

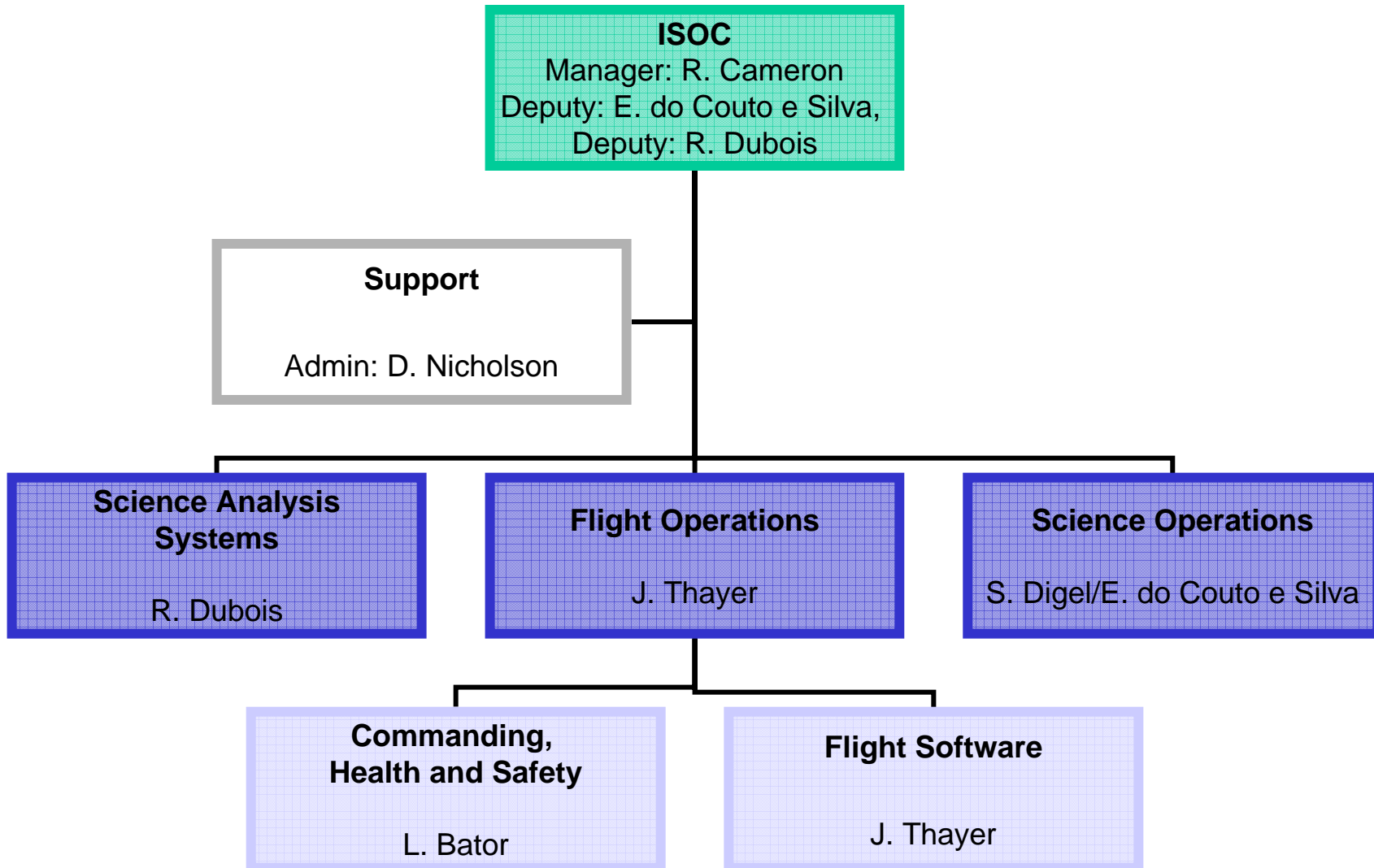
# GLAST Large Area Telescope Instrument Science Operations Center

## Science Operations Overview

Seth Digel and Eduardo do Couto e Silva



# ISOC Organization





# Outline

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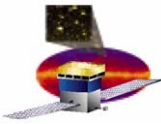
- ❑ **Overview of Science Operations**
  - **Elements of Science Operations**
  - **Data Flow Diagram**
  - **Functional Diagram**
- ❑ **Duty Scientist Program**
- ❑ **Pre-Launch operations experience**
- ❑ **Summary**



# Science Operations Elements

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- ❑ **Science Processing and Monitoring**
  - **Automated Science Processing**
    - used to be called quick look
  - **Instrument Monitoring**
    - with celestial gamma rays and cosmic rays
  - **Level 1 Processing and Pipeline Operations**
  
- ❑ **Performance and Optimization**
  - **Event Classification and Instrument Response Functions**
  - **Background monitoring and updates to background models**
  - **Optimization of the Observation Time**
  - **Instrument Optimization**
  - **Calibrations**
  
- ❑ **Operations**
  - **Duty Scientist Program**
  - **Anomaly Resolution**



# LAT Collaboration and Science Operations

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❑ LAT Collaboration participation is needed at many stages

– **Pre- Launch (use LAT integration and beam test data)**

- Data Analysis of Instrument data
- Development of Data Analysis Software and Methods and MC simulation to prepare for on-orbit operations
  - » with LAT C&A Science Group
- Development of tools for instrument monitoring and validation of data
- Development of tools to support anomaly resolution



– **Post-launch**

- Data Analysis using Galactic Cosmic Rays and celestial gamma rays
- Instrument Performance Monitoring (include calibrations)
  - » 24/7 coverage to benefit from geographical distribution of Collaborators (at least during first 60 days)
- Coordination and leading roles within the ISOC
  - » Some presence at SLAC may be desirable
  - » Encourage rotation among LAT collaborators

❑ Interaction of the Collaboration with the ISOC:

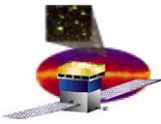
- **Weekly VRVS Meetings**
- **Science Operations Workshops**



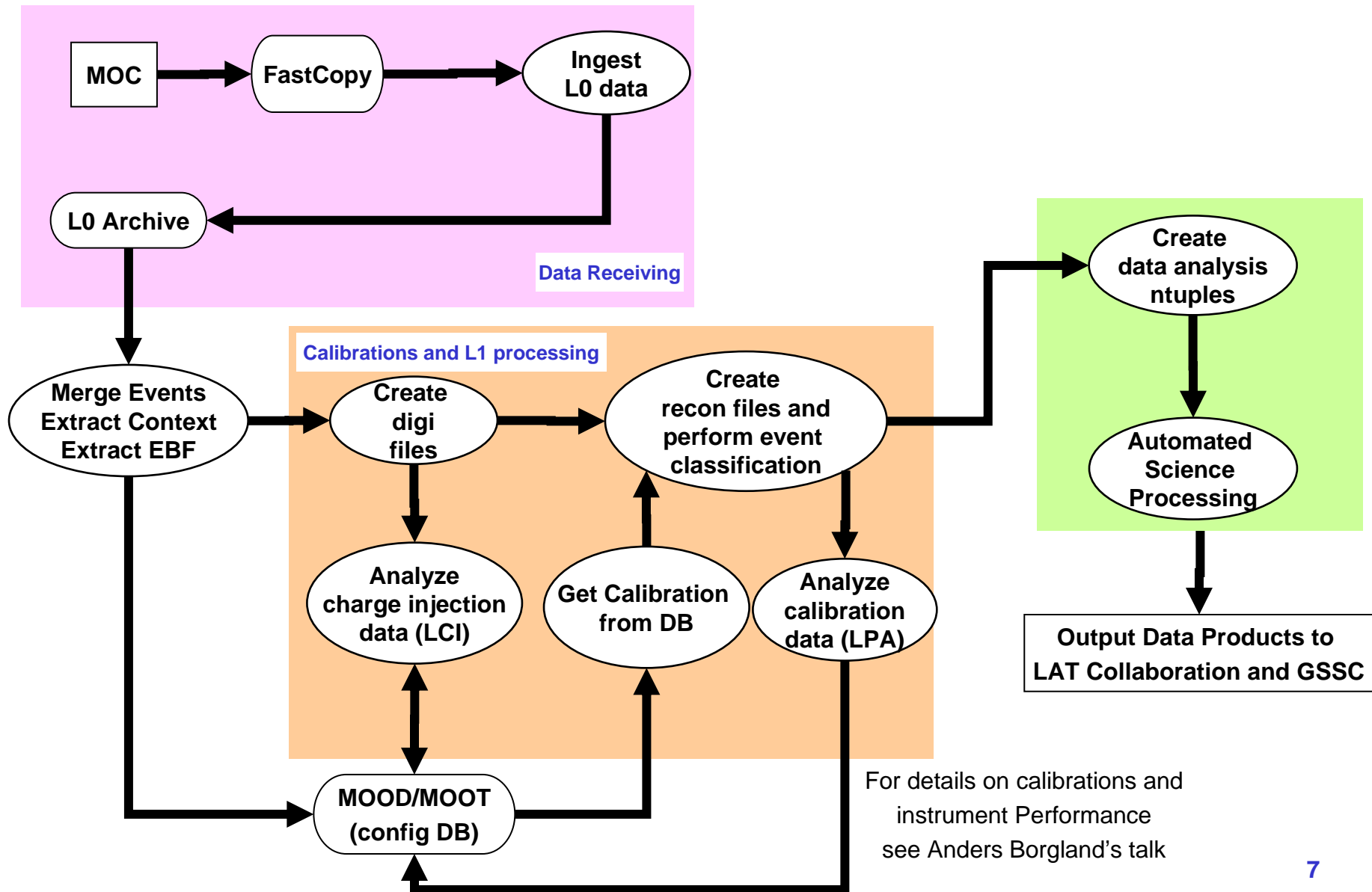
# Science Operations Overview

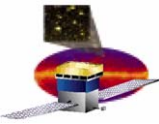
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- **Automated** functions are developed and maintained by the Science Operations Team in conjunction with the LAT Collaboration (relies on Duty Scientist Program) and LAT Science Groups and involves
  - **Delivery of data**
    - to LAT collaboration and scientific community (through GSSC)
  - **Verification of Data Quality**
    - Automated reports and inspection of data with data analysis tools
  - **Monitoring of pipeline operations**
    - processing and operations are automated through a data processing facility (pipeline)
  
- **Non-automated** functions are developed and maintained by the Science Operations Team in conjunction with the LAT Collaboration and involves
  - **Optimization of scientific return of the LAT instrument**
    - Propose change of instrument configurations (trigger, timing, on-board filters, detector settings, etc.)
      - » instrument optimization in first year after launch
      - » address changes due to space environment and instrument degradation with time
    - Propose allocation of time in Engineering Mode
      - » for anomaly resolution, calibrations and verification of instrument performance
    - Perform studies using MC simulations
      - » to evaluate contingency scenarios and support optimization tasks

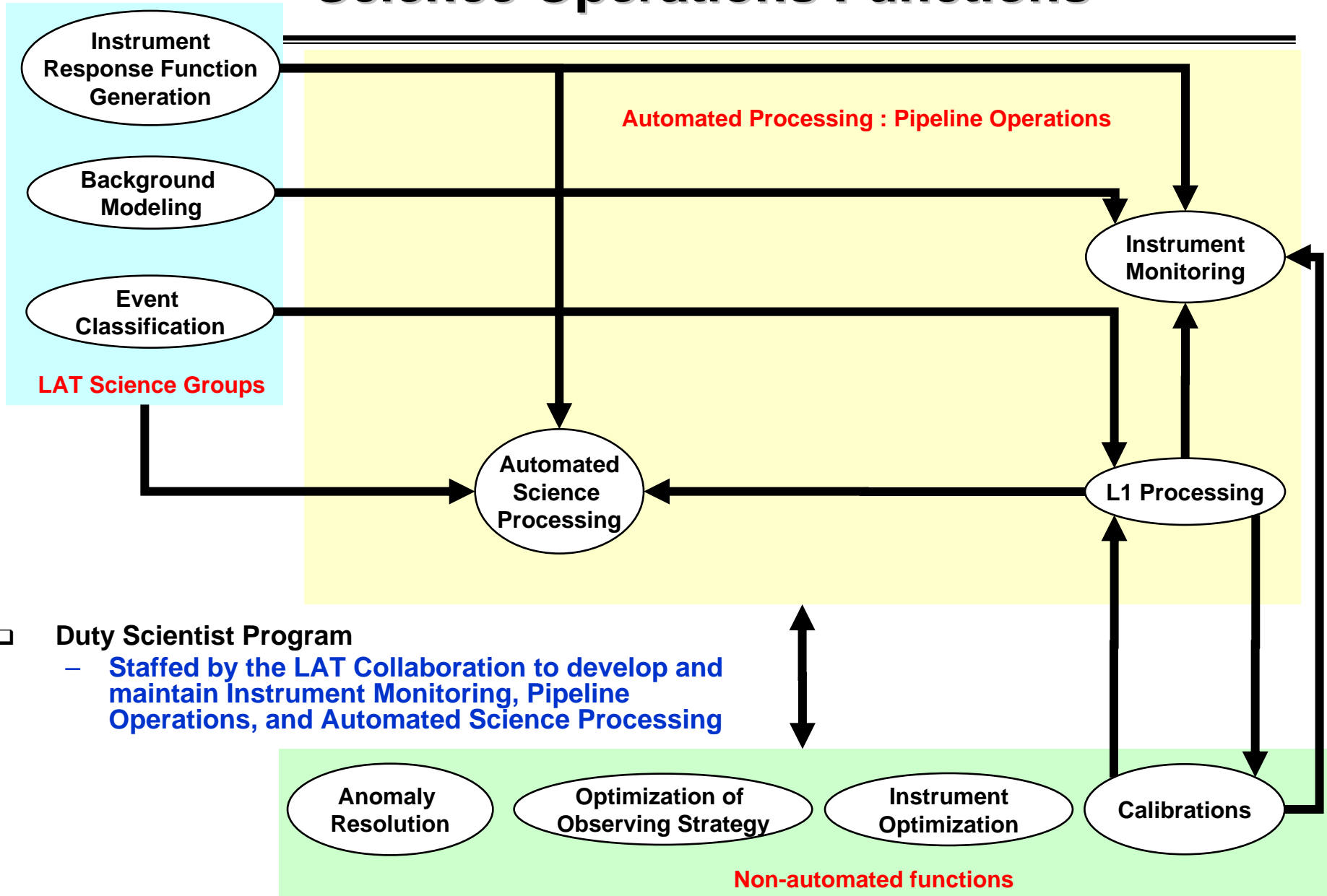


# Simplified Functional Diagram for Data Flow





# Science Operations Functions



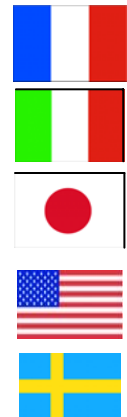


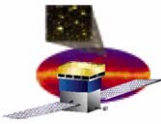
# Duty Scientist Program

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- **Main tasks**
  - **Monitor instrument behavior for each data pass**
    - requires knowledge of instrument and gamma ray science
  - **Ensure Automated Science Processing products are being correctly delivered**
  - **Identify anomalies/problems beyond health & safety**
  - **Ensure Science Products are being created and transients are being monitored**
  
- **Organization concept currently under discussion**
  - **Leading roles should rotate among LAT Collaborators**
  - **Science Operations Coordinator**
    - In the beginning require presence for a few months at SLAC
    - Coordinate shift activities, and liaise with management when necessary
    - Initiate anomaly resolution process
  - **Shift Leader**
    - Summarize shift activities in daily coordination meetings
    - Provide follow-up and contact on-call experts for troubleshooting
  - **Shift Scientists**
    - Verify that data processing proceeds as expected
    - Monitor data quality to ensure science is accomplished
    - Identify and document problems
  
- **Training and software development (already started with beam test)**
  - **Science Operators will organize workshops to train people**
  - **Prepare documentation**
  - **Create web based and console driven tools for scientists on duty**

**Staffed by the  
LAT  
Collaboration**



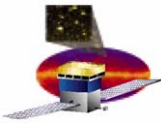


# Automated Science Processing

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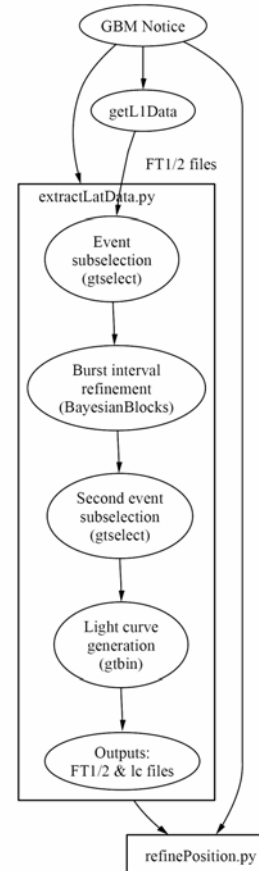
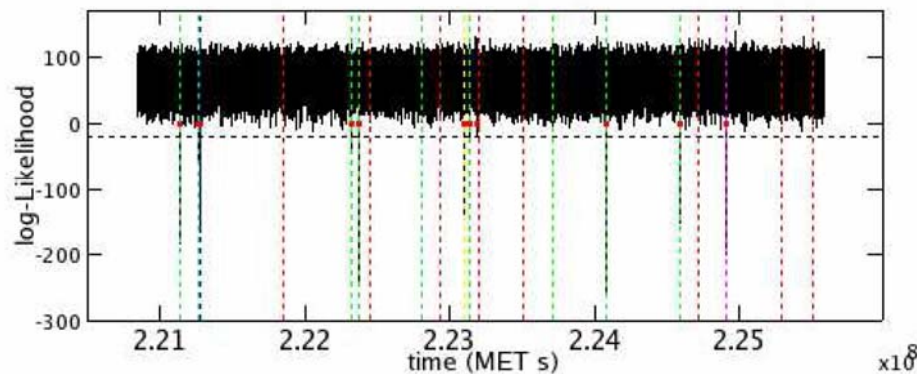
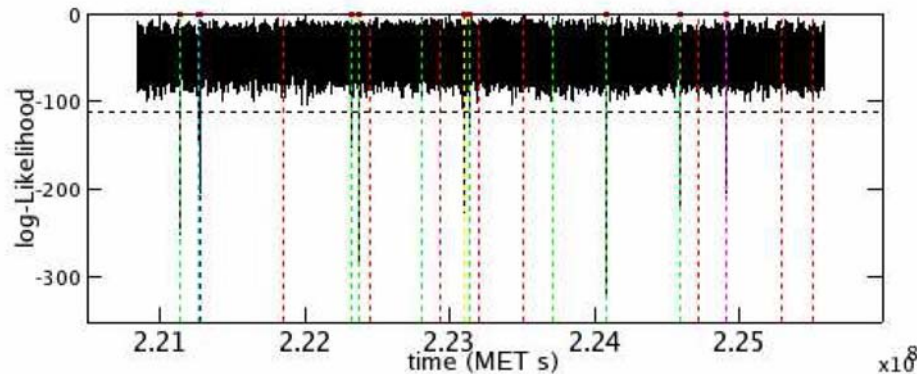
- ASP is *not*
  - instrument monitoring
  - monitoring of backgrounds
- ASP tasks
  - **Gamma-Ray Bursts (*impulsive transients*\*)**
    - Refinement of parameters for GRBs detected onboard by LAT
    - Detection and characterization of GRBs not detected onboard
    - Search for delayed high-energy emission
  - **Transient sources (primarily blazar active galaxies)**
    - Monitoring of predefined list of sources
    - Search for (new) transient sources

\* Also would include solar flares (but no alerts needed for these) and evaporating primordial black holes (but when they're gone, they're gone)



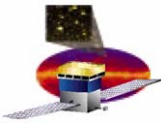
# ASP : GRB example (Jim Chiang)

- Blind search with 2 algorithms (construct a likelihood to compare with a null hypothesis that there is no burst)
  - Acceptance cone method
    - Location of each event in a group is treated as a candidate GRB position. FOM for that position is the number of events in the group that lie within a pre-defined acceptance cone
  - PSF method
    - Evaluate the log-likelihood under the hypothesis that there is a point source at the candidate location



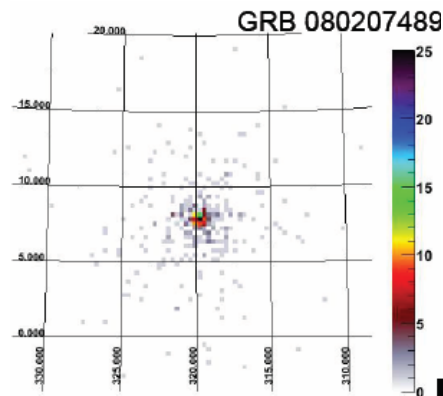
For more details see talk from Jim Chiang in the GRB splinter session

Interaction with LAT Science Groups

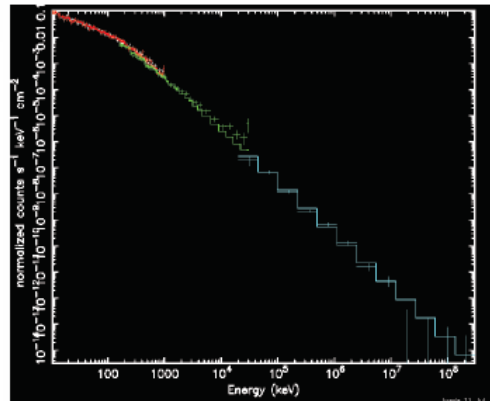


# ASP : GRB and AGN examples

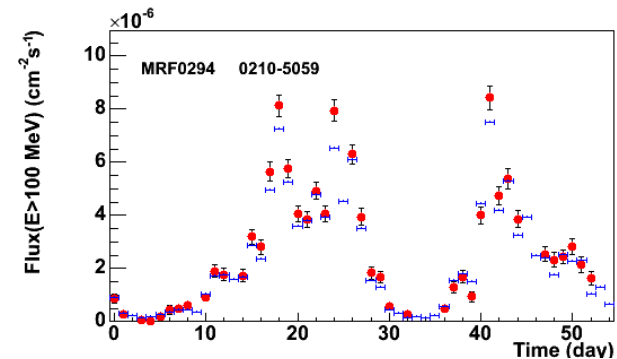
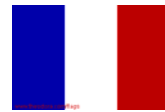
- GRB analysis code to produce automated science plots
  - Could be implemented in the ISOC’s pipeline
  - Need to consolidate with Jim Chiang’s work



For more details see talk from Nukri Komin in the GRB splinter session

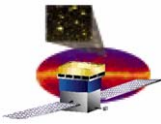


- Code to produce automated light curves for AGNs
  - Could be implemented in the ISOC pipeline
  - Need to discuss with AGN group what needs to be automated



For more details see talk from Benoit Lott in DC2

Interaction with  
 LAT  
 Science Groups



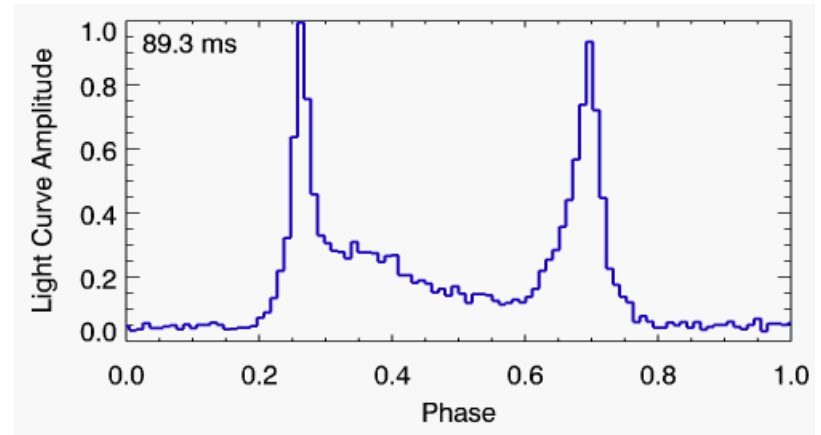
# Instrument Monitoring : bright sources

- **Monitoring of LAT performance with celestial gamma rays**
  - **Check absolute time and spacecraft position by precision timing of the bright pulsars**
    - Small errors in either disrupt phases
  - **Monitor PSF, Effective Area, and energy dispersion (IRFs)**
    - Use pulsars as bright, steady (phase averaged) 'calibration' sources
  - **For high energies, look at spectrum of Galactic Diffuse emission**
    - Pulsar spectra roll off in GeV range, but we need to monitor response to >100 GeV

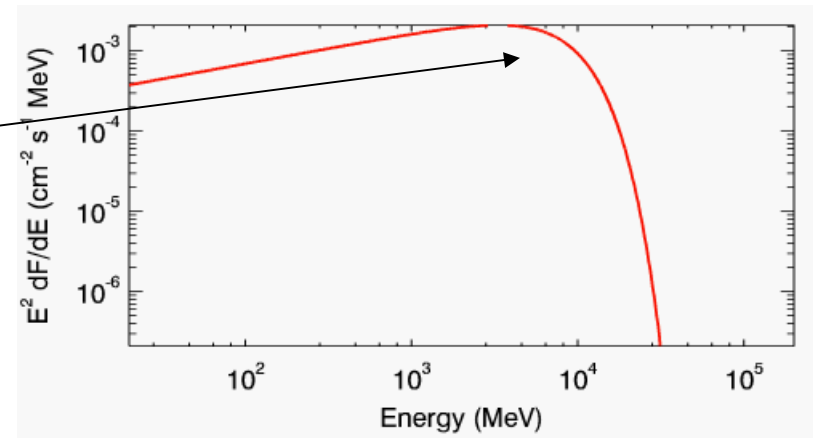


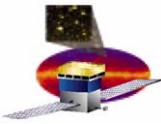
**Interaction with  
LAT  
Science Groups**

Vela light curve (DC2 sim.)



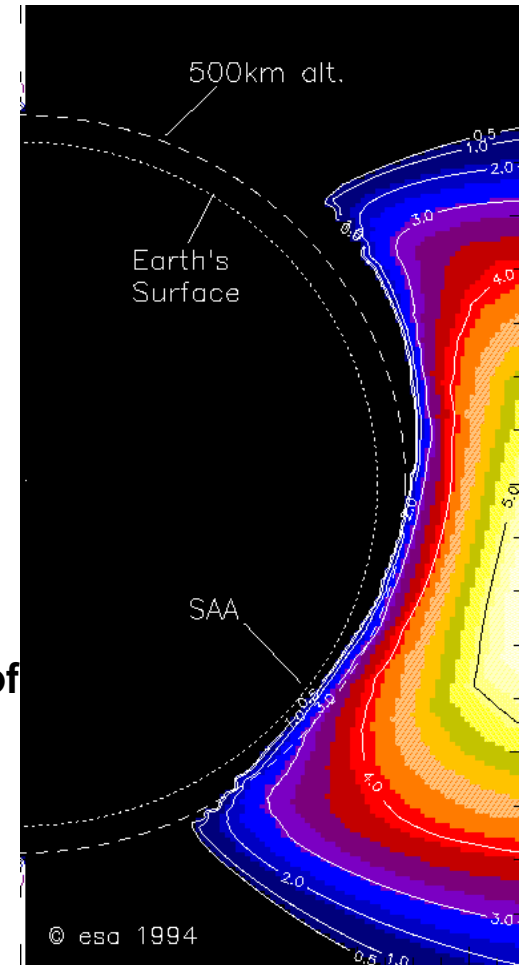
Vela spectrum (DC2 sim.)





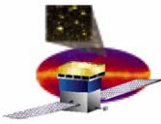
# Instrument Monitoring: Background Model

- ❑ **Background Model Updates**
  - On an on-going basis revisit the background modeling and evaluate consistency with the LAT observations.
  - This work is done mostly by the C&A group and the ISOC has at least one representative working in that area.
  
- ❑ **Monitor intensities of charged-particle and gamma-ray albedo backgrounds**
  - using sampling triggers that allow a small fraction of events to bypass on-board filter
    - These intensities will change with solar activity, the solar cycle, and the altitude of the LAT and relate directly to the trigger rate of the LAT
  
- ❑ **Fine tune and update the definition of the perimeter of the SAA boundary**
  - within which the LAT does not take science data



[http://www.estec.esa.nl/wmwww/wma/rad\\_env.html](http://www.estec.esa.nl/wmwww/wma/rad_env.html)

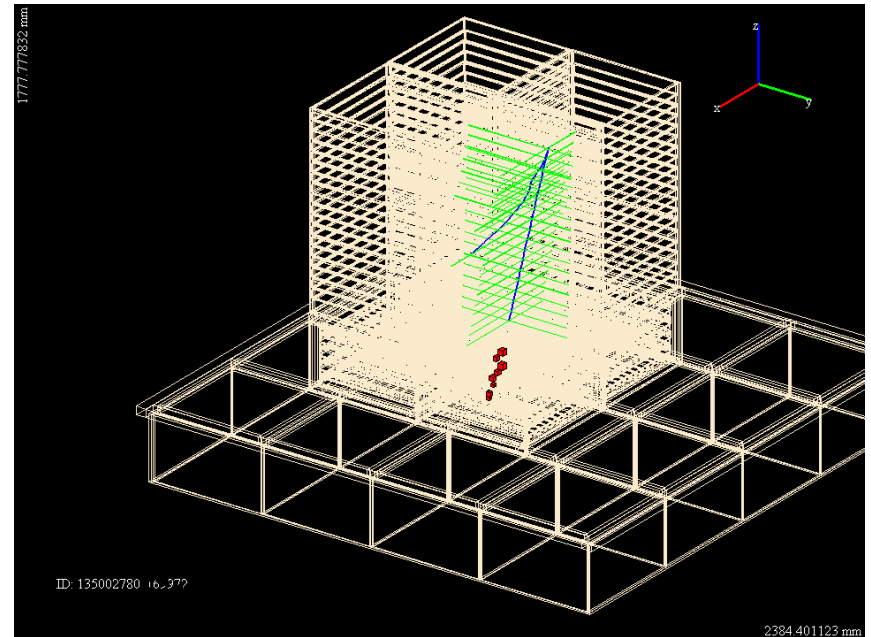
Interaction with  
LAT  
Science Groups



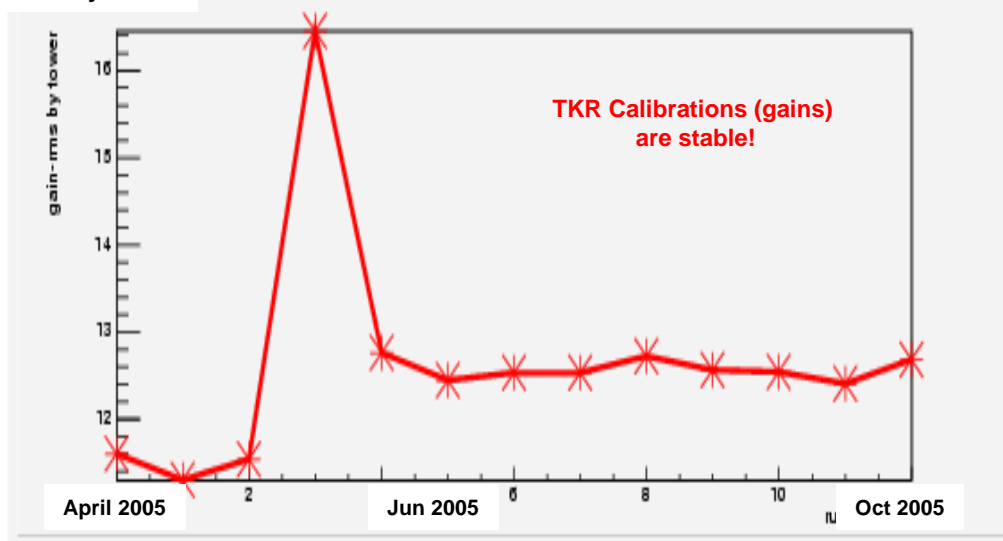
# Instrument Analysis Workshops

- ❑ Exercise reconstruction algorithms and data analysis tools
  - Use simulated and real data
- ❑ Uncover and quantify instrumental effects
  - Could potentially affect science data
- ❑ Create a core and trained group
  - to participate in the analysis of the beam test data
  - to lay foundations of the LAT Science Operations Group of the ISOC

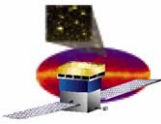
Currently led by Anders Borgland and as of Sep 2006 will merge back into Science Operations



RMS by Tower

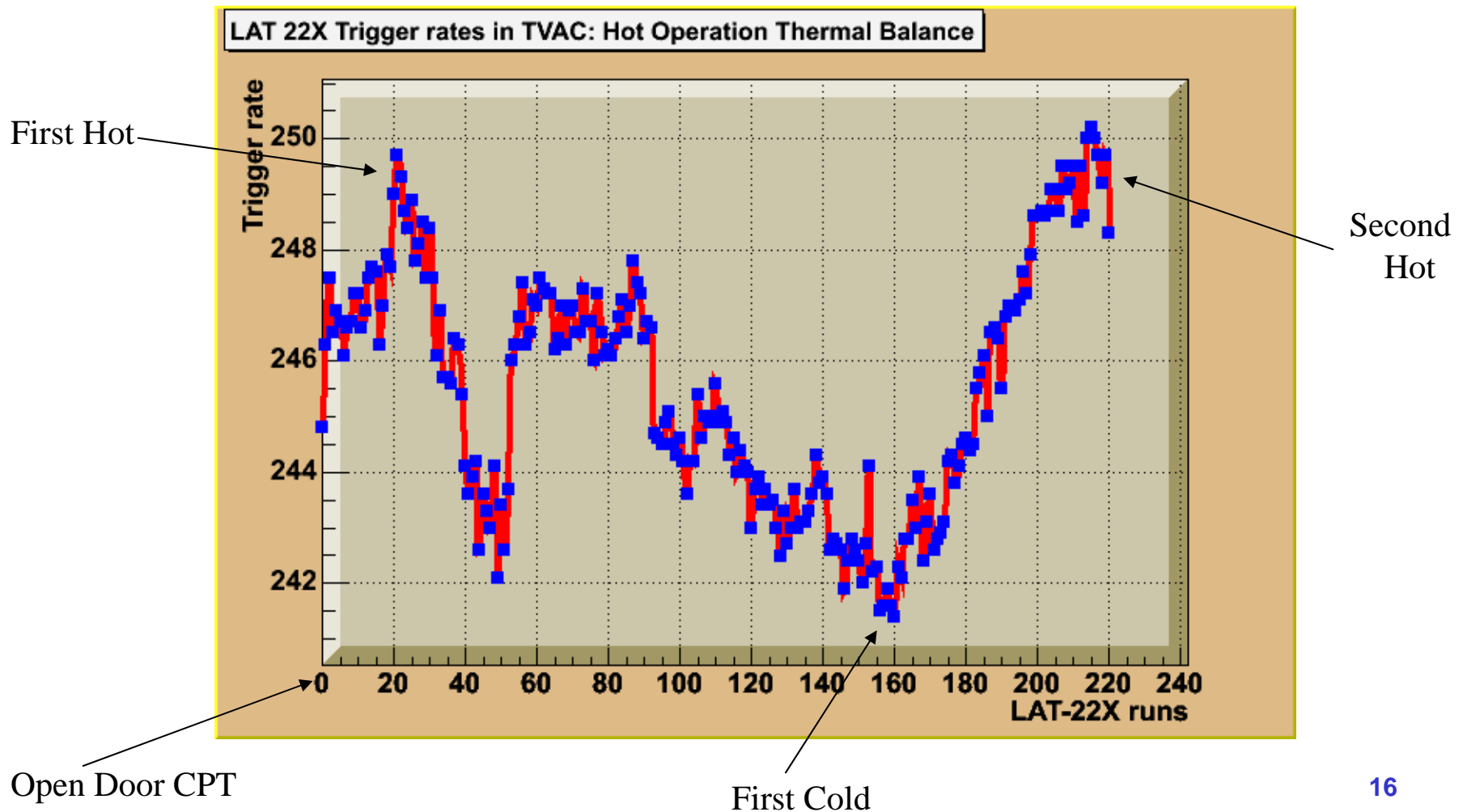


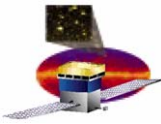
6 Workshops at SLAC  
from Jun/2004 to Feb/2006



# Instrument Monitoring: Detector level

- Trigger rate at TVAC tests @ NRL
  - For more details see presentations in Instrument Analysis Meetings

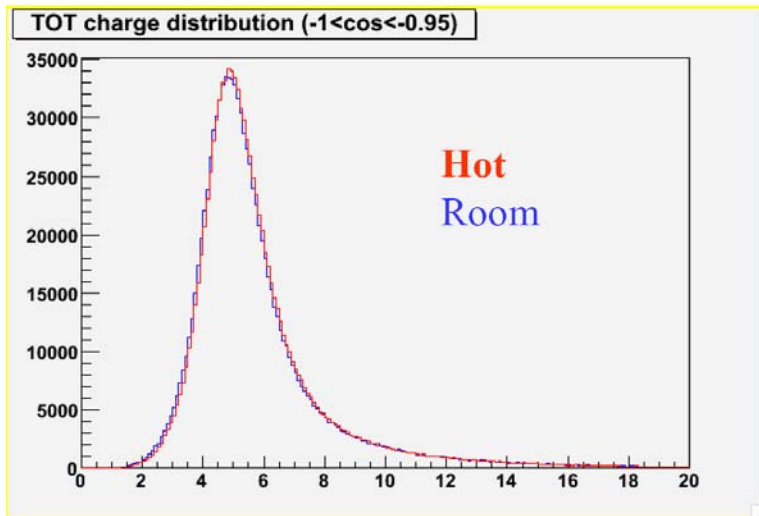




# Instrument Monitoring: TVAC

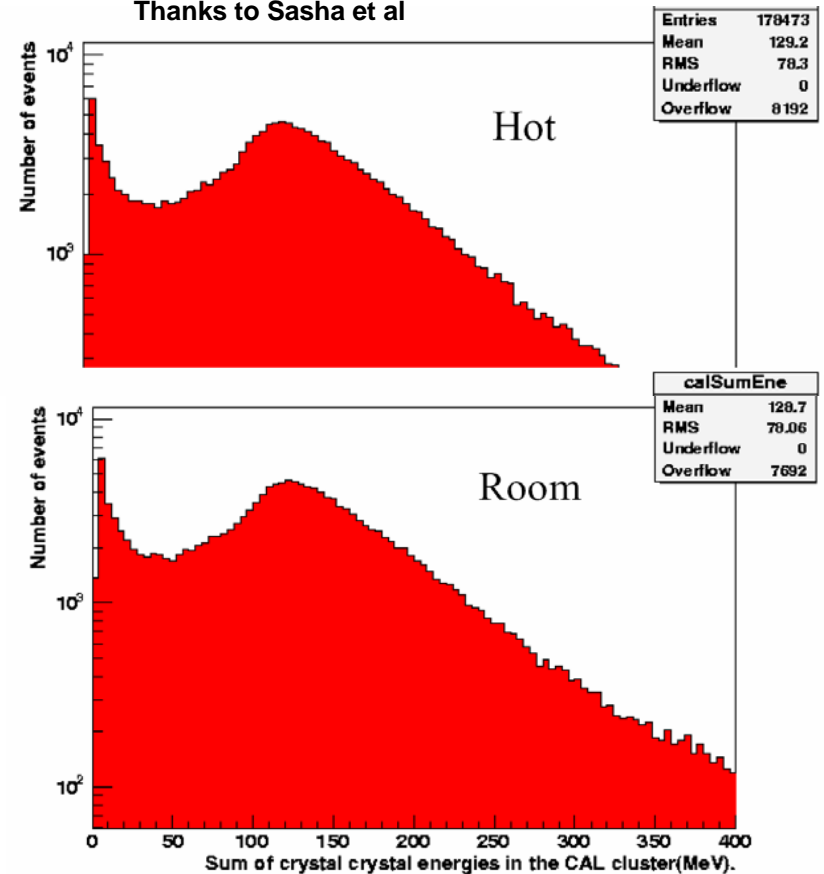
- Searching detector effects due to temperature changes

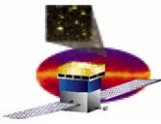
Thanks to Hiro Tajima



For details see talk from Eric Grove on the LAT Commissioning (LAT monthly status)

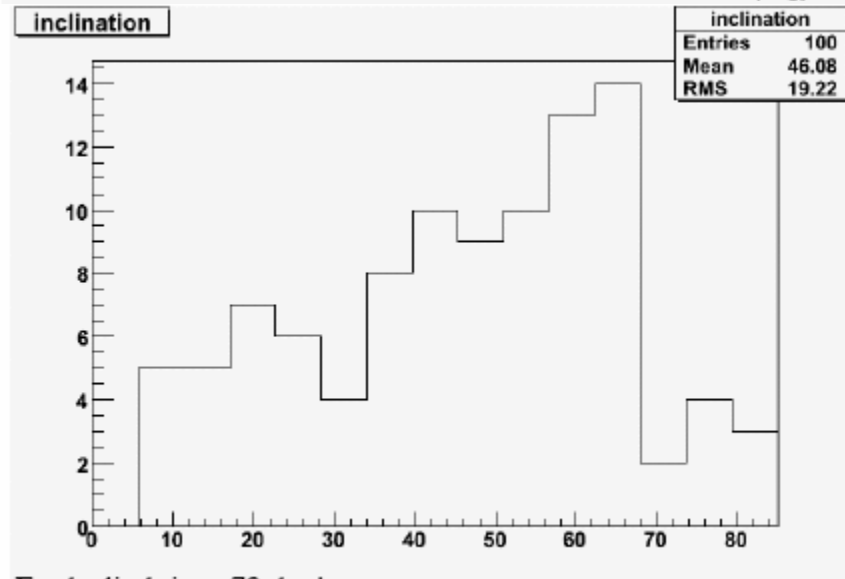
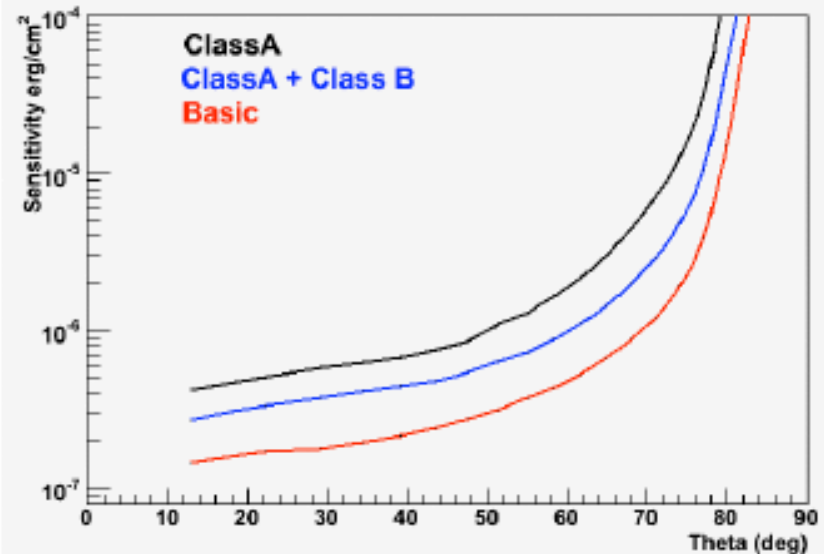
Thanks to Sasha et al



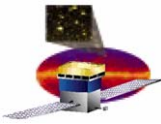


# Instrument Optimization : GRB example

- ❑ Analysis cuts used for steady sources may not be optimal for GRB detection/searches
- ❑ GRB features
  - High flux
  - Low background
  - Short duration
- ❑ For more details see **Julie McEnery's talk** in the GRB splinter session during Collaboration week meeting in Stockholm



The Earth's limb is at 78 deg!



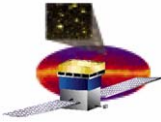
# Operations: Beam Test @ CERN

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- **Beam Test @ CERN (Aug – Sep 2006) is serving as a test to**
  - **interact with scientists from the LAT Collaboration in an operations environment (of course not space environment yet!)**
    - understand mindset and skills of potential ISOC duty scientists
    - tailor tools to be more user-friendly and adequate for the people involved
    - Working 24/7 for almost 60 days (similar to Science Ops support during L&EO)
  - **train LAT Collaborators on essential ingredients necessary for operations in the ISOC era**
    - pipeline operations, L1 processing (code release management), data quality monitoring, CCB process for code release
  - **develop, test and improve operations tools (see next 2 slides)**
    - confluence pages for documentation
    - shift log for recording anomalies and data taking observations including posting plots

See Luca  
Latronico's talk  
for more  
details



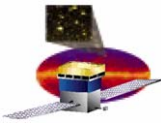


## Operations: Environmental Tests TVAC @ NRL

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- Using TVAC as Launch and Early Ops Demo
  - LEO LAT register settings are based on pre-launch calibrations
  - ACD and CAL have significant variation of pedestals and thresholds with temperature
    - With wrong thresholds, trigger rate and data volume can run away
  - TVAC settings have ACD and CAL thresholds safely above trends
    - ACD zero suppression : 3 x flights settings but still 0.1 MIP
    - CAL zero suppression : 2 x flights settings but still 0.3 MIP
  - LAT data at Hot and Cold clearly demonstrate that LAT can be operated perceptively on orbit at first power-up with safe thresholds

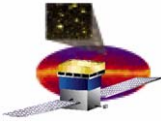
Slide from Eric Grove's on the  
LAT Commissioning  
(LAT monthly status)



# What next?

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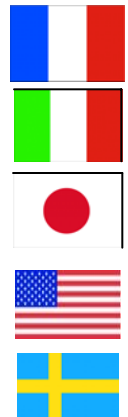
- ❑ We are ramping up Science Operations in three main areas
  - Pre launch data analysis (currently through IA meetings)
    - Environmental tests, spacecraft integration and beam test
      - » Essential for debugging and calibrations after launch
      - » Collecting lessons learned and idiosyncrasies of the instrument
  - Launch and Early Orbit
  - Data Taking, calibrations and data analysis during first year
  
- ❑ LAT Instrument will be delivered to spacecraft integration in Sep 2006
  - Instrument Analysis (IA) Activities will be absorbed in Science Operations
    - Whenever necessary IA talks will be given priority in weekly meetings
  
- ❑ Science Operations Friday Meetings on VRVS 9 to 10am (PDT, i.e. SLAC time)
  - First meeting: Sep 8, 2006: tentative agenda
    - Interactions with LAT Science Groups (C&A in particular)
    - Lessons learned from IA data analysis experience
    - Initiate discussions for launch and early orbit operations
    - How to support Service Challenge Activities
      - » See Richard Dubois's talk for more details

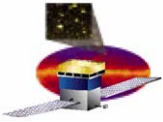


# Summary

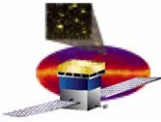
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- ❑ **We presented an overview of Science Operations**
  - **Ramping up activities through weekly meetings**
    - First VRVS meeting on Sep 8, 2006
      - » sharpen definitions of functions
      - » breakdown of tasks in smaller units
      - » Prioritize to match ISOC timeline
  
- ❑ **Science Operations depends on the LAT Collaboration:**
  - **Engaging the LAT Collaboration in the definition and implementation processes for Science Operations**
    - informally started during beam test @ CERN
      - » See talk from Luca Latronico
    - Plan a series of workshops at SLAC
      - » Following Instrument Analysis experience
  
  - **Test each of the science operations' functions the Service Challenge**
    - Following Data Challenges experience
      - » See slides from Richard Dubois and Julie McEney

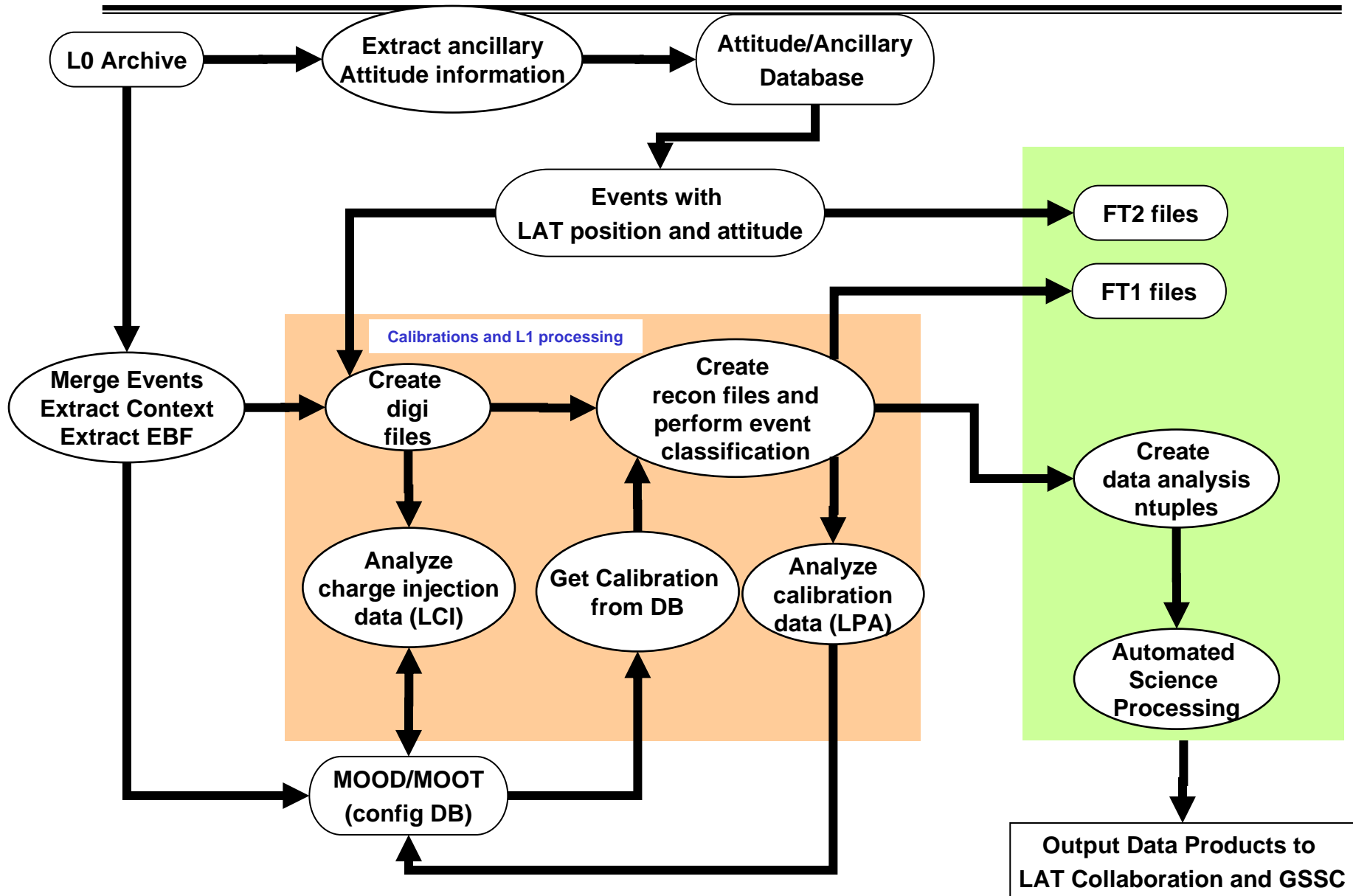


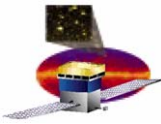


**backup**



# Functional Diagram for Data Flow (more details)

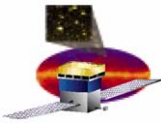




# Definition of Science Operations Functions (1)

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- ❑ **Automated Science Processing**
  - **Detect and characterize transient sources for follow-up by GLAST and other observatories, as per GLAST data release policy**
- ❑ **Instrument Monitoring**
  - **Monitor High Level Performance with celestial sources**
    - Sensitivity, spectra, localization, etc.
    - Verification of time and position information in the LAT science data
    - Verification of Instrument Response Functions
    - Monitor high energy response of the LAT
  - **Monitor LAT performance as a system.**
  - **Monitor instrument quantities to identify hardware problems**
    - trigger rates, bad channels, on-board filters, individual LAT detectors
    - correlations between LAT detectors
- ❑ **Calibrations**
  - **Coordinate, generate and validate calibrations**
    - L1 and L2 data
      - » IRFs are covered as a separate topic
  - **Trend and correlate calibration data with other data sources**
    - e.g. housekeeping



## Definition of Science Operations Functions (2)

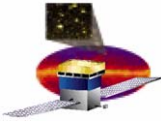
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### □ Background Model Updates

- On an on-going basis revisit the background modeling and evaluate consistency with the LAT observations.
  - This work is done mostly by the C&A group and the ISOC has at least one representative working in that area.
- Fine tune and update the definition of the perimeter of the SAA boundary
  - within which the LAT does not take science data

### □ Event Classification and Instrument Response Functions

- Optimization of background rejection cuts and definition of event classes.
  - Will change as the performance of the LAT changes.
  - Most likely done by C&A group and SO will have at least one representative there.



## Definition of Science Operations Functions (3)

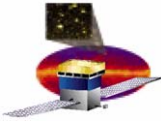
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### □ Level 1 Processing

- Define scripts and databases for
  - reconstruction and classification of events in the science data telemetry
  - creation of pointing/livetime history.
- Coordinate validation of results and reprocessing (as needed)
  - with C&A group

### □ Pipeline Operations

- Tailor pipeline for
  - instrument monitoring and
  - for generation of automated science products
- Coordinate and monitor all of the pipeline tasks at Levels 1 and 2



## Definition of Science Operations Functions (4)

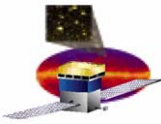
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### ❑ Anomaly Resolution

- Define processes for anomaly resolution and escalation.
- Ensure ability to understand and analyze pre-launch data (includes beam test)
  - may be used for reference during flight

### ❑ Duty Scientist Program

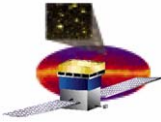
- Provide support for Science Operation Functions
  - Requires understanding of instrument and the gamma ray science and basic knowledge of pipeline
- The baseline is to reduce the need for 24/7 coverage, but not in the beginning.
- Organize workshops to train people
  - Some activities will require presence at SLAC.



# Optimization of the Observation Time (year 1)

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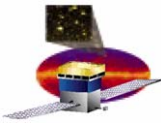
- ❑ **Science Mode and Calibrations**
  - **During science observations the LAT is configured to continuously collect data necessary to evaluate**
    - Pedestals, noisy and dead channels and stability of alignment
  - **Engineering Mode may be used for dedicated calibrations as needed**
    - expected to be infrequent after 60 days
  
- ❑ **Define SAA boundaries (see Seth's talk)**
  - **Use LAT Data to fine tune and update the definition of the perimeter of the SAA boundary, as the orbit decays, the solar cycle advances, and the SAA drifts**
    - Develop a monitor and study false rate increases in the beginning of the mission
    - Develop graphical representation of the SAA using rates
    - Correlate with Real time information (if available)
  
- ❑ **Propose changes in survey mode, for example,**
  - **To accommodate optimization of the instrument when we have to deal with contingencies (loss or degradation of detectors/electronics)**
    - considerations include changes in response functions (profile of effective area with inclination angle and energy)
  - **to optimize uniformity of the sky coverage**



# Instrument Optimization

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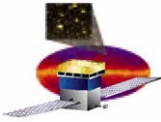
- ❑ **Optimize LAT register settings to**
  - ensure LAT meets data volume requirements (1.2 Mbits/s)
  - best use of the telemetry bandwidth available for science data
  - maintain high quality of the science data.
  
- ❑ **Optimize rate and quality of photons to support the scientific goals of the mission.**
  - In conjunction with C&A and other science groups
  
- ❑ **Optimization Process**
  - **Identify needs for change through**
    - Standard monitoring functions
    - Data analysis from ISOC, LAT science groups
      - » Using data and MC simulations
  - **Elaborate rationale for change**
    - Escalation to higher level depending on nature of changes
    - Record and traceability through a CCB process
      - » Use same logging tools developed for anomaly resolution
  - **Provide input and make requests to ISOC Flight Operations**
    - Feedback from CHS/FSW until feasible implementation of instrument configuration is achieved
    - Develop a plan with CHS/FSW for tests to understand impacts on LAT science data
  - **Validate changes**
    - Validate data with modified settings through data analysis
    - Close the documentation loop and promote new settings as production quality



# Anomaly Resolution (1)

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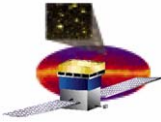
- **Identify and classify anomalies according to criticality**
  - **Classification system**
    - Clear and documented rules for classification (e.g major, minor, critical)
  - **Documentation from pre-launch phase**
    - summarizes known or potential problems in a database so that they can be queried
  - **Logging capabilities tailored for ISOC needs**
    - allow posting of plots, screen dumps and annotations. Records can not be tampered.
  - **Training of back-up personnel for normal operations capable of identify problems**
    - Minimize false alarms
  - **Automation of system to identify problems**
    - Begin implementation after first year of operations



## Anomaly Resolution (2)

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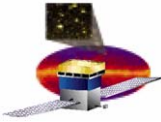
- ❑ **Assess impact and root cause of anomalies**
  - **Science Operations group coordinates anomaly resolution**
    - Assign tasks to a group of experts
    - Ability to mobilize experts within 1 hour to initiate process for critical items
      - » Not necessarily in the control room, but with access to computer
  - **Documentation for traceability and reporting after problem is identified**
    - Use same tools for logging identification and resolution of problems
  - **ISOC operations meeting reviews previous days anomalies and schedules follow up**
    - Training with simulated anomalies prior to launch
- ❑ **Follow the escalation process (details under discussion)**
  - **Determined by the criticality of the problem**
    - Escalation process may differ if MOC is involved or not
      - » but still require authorization for emergency repairs/fixes/actions
  - **Documentation for escalation**
    - Same tools that were used for identification and resolution of problems
    - Approved summary reports are required for escalation process
  - **Communication protocols to be tailored/agreed within different groups**
    - ISOC Steering Committee, LAT, GBM, GSSC and MOC
      - » Some may require different level of formality than others



# Level 1 Processing

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- ❑ **Define scripts and databases for**
  - reconstruction and
  - classification of events in the science data telemetry
  - construction of pointing/livetime history.
  
- ❑ **Science Operations coordinate validation of results and reprocessing**
  - with C&A group, LAT and LISOC
  
- ❑ **Reprocessing of Data**
  - **Identify software changes required to reprocess data**
    - Documentation for traceability
      - » Based on LAT integration experience
    - Logging capabilities tailored for ISOC needs
  - **Assess impact of reprocessing**
    - Verify existence of validate calibrations
    - Training of back-up personnel capable of recognizing reprocessing issues
    - Considerable experience during LAT integration and Beam test including time critical changes
    - Test code prior to implementation in the pipeline
  - **Approval process**
    - Through CCB
  
- ❑



# Pipeline Operations

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- Pipeline tasks are responsible for data processing and are divided into two areas
  - **Time critical (from the LAT point of view)**
    - For transients (Automated Science Processing)
    - Does not depend on reprocessing of data
    - Fully automated from start of mission
    - Require human intervention for final validation
  - **Non time critical (from the LAT point of view)**
    - Products from each pass must be processed within 2 hours of the next pass
      - » To allow data analysis prior to next contact
      - » These is the bulk of the science data
- Science Operations coordinate all of the pipeline tasks at Levels 1 and 2, including
  - **Definition**
  - **Monitoring**
  - **Participate in CCB process**