & Test
      - Beam Test Calibration Unit
        - » 2 Trackers (flight spare + non-flight)
        - » 4 CAL units (3 flight spares + 1 EM)
        - » 4 flight TEMs
        - » GASU and other support electronics
      - LAT Power Rack/LAT Control Rack
      - Mobile Computing Racks
      - SIIS (Spacecraft to Instrument Interface Simulator)
      - Mini-LAT with muon telescope
- ISOC operations staff offices are being consolidated into building 84, near operations facility, as part of larger scale SLAC office moves

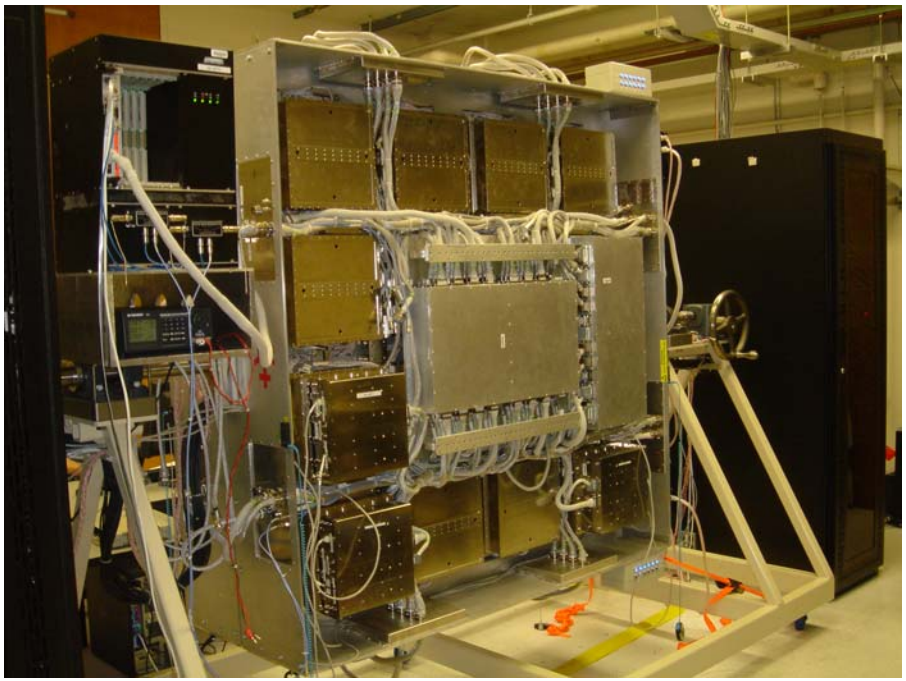
LAT Operations Facility (2)

- **Operations Control Room for LAT flight operations activity**
  - **Mission Planning**
  - **Realtime LAT telemetry display and monitoring**
  - **Testbed operations**
  - **Subsystem analysis**
  - **Dedicated display for GLAST and LAT flight information and status**

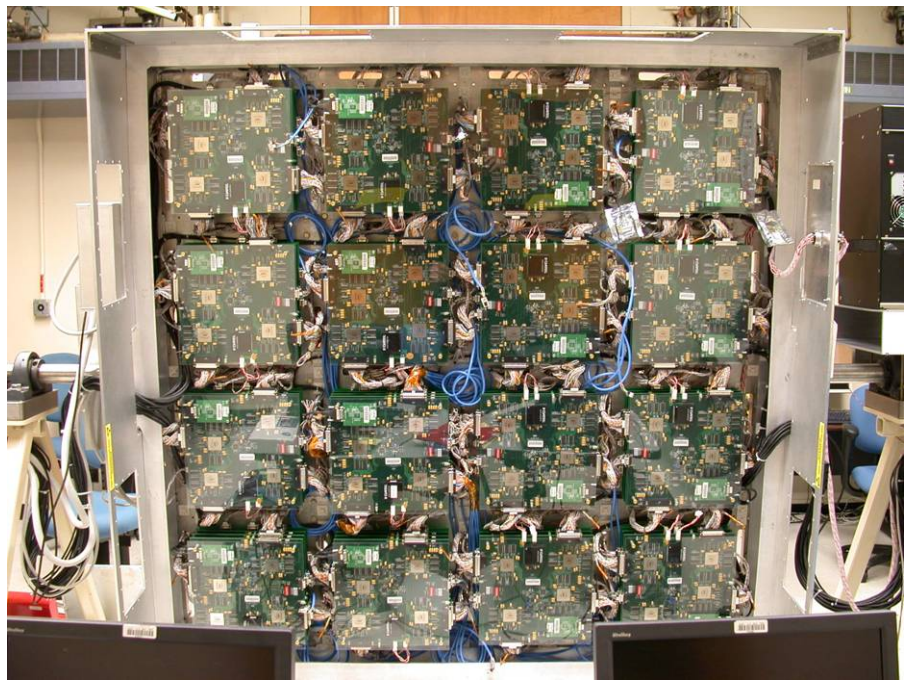


LAT Dataflow Lab

- Provides a full Trigger and Dataflow system with flight-like interfaces and hardware
- Front-end Simulator (FES) ingests Monte Carlo data
  - Dataflow integrity and throughput
  - Filter
- Real detector front-ends in LAT calibration unit detectors
- Supports ISOC operations
  - Command load verification before uplink
  - Instrument configuration validation
  - Flight software development and test platform

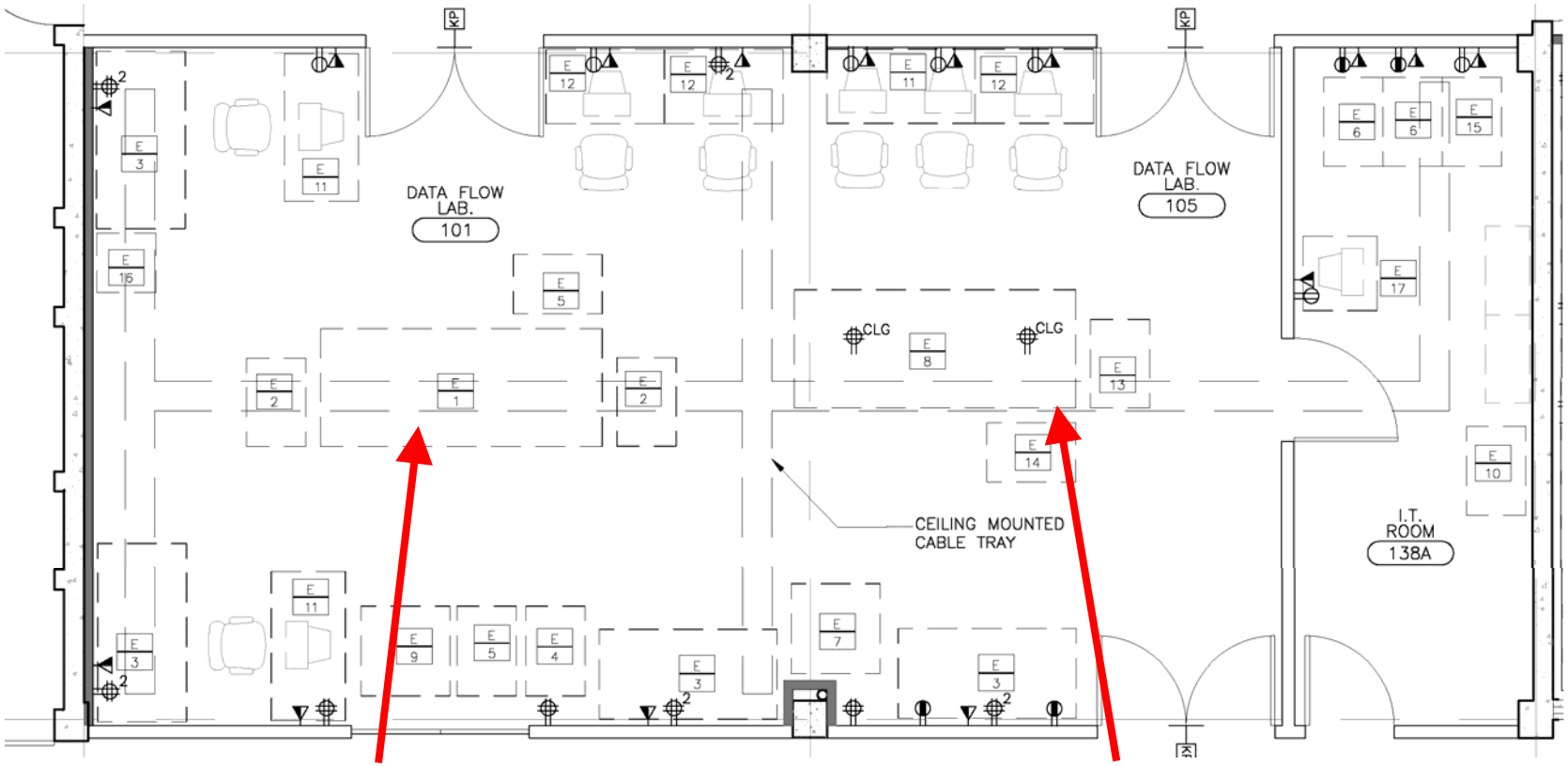


DAQ Testbed

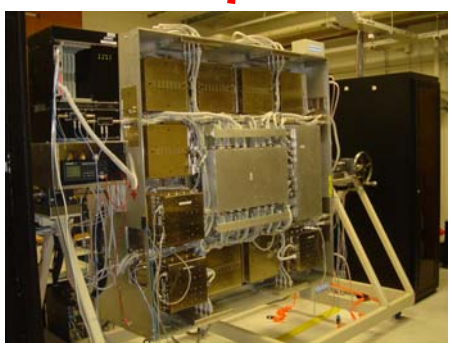


Simulator

Dataflow Lab Expansion

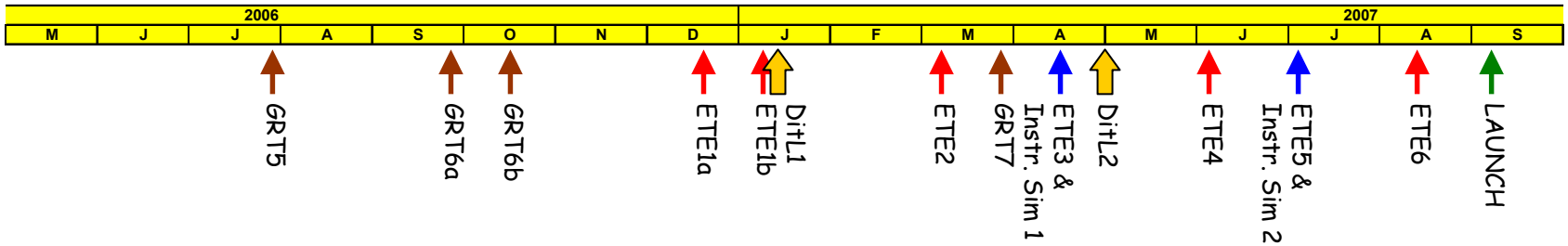


DAQ Testbed



Future: LAT Calibration Unit

The Road to Launch



- ISOC is participating in GLAST ground system tests with MOC, GSSC, GIOC
  - 2 Ground readiness test (GRTs) completed successfully to date
    - GRTs test and exercise interfaces between ground system elements
  - 6 End-to-End (ETE) tests, late 2006-2007
    - Exercise and verify ground systems with the integrated GLAST Observatory
  - Joint mission simulations with FOT, GBM and spacecraft teams
    - ISOC staff working in the MOC, to rehearse instrument activation and checkout
  - "Day in the Life" tests
    - Exercise mission planning activities and normal mission real-time commanding
- Workshops and Data Challenges
  - First ISOC workshop held in late 2005, modeled on successful Instrument Analysis workshops
  - Recently completed Data Challenge 2 - a great success
  - Planning for third Data Challenge is starting:
    - Further coordinated science group studies – multiple simulation datasets; no "secret sky"
    - ISOC service challenges and operations rehearsals – prepare for Science Operations
    - Joint activity between ISOC and LAT science groups – prepare for early operations analyses, first light observations, analysis tuning, background measurement ops, survey & pointed ops, ...

Backup Slides

ISOC Glossary

3EG	3rd EGRET Catalog
µm	10^{-6} meter
IA and DC2 Workshop	Instrument Analysis and Data Challenge 2 Workshop

A

ACD	The LAT Anti-Coincidence Detector Subsystem
AGN	Active Galactic Nuclei
Ahr	Amp-hour
ATS	Absolute Time Sequence
ATT/ANC	Attitude/Ancillary

B

BGO	Bismuth Germanate Detectors
Bkg rej	Background rejection

C

C&A	Calibration and Analysis Methods Groups
CAL	The LAT Calorimeter Subsystem
CCB	Configuration Control Board
CCSDS	Consultative Committee for Space Data Systems; a Spacecraft Packet Telecommand Standard approved by the Consultative Committee for Space Data Systems
CFG	Configuration
CHS	Commanding, Health and Safety
CM	Configuration Management; also: Center of Mass
CMD, Cmd	Command
CMX	CMT (Configuration Management Tool) eXtra
CNE	NASA's Center Network Environment
Config	Configuration
COTS	Commercial Off-the-Shelf
CPU	Central Processing Unit
CsI (Tl)	Cesium Iodide crystal doped with Thallium
CU	Calibration Unit
CVS	Concurrent Versions System
CY	Calendar Year

D

DAQ	Data Acquisition System also: LAT Electronics, Data Acquisition and Flight Software Subsystem
DB	Data Base
DC	Data Challenge
Diag	Diagnostic
Digi	Digitized Event Data
DOE	Department of Energy
DPF	Data Processing Facility
DS	Data Stream

E

EGRET	Energetic Gamma Ray Experiment Telescope on CGRO
EGSE	Electrical/Electronics Ground Support Equipment
EM	Engineering Model or Electromagnetic
Eng	Engineer/Engineering
EPO, E/PO	Education and Public Outreach
EPU	Event Processing Unit
ETE	End-to-end
ETech	Electrical Technician
EU	Engineering Unit

ISOC Glossary (II)

F

FDF	Flight Dynamics Facility
FES	Front-End Simulator
FITS	Flexible Image Transport System
FMX	tool for tracking LAT Configuration
FOV	Field of View
FQT	Flight Qualification Testing
FRED	Fox and Ruby Event Display
FSW	Flight Software
FTE	Full Time Equivalent

G

GASU	Global Trigger, ACD, Signal Distribution Unit
GBM	Gamma-ray Burst Monitor
gcc	GNU Compiler Collection
GCM	GLAST Contingency MOC (Mission Operation Center)
GCN	Gamma-ray Burst Coordinate Network
GD	General Dynamics
GEANT4	Detector description and simulation tool
GeV	10^9 electron Volts
GFEP	GLAST Front-End Processor
GIOC	GBM Instrument Operations Center
GLAST	Gamma-ray Large Area Space Telescope
GPS	Global Positioning System
GRB	Gamma-ray Burst
GRID	Computing grid
GRT	Ground Readiness Test
GS	Ground Systems
GSFC	Goddard Space Flight Center
GSSC	GLAST Science Support Center

H

H&S	Health & Safety
HEASARC	High Energy Astrophysics Science Archive Research Center
HEP	High Energy Physics
HK, HSK	Housekeeping
HW, h/w	Hardware

I

I&T	Integration & Test
ICD	Interface Control Document
INFN	Istituto Nazionale Di Fisica Nucleare, (Italy)
ISOC	Instrument Science Operations Center
IS	Instrument Scientist
IT	Information Technology
ITAR	International Traffic in Arms Regulation
ITOS	Integrated Test and Operations System

J

JIRA	Bug/issue tracking software

K

Kbps	Kilobits per second
keV	10^3 electron Volts
kg	Kilogram
km	kilometer
KSC	Kennedy Space Center
Ku-Band	A range of frequencies in the electromagnetic spectrum, 12 – 18 GHz, primarily used for satellite communications

ISOC Glossary (III)

L

L&EO	Launch and Early Orbit
L0, L1, L2	Level zero, Level one, Level two data processing
L0P	Level zero Products
LAT	GLAST Large Area Telescope
LATTE	LAT Test Executive
LHK	LAT Housekeeping
LICOS	LAT Instrument CheckOut System
LISOC	LAT Instrument Science Operations Center *
LSF	LAT Science Format
LSG	LAT Collaboration Science Groups

M

m	meter
M&S	Materials & Services
Mbps, Mb/s	Megabits per second
MC	Monte Carlo
MCR	Mobile Computing Rack
MeV	10^6 Electron Volts
MGSE	Mechanical Ground Support Equipment
MILA	Meritt Island Launch Annex
MOC	Mission Operation Center
MSFC	Marshall Space Flight Center
Mtech	Mechanical Technician

N

NASA	National Aeronautics and Space Administration
NP	Narrative Procedures
NRL	Naval Research Laboratory
NSSTC	National Space Science and Technology Center

O

OMB	Office of Management and Budget
Ops	Operations
OSU	The Ohio State University

P

PDA	Personal Digital Assistant
PDU	Power Distribution Unit
PI	Principle Investigator
PROC	Procedure
PSF	Point Spread Function
PVO	Performance, Verification, and Optimization

Q

R

RDBMS	Relational Data Base Management System
Recon	Reconstruction
RMS	Root Mean Square
RPM	RPM Package Manager, a package management system for installing and updating computer software packages
RT	Remote Terminal
RWA	Reaction Wheel Assembly

ISOC Glossary (IV)

S

s	second
S/A Drive	Solar Array Drive
S-Band	A frequency range from 1.55 – 5.2 GHz used for satellite communication
SAA	South Atlantic Anomaly
SAS	Science Analysis Systems
SAS	Science Analysis Software
SASS	Spectrum Astro Space Systems
SCS	SLAC Computing Services
sec	second
SEM	Standard error of the mean
Si	Silicon
SIIS	Spacecraft Simulator
Sim	Simulated
SIRU	Spacecraft Inertial Reference Unit
SIU	Spacecraft Interface Unit
SLAC	Stanford Linear Accelerator Center
SLC	SLAC Linear Collider
SNITZ	ASP based bulletin board system
SNR	Super Nova Remnant
SO	Science Operations
SSAC	Senior Scientist Advisory Committee
SSC	Science Support Center
SSCS	Science Support Center something?
SSD	Silicon Strip Detector
STOL	Systems Test and Operations Language
SU	Stanford University
SVAC	Science Verification, Analysis and Calibration
SW, s/w	Software
SWIFT	Swift Gamma Ray Burst Explorer Mission

T

Tl	Thallium
T&DF	Trigger and Dataflow
TBD	To Be Determined
TDRSS, TDRS	Tracking and Data Relay Satellite System
Telem	Telemetry
TEM	Tower Electronics Module
TIM	Technical Interface Meeting
TKR	The LAT Tracker Subsystem
TLM	Telemetry
TOO	Target of Opportunity
TPG	Trigger Pattern Generator

U

UCSC	University of California at Santa Cruz
UPS	Uninterruptible Power Supply
USN	Universal Space Network

V

Verif	Verification
VME	Versa Module Eurocard
VRVS	Virtual Room Videoconferencing System
VSC	Virtual Spacecraft

W

WIRED	BaBar event display
WMAP	Wilkinson Microwave Anisotropy Probe