The GLAST Science Support Center

David Band – Science Lead, GSSC

Jay Norris – GSSC Manager

GSSC Staff

Seth Digel—LAT Science Tools Coordinator

Scope of Presentation

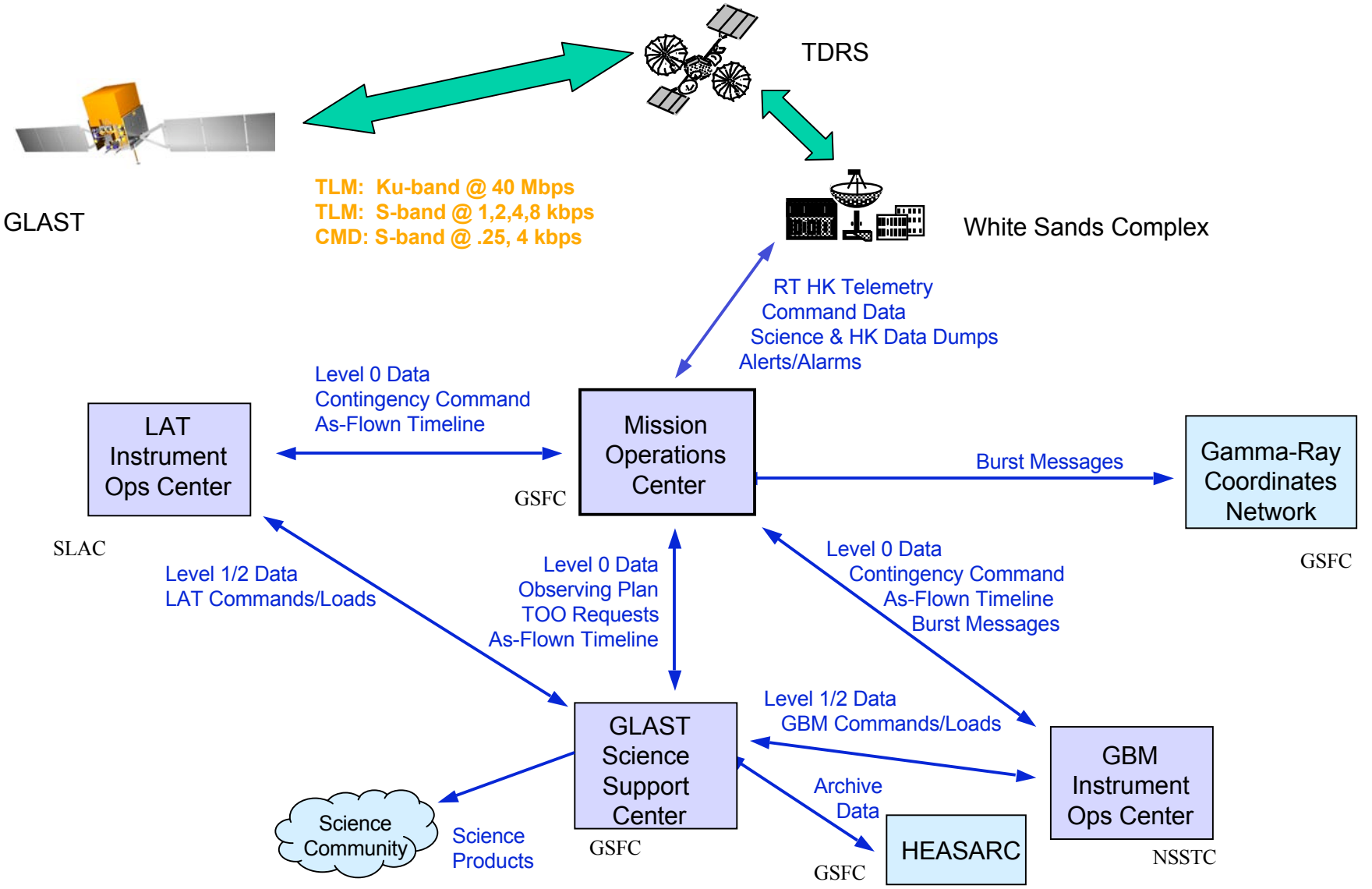
- We are treating this presentation as a review of the GSSC's science functions.
- The GSSC operations will be reviewed at a peer review 11/24/03 and at the GLAST Ground System Design Review (5/04).
- For completeness we include the plans for functions that are not solely in the GSSC's purview, such as for the development of the science analysis tools.

Outline

- Mission Concepts
- Overview of the Ground System
- The Structure of the GSSC
- The Guest Investigator Program
- Investigator Support
- Science Analysis Software—presented by Seth Digel
- Operations
- Schedule

Mission Concepts

Mission Architecture



Time

- The required mission lifetime is 5 years, with a goal of 10
- Mission Phases
  - Phase 0— ~ 60 day checkout after launch
  - Phase 1—1 year sky survey while the instrument teams calibrate their instruments. Data are proprietary to the instrument teams, guest investigators (GIs) and interdisciplinary scientists (IDSs), except for transients. The GIs and the IDSs may NOT change the observing plan.
  - Phase 2—the rest of the mission. Observations are GI-driven.
- Guest Investigator (GI) cycles—periods of 1 year during which GIs carry out investigations. The first cycle is during Phase 1.

Observations

Concept: GLAST can point anywhere, anytime.

- **Survey Mode—the default, designed for uniform sky exposure. The pointing is offset ±30° from the zenith above and below the orbital plane. The offset is changed every orbit, giving a 2 orbit periodicity.**
- **Pointed Mode—inertial pointing at a target. The Earth is kept out of the central 30° to avoid albedo gamma-rays.**
- **Pointed-Scan Mode—the target is kept within the central 30° to maximize target exposure and avoid the Earth.**
- **Autonomous repoint—when the GBM or LAT detects a sufficiently bright burst, GLAST will repoint towards the burst location for 5 hours, except for Earth occultations.**
- **Target of Opportunity (TOO)—repointing commanded from the ground in response to an astronomical event. Repointing should occur within 6 hours of the approval of the TOO.**

Telemetry

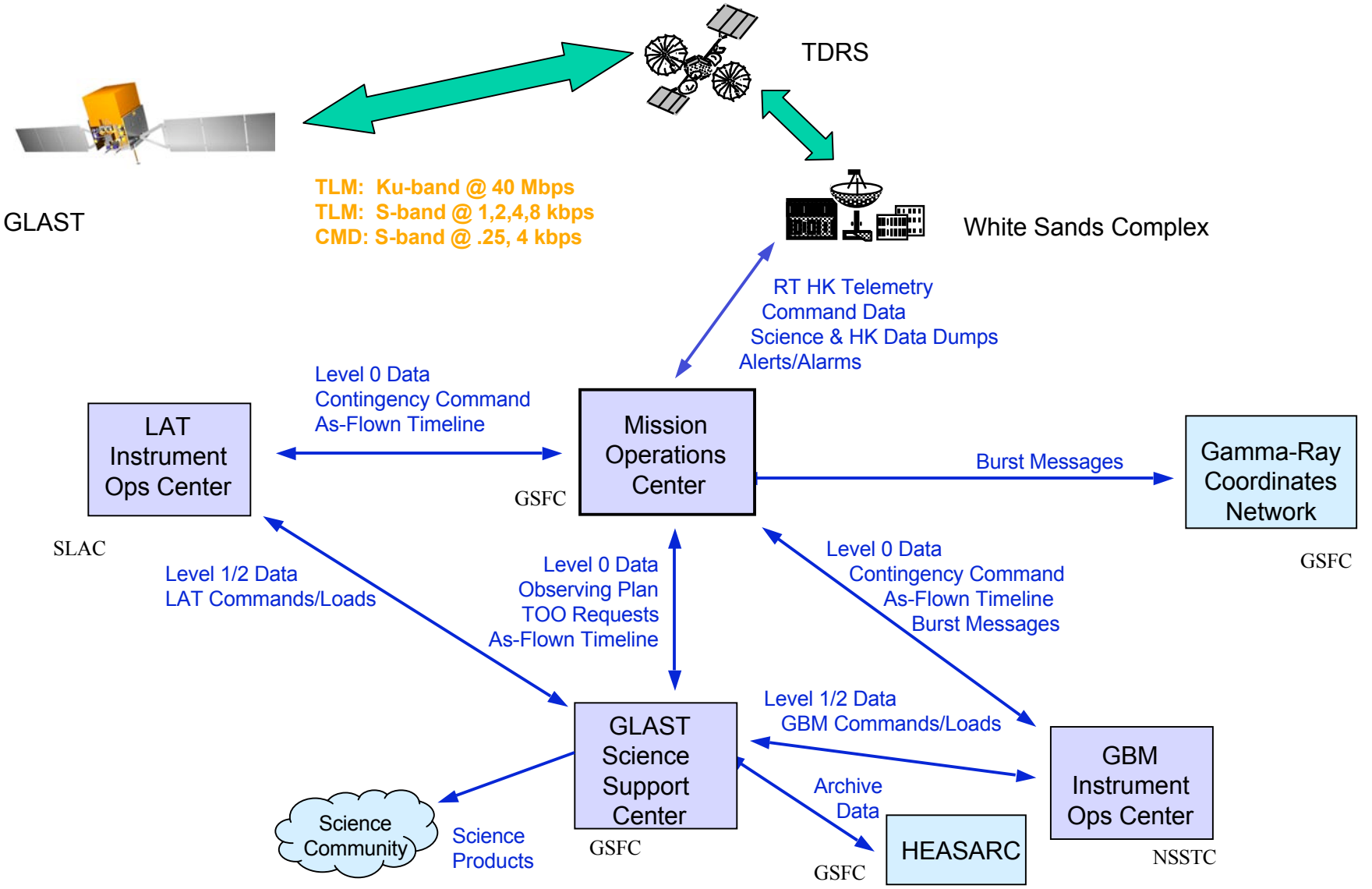
- The mission data (science & housekeeping) are downlinked ~4-5 times per day through a 40 Mbps Ku-band TDRSS link, while commands are uplinked on a 4 kbps S-band link.
- If necessary (e.g., to uplink a large flight software update or to implement a TOO), additional S-band uplinks can be scheduled.
- GLAST can initiate a downlink for a burst or mission alert.
  - If either the LAT or the GBM trigger on a burst, a burst alert will reach the GCN within 7 s of the trigger. Burst telemetry with onboard localizations and basic burst data will continue to be downlinked, primarily through TDRSS.
- Residual S-band ground-network up and downlinks will be maintained as a back-up, and to assist with the mission checkout.

Data Levels

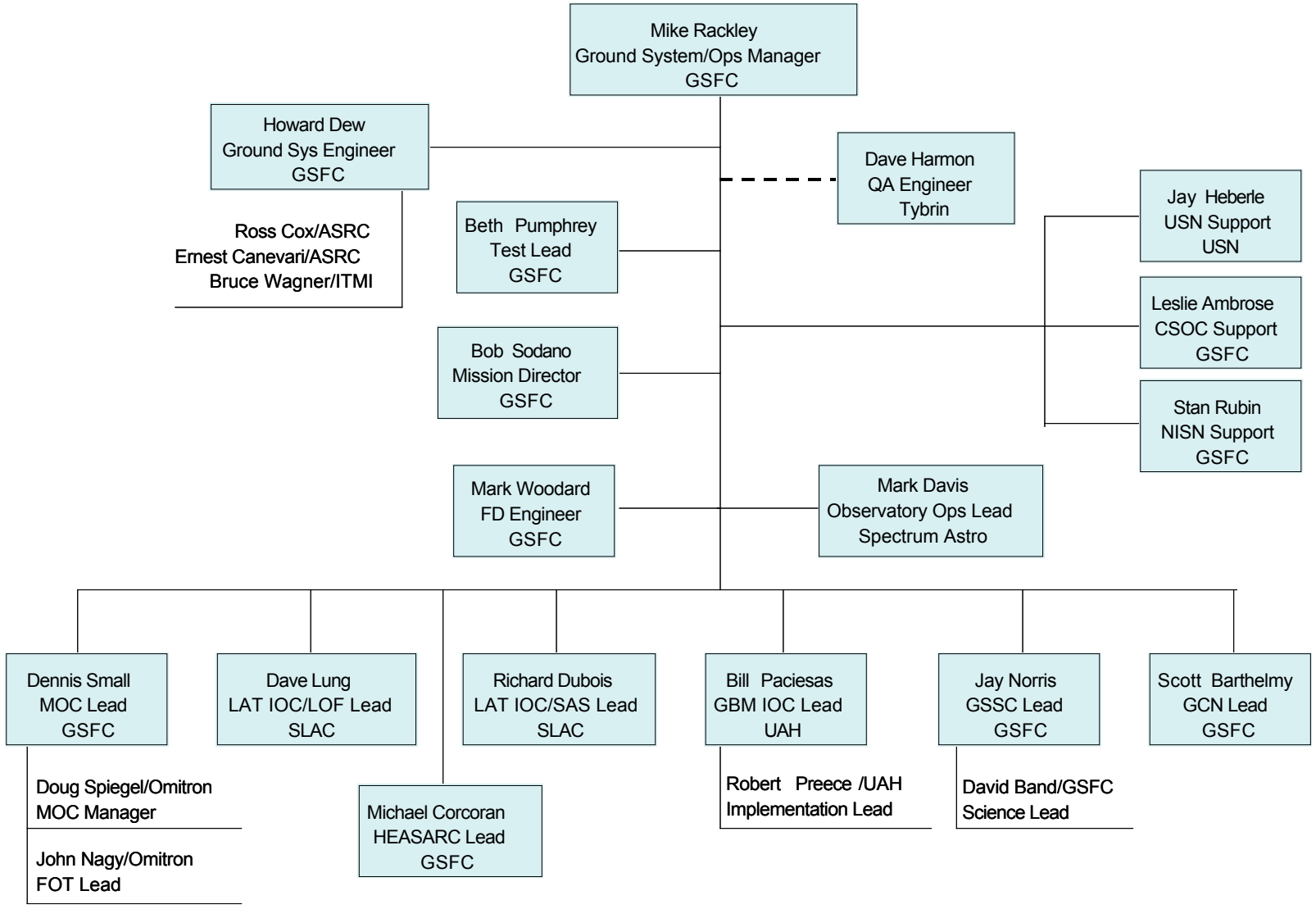
- Level 0—the cleaned-up telemetry: packets are time-ordered; repeated packets are removed; corrupted packets are flagged.
- Level 1—data processed by the instrument teams and ready for astrophysical analysis. LAT events are reconstructed, characterized as photon/non-photon, and described physically (energy, arrival time, origin,…).
- Level 2—result of routine data analysis, e.g., spectral fits.
- Level 3—compendia of Level 2 data, e.g., catalogs.
- Ancillary data—the astrophysical analysis will require a model of the diffuse background, and a database of pulsar ephemerides.

Overview of the Ground System

Mission Architecture



Ground System/Ops Organization



Version: 10/6/03

Mission Operations Center

- Will be located at GSFC and operated by Omitron. It will draw upon Swift heritage.
- Ingests telemetry from TDRSS.
- Performs Level 0 processing (time orders packets, removes duplicate packets, flags corrupted packets) with latency of 4 hours.
- Sends Level 0 data to:
  - Instrument Operation Centers (IOCs) for further processing
  - GSSC for archiving
- Monitors housekeeping for spacecraft and instrument anomalies
- Commands observatory

LAT Instrument Operation Center (LIOC)

- Will be located at SLAC.
- Ingests Level 0 data from MOC.
- Performs Level 1 processing: reconstructs events from LAT data and categorizes them as photon/non-photon. Processing has 1 day latency.
- Sends Level 1 data to:
  - GSSC for dissemination to the science community and for mission archiving
  - Local databases for use by LAT collaboration
  - LAT collaboration mirror sites
- Maintains instrument: monitors housekeeping and updates instrument calibrations.
- Creates instrument commands that are sent to the observatory through the GSSC and the MOC.

LIOC, cont.

- Maintains diffuse emission model.
- Creates point source catalog after 1, 2, 5 years and the entire mission. A preliminary catalog will be released before the proposals for the 2nd cycle are due.
- Level 1 pipeline includes a search for transients.
- At least initially, the LIOC will monitor and post the light curves of ~ 20 bright sources.
- Creates the instrument response functions.
- Responsible for development of science analysis tools.

GBM Instrument Operation Center (GIOC)

- Will be located at the National Space Science & Technology Center (NSSTC) in Huntsville, AL, a joint MSFC-UAH center.
- Ingests Level 0 data from MOC.
- Performs Level 1 processing: calibrates counts and creates response matrices for bursts. Processing has 1 day latency.
- Sends Level 1 data to:
  - GSSC for dissemination to the science community and mission archiving
  - Local databases for use by GBM collaboration
  - GBM collaboration mirror site in Germany
- Maintains instrument: monitors housekeeping and updates instrument calibrations.
- Creates instrument commands that are sent to the observatory through the GSSC and the MOC.

GIOC, cont.

- Creates and maintains burst catalog.
- Responsible for development of science analysis tools, including tool to create response matrices.
- Will create Burst Alert Processor (BAP) that will be in the MOC (and serviced by GSSC). The BAP will be the MOC's interface to the GCN, and will calculate burst locations from data transmitted through TDRSS.

GRB Coordinate Network (GCN)

- Located at GSFC, created as BACODINE to distribute BATSE coordinates.
- Sends burst alerts (machine readable burst locations) and messages (similar to IAU circulars) for many missions.
- Will disseminate the following GLAST notices:
  - Locations calculated by the GBM (or LAT?) and transmitted from the spacecraft to the MOC to the GCN.
  - Locations calculated in the MOC from GBM data by the Burst Alert Processor provided by the GBM team. No human intervention.
  - Locations calculated by the IOCs with human intervention.

HEASARC

- The High Energy Astrophysics Science Archive Research Center (HEASARC) at GSFC will be the ultimate archive of the GLAST data.
- The GSSC databases are being constructed to HEASARC standards: data in FITS files and metadata pointing to these FITS files.
- Similarly, the science tools are being developed within the HEASARC's HEADAS software system. Tools will use IRAF-style parameter files.
- During the mission the GSSC and the HEASARC may access the same databases.
- The GSSC computer system will be part of the HEASARC system.

Databases and Archives

- The GSSC will ingest the data it receives or produces into databases.
  - In general these databases will be in HEASARC-standard form: data in FITS files and metadata describing the data and where it is stored
  - In some cases the GSSC will use a database that is optimized for operational use (e.g., access speed). For example, event data may be distributed over a number of computer nodes.
- The GSSC will deliver its databases to the HEASARC as the permanent mission archive.
  - While the mission is in progress the HEASARC may begin accessing GLAST data.
  - The HEASARC will NOT have to use or maintain the databases optimized for operational use.

The Structure of the GSSC

GLAST Science Support Center

- A component of the Office of Guest Investigator Programs (OGIP) in the Laboratory for High Energy Astrophysics (LHEA) at GSFC.
- Will not have a physical Guest Observer Facility (GOF) to which investigators come for assistance in analyzing data.
- In brief, the GSSC will:
  - Support the Guest Investigator Program
  - Disseminate data, analysis tools and documentation to the science community
  - Maintain the science timeline
  - Vet IOC commands for impact on timeline
  - Upon the Project Scientist's approval, send ToO order to MOC
  - Archive data in the HEASARC
  - Support the Project (e.g., running conferences)

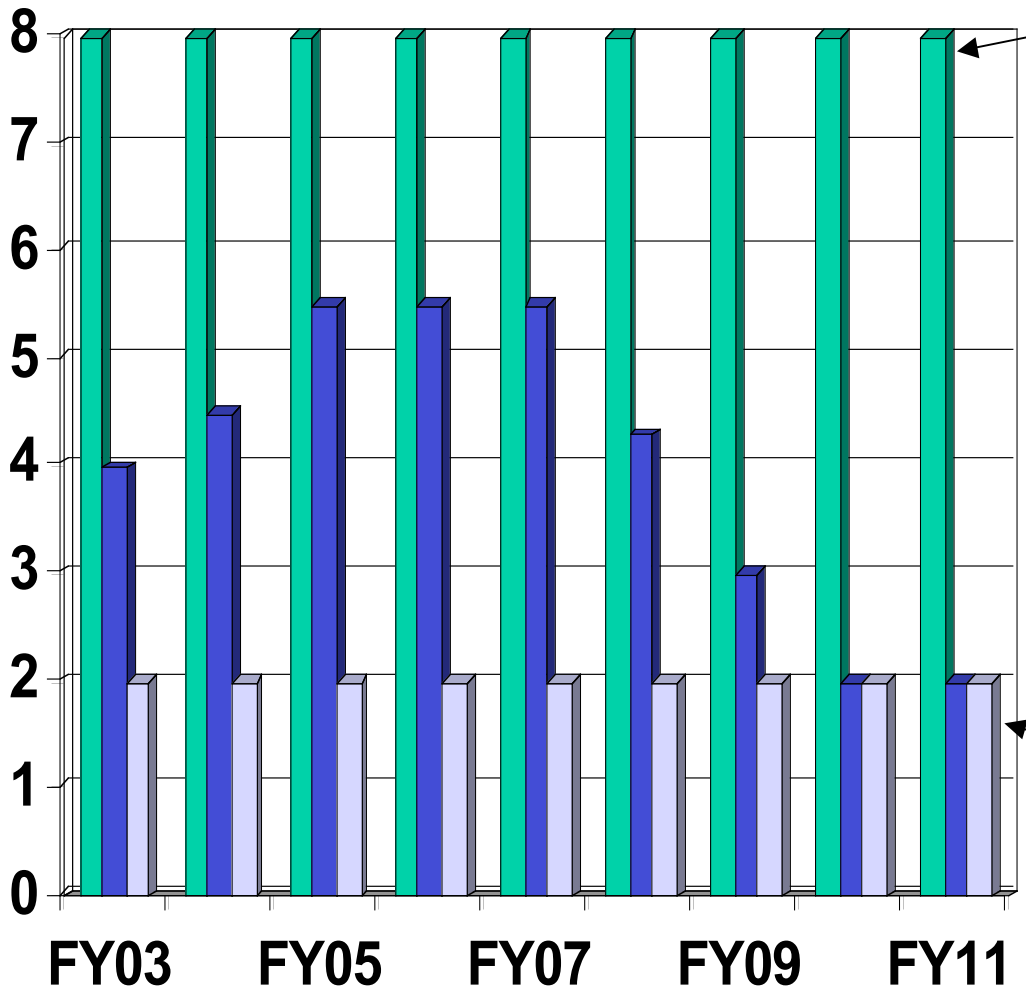
Mission-Specific Features

- Note that the IOCs perform many of the functions often performed by a science operations facility:
  - Development of the instrument response functions.
  - Responsibility for creation of science analysis tools.
  - Operation of the telemetry processing pipeline.
- However:
  - The GSSC will have "backup" data processing pipelines.
  - The GSSC will have an understanding of the instrument calibrations, and will ensure that use of the resulting response functions is feasible given users' CPUs and data memory.
  - The GSSC collaborates with the instrument teams in defining the suite of analysis tools, and is contributing resources towards their development.
- Other than during the first year, there are no proprietary data.

Members of the GSSC

- Jay Norris—manager
- David Band—science lead
- Scientists:
  - Dave Davis—databases
  - Masaharu Hirayama—LAT scientist
  - Yasushi Ikebe—calibrations
  - Dirk Petry—user services
  - Jim Chiang—ambassador to LIOC
  - Valerie Connaughton—GBM scientist, ambassador to GIOC
  - Jerry Bonnell—GRBs/PR
  - Robin Corbet (part time)—operations
- Software:
  - Bob Schaefer—databases
  - Sandhia Bansal—programmer
  - Chunhui Pan—programmer
  - Tom Stephens—programmer
  - James Peachey (part time)—programmer
  - Zvi Band (part time)—programmer
- Support
  - Sandy Barnes—administrator
  - JD Myers (part time)—webmaster

Staffing Profile



Includes one GSSC scientist at the LIOC and one at the GIOC

Science
Software
Administrative

Includes support to the GLAST project

Responsibilities

- Overall management of the GSSC is shared by Jay Norris, GSSC Manager, and David Band, GSSC Science Lead
  - Jay is responsible for budget and personnel
  - David is responsible for day-to-day operations
- GSSC staff members are responsible for different areas:
  - Software—Bob Schaefer
  - Operations—Robin Corbet
  - Hardware, databases—Dave Davis
  - Investigator support—Dirk Petry
  - Computer security—Masa Hirayama

The Requirements: Paper Trail

- The formal hierarchy
  - Science Requirements Document (433-SRD-0001)
  - Mission System Specification (433-SPEC-0001)
  - Ground System Requirements Document (433-RQMT-0006)
  - SSC Functional Requirements Document (433-RQMT-0002)
- Other applicable documents include
  - GLAST Announcement of Opportunity (AO)
  - Project Data Management Plan (PDMP—433-PLAN-0009)
  - Operations Concept Document (433-OPS-0001)
  - GSSC-HEASARC MOU
  - Report of Data Products Working Group

Relevant Documents

Document	Purpose	Draft	Final	CCB
Project Data Management Plan	Describes the mission's flow of data. Includes data policy statement. Reviewed but not signed.	9/01	10/03	Project
GSSC Functional Requirements Document	The GSSC's requirements. Written before the Ground System Requirements Document; update has not yet been through CCB.	9/01	12/02	Project
Science Data Products ICD	Describes the science data products. Based on a 2 year-old working group report. The GSSC is the lead.	10/03	5/04	Ground System
Operations Data Products ICD	Describes the operations data products that will be exchanged among the ground system elements. The MOC is the lead.	10/03	5/04	Ground System
GSSC-HEASARC MOU	MOU establishing mutual GSSC and HEASARC requirements.	9/02		GSSC
The Standard Environment for the Analysis of LAT Data	Defines the tools and software environment for the scientific analysis of LAT data. Developed by GSSC-LAT Software Working Group.	9/02		LAT team
LHEA IT Security Plan	Establishes the IT security plan for LHEA			LHEA

Internal GSSC Documents

Document	Purpose	Status
GSSC Development Plan	Plan for developing the GSSC	Draft 12/03
GSSC Design Specification	Design of the GSSC	Draft 4/04
GSSC Test Plan	Plan for testing GSSC's functions, particularly software	Draft 5/04
LAT Event Summary Database Requirements Document	Requirements for the database from which lists of LAT photons will be extracted	Draft 3/02
GSSC Database Architecture Document	Architecture of the GSSC's databases, including the computer system	Draft 5/03
GSSC Software Management Plan	Plan for the development of the GSSC-specific software	Designed, not yet drafted
GSSC Internal Software Requirements	Requirements for the GSSC-specific software	In development
Informal documents on GSSC internal website: memos, white papers, etc.		

- ***These documents will be under internal CM.***

Reviews

- Operations—except for a peer review next month, the ground system reviews will also be the reviews of GSSC operations
  - Ground System Requirements Review (7/03)
  - GSSC Peer Review (11/24/03)
  - Ground System Design Review (5/04)
  - Mission Operations Review (4/05)
  - Operations Readiness Review (7/06)

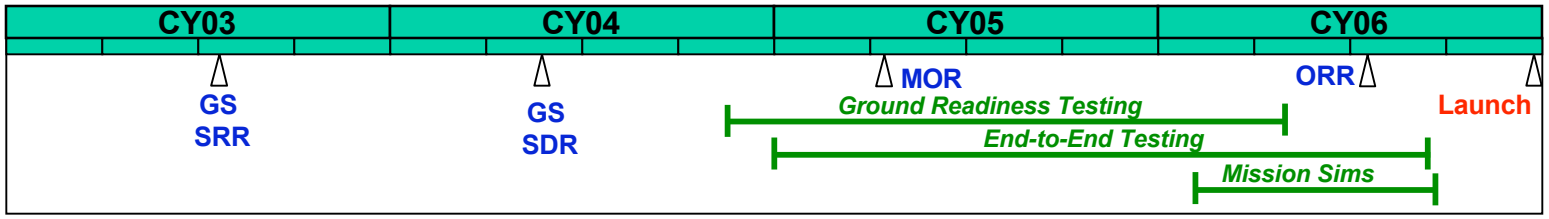
- Science—you are reviewing our science plans; the peer review panelists include scientists experienced in ground operations

Ground System-Level Documents

Document	*Purpose*	*Draft*	*Final*
Ground System Project Plan	Describes approach to implementing and testing the overall ground system	May 2003	GS SRR (July 2003)
Operations Concept Document – Rev 1	Describes the operations approach and scenarios for the mission (normal operations)	April 2003	GS SRR (July 2003)
Ground System Requirements Document	Documents the Level 3 requirements for the complete ground system; traces to Mission System Spec, Operations Concept Document, ICD's etc.	May 2003	GS SRR (July 2003)
Ground System Test Plan	Describes approach to planning and coordinating the ground readiness and end-to-end tests	November 2003	May 2004
Operations Agreement on Roles and Responsibilities	Defines the ops roles and responsibilities among Project, Spectrum, and instrument team personnel for preparing for launch	October 2003	GS CDR (June'04)
Mission Ops Readiness Plan	Provides a more detailed description of the approach to be taken to ensuring the products, processes, and personnel are ready for launch – presented at MOR	GS Design Review (5/04)	MOR-2 mos
Operations Agreements	Various agreements among the operations teams for how they will interact on a day-to-day basis	MOR	ORR

Ground System-Level Documents

Document	Purpose	Draft	Final
IT Security Plan	Describes how the entire ground system will meet IT Security Requirements defined in NPG 2810.1	GS Design Review (5/04)	GS Design Review (5/04)
Contingency Plan	Describes how contingencies will be handled in terms of facilities and networks	GS Design Review (5/04)	GS Design Review (5/04)
Risk Management Plan	Identifies MOC facility and IT security risks and how they will be addressed	GS Design Review (5/04)	GS Design Review (5/04)



The Guest Investigator Program

Guest Investigator (GI) Program—Time Periods

- The mission has 3 phases:
  - Phase 0—the ~ 60 day checkout period after launch
  - Phase 1—the 1 year sky survey. Except for observations of transients, the data are restricted to the instrument teams and a small number of guest investigators.
  - Phase 2—the rest of the mission until deorbit. The GI program drives the observations, although survey mode will probably predominate.
- There will be yearly GI cycles. Cycle 1 will coincide with Phase 1, and only ~a dozen GIs will be selected. ~100 GIs will be selected in each subsequent cycle.
- During Phase 2 the budget will be ~$6M/year. Accounting for the cost of administering the program, the average grant will be ~$50K.
- The exact numbers are subject to the vagaries of the federal and Project budget.

Support of the GI Selection Process

- By administering the GI program, the GSSC will support NASA HQ's selection of GIs.
- We anticipate that most proposals will only request funding, and that most data requirements will be met by survey mode observations.
- The GSSC will write or collect the text of the NRA and supporting materials
  - Neil Gehrels has been writing the Science Plan
  - NASA HQ (including lawyers) will review and release the NRA
  - The entire package will be posted on the GSSC's website, along with proposal development tools (discussed below)
- A two step proposal process will be used: the funding proposal will be submitted only if the science proposal has been accepted.
- The proposals will be submitted electronically; RPS will be used.

GI Selection, cont.

- The GSSC will provide NASA HQ with a list of potential reviewers.
- The review will enforce standard conflict-of-interest policies
- The GSSC will support the peer review
  - The proposals will be categorized and distributed to panels covering different topics
  - The logistics of the review will probably be handled by a contractor, under GSSC supervision
- Consisting of the GSSC, the IOCs, the Project Scientist, and representatives of the community, a Timeline Committee will consider whether the observing proposals selected by the peer review panels can be scheduled. Only those that can be scheduled will be recommended for NASA HQ approval.
- The GSSC will support the notification of proposal acceptance and rejection, and the disbursement of funds.

GI Program Schedule

	Cycle 1	Subsequent Cycles
NRA Development	T_0-18 months	T_0-14 months
HQ Review of NRA	T_0-14 months	T_0-12 months
NRA Release	T_0-10.5 months	T_0-9 months
Proposal Deadline	T_0-7.5 months	T_0-6 months
Peer Review	T_0-4.5 months	T_0-4 months
Notification of Rejections	T_0-4 months	T_0-3.5 months
Timeline Meeting	T_0-3.5 months	T_0-3 months
Request Funding Prop.	T_0-3 months	T_0-2.5 months
Funding Proposal Due	T_0-1.5 month	T_0-1 month
Funding Decision	T_0-1 month	T_0-0.5 month
Beginning of Cycle	T_0=L+60 days	T_0
End of Cycle	T_0+1 year	T_0+1 year

Proposal Preparation Tools

- Support will be primarily through the GSSC's website
- Exposure maps from past observations will be posted—allows users to see what is available.
- Exposure prediction:
  - Tables predicting time to accumulate a specified exposure for both survey and pointed modes (averages over actual orbital constraints).
  - Tables for exposure accumulation considering orbit precession (does not require very accurate orbit simulator)
  - Orbit simulator for planning simultaneous observations. May not be sufficiently accurate more than a few weeks in advance.
- Detectability tables—predicts exposure necessary to detect source of given strength and spectrum.
- Observations simulator—may use analysis tools with real or simplified (for computational speed) response functions.

GI Program Principles

- During Phase 1 (first year) the sky survey cannot be disturbed by GI proposals. GIs will be expected to work with the instrument teams, and proposals supporting the mission will be favored.
- The ToO allocation will have an expectation value of 1 per month.
- Proposed research may be:
  - Data analysis of new observations
  - Data analysis of archived observations
  - Related theory
- In Phase 2 data will be accessible immediately to the world. It would be difficult to reserve portions of the sky from a wide field-of-view instrument with a large PSF.

Investigator Support

Overview

- As will be discussed below, analyzing LAT data will be different from analyzing other high energy astrophysics data. We want to encourage investigators to analyze GLAST data, and to assist them when they do so.
- Since the data are not proprietary in Phase 2, we will assist both successful GIs and investigators without accepted proposals.
- Categories:
  - Pre-launch meetings
  - Post-launch meetings
  - Practice data analysis
  - Investigator support through the GSSC website
- Because users will have sufficient computing resources and easy access to the internet, we will not support a dedicated facility where users analyze data.

Pre-Launch Meetings

- Presentations at meetings (AAS, HEAD, conferences) dealing not only with GLAST but specifics of the nature of the data and its analysis. As launch approaches these presentations should become more detailed.
  - For example, at the GRB 2003 conference in Santa Fe, there was a GLAST talk (Michelson) and posters on the GBM (Bhat *et al.*), the LAT trigger (Bonnell *et al.*), the GBM trigger (Band *et al.*) and the analysis of LAT burst observations (Band *et al.*).

- Dedicated pre-launch workshop (similar to pre-CGRO workshop) to coincide with the release of the 1st NRA (~9 months before launch). Should include hands-on demonstrations.

Post-Launch Meetings

- A workshop describing the observatory on-orbit. This workshop should focus heavily on the analysis system and proposal tools (it will be too early for many scientific results). The workshop should be timed for the release of the 2nd NRA (only 3 months into Phase 1!).

- Annual conferences (similar to the Compton and Huntsville conferences), timed for NRA releases. In the early years the analysis tools should be emphasized.

Practice Data Analysis

- Make tools available with simulated GLAST data and real EGRET data before real GLAST data are available. The GLAST tools will operate on EGRET data and response functions. These tools are being released with the Data Challenges and thus the full set should be available before launch.

- Hands-on data analysis workshops every ~1/2 year (similar to Chandra's) starting the first year after launch.

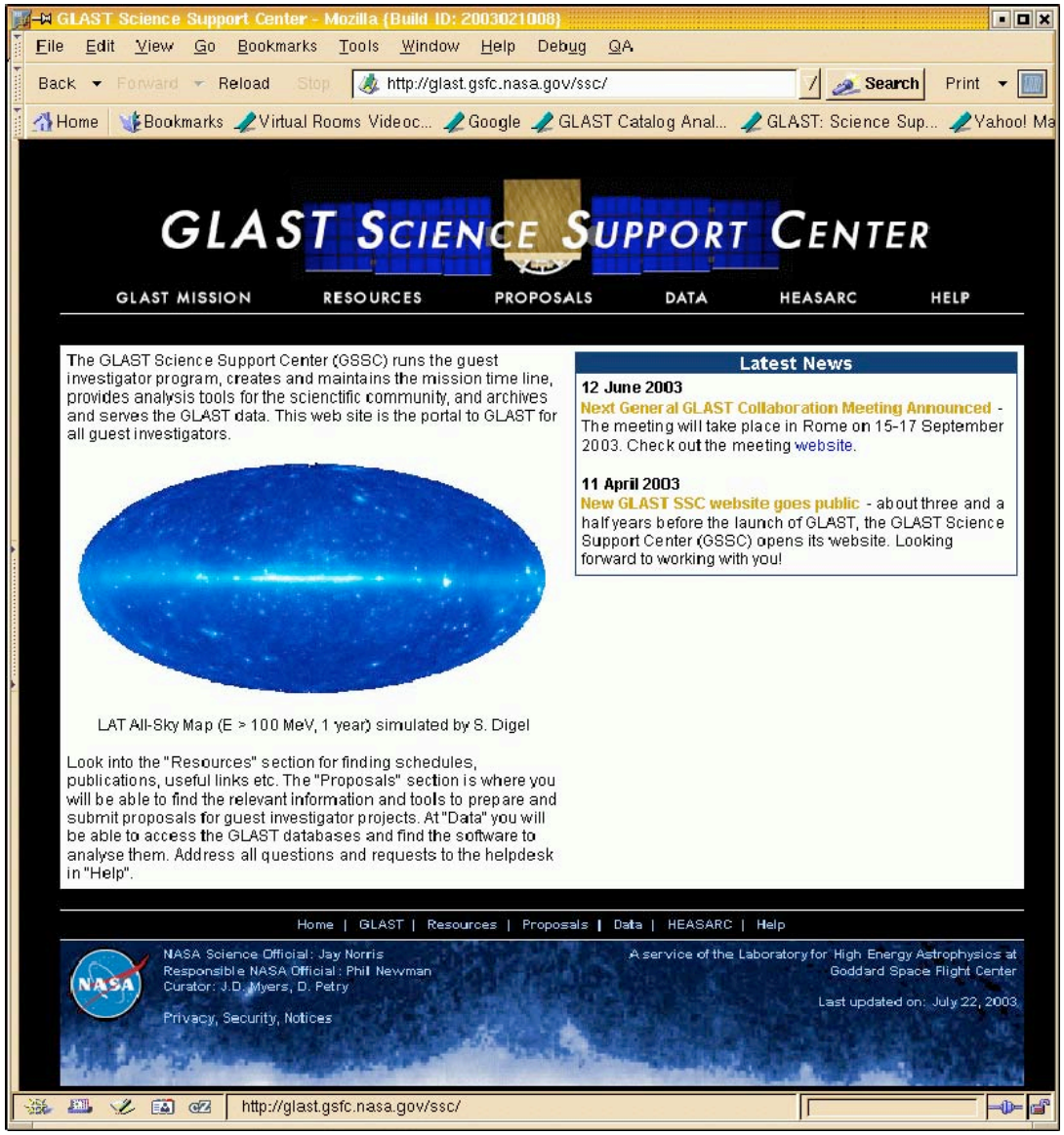
Investigator Support

- Online documentation—on GSSC website. Including the use, applicability and methodology of each tool. Clear documentation is crucial!
- Analysis threads—on the GSSC website. Scripts for standard data analysis operations. Will be updated by user contributions.
- Helpdesk—through the GSSC website (and NOT by telephone!). Q&A will be logged.
- FAQ—posted on the GSSC website, based on the Helpdesk Q&A.

The GSSC website is posted:

glast.gsfc.nasa.gov/ssc

Top Page of GSSC Website



GSSC Website Design Concepts

- Flat hierarchy
- Four main sections—Resources, Proposals, Data, Help—always accessible directly from the top navigation bar, side menu for navigation inside each main section
- Section 508 compliant
- Low number of images for quick loading

Website Map

- Mission ⇒ to NASA GLAST site
- Resources:
  - Mission Status
  - Observing Timelines
    - Short Term
    - Long Term
    - Past
  - Observations
    - LAT All-Sky Survey
    - LAT Pointed
    - LAT ToO
    - GRBs
    - Exposure
  - Library
  - Useful Links
  - News Archive

Website Map, continued

- Proposals:
  - General Information
  - Cycle Timeline
  - Cycle 1 (Proposal Preparation, Accepted Proposals)
  - Cycle 2 (Proposal Preparation, Accepted Proposals)
  - …Cycle n
- Data:
  - Data Access
    - LAT Data
    - GBM Data
  - Data Analysis
    - System Map
    - Software Download
    - Documentation
    - User Contributions

Website Map, continued

- HEASARC ⇒ to HEASARC front page
- Help:
  - Helpdesk
  - FAQ
  - About the GSSC

Science Analysis Software

Analysis Software—Overview

- The instrument teams are responsible for developing the analysis software, and the GSSC for its distribution.
- The LAT tools for GRB analysis are designed to be multi-mission, and the burst tools will also analyze GBM data.
- The only GBM-specific tools we need are to create the detector response matrix (DRM) and the background for GBM data. The GBM team will provide this, with GSSC assistance.
- The GBM team will also update and provide RMFit, an IDL burst spectral analysis tool.
  - Both the IDL procedures and an executable that will be free to the users will be available.
  - However, RMFit does not fit smoothly into the GLAST analysis environment (discussed below), and therefore the tools in the LAT analysis environment will have basic burst spectral analysis capabilities.
- The rest of the discussion of analysis tools focuses on LAT tools.

Science Tools

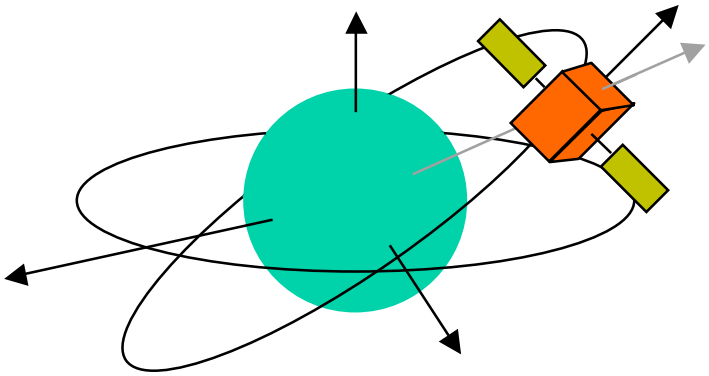
- Definition of the Standard Analysis Environment
  - Design considerations & Definition process
  - GSSC-LAT working group, with HEASARC representation
  - Components, walk through & example
- Infrastructure, development and testing
  - Infrastructure
  - Testing
- Current status
  - Infrastructure & Science tools
  - Preparation for DC1
- Milestones
  - DC1 (& Invitation to participate)
  - Post-DC1 schedule
- Organization for development – who and what

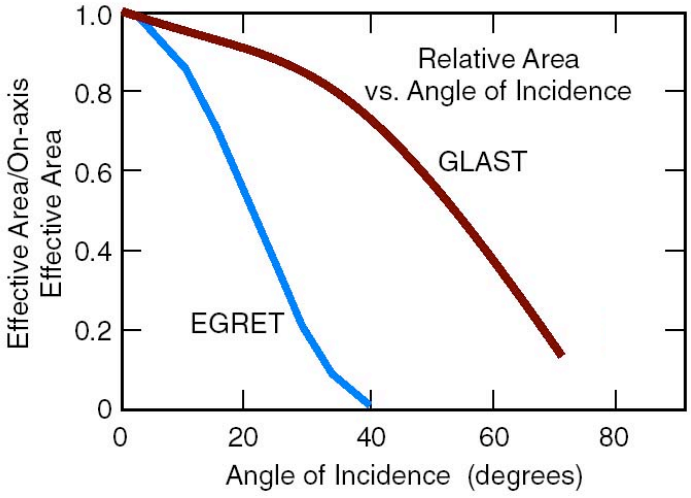
LAT Science Analysis Tools: The Standard Analysis Environment

- The standard analysis environment consists of the tools and databases needed for routine analysis of LAT data.
- This environment will be used by both the LAT team and the general scientific community.
- This environment was defined jointly by the LAT team and the GSSC, but will be developed under the LAT team's management with GSSC participation.
- The analysis environment does not support all possible analyses of LAT data. Not included, for example:
  - Analysis of multi-gamma events or cosmic rays
  - High-resolution spectroscopy
  - Quick-look analysis
  - Software for developing the point source catalog

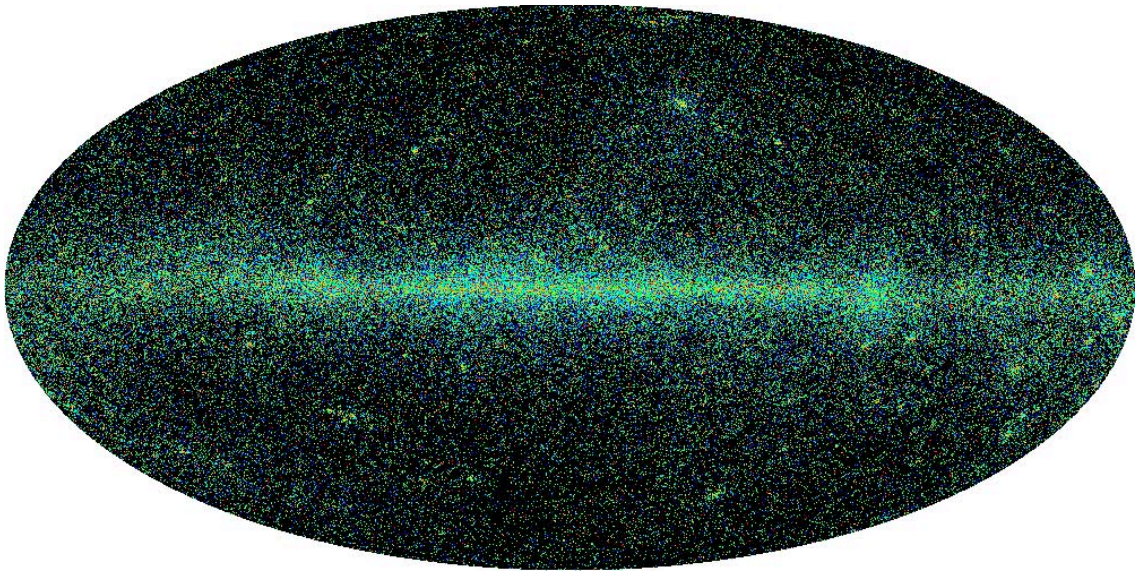
Design Considerations

- **The special challenges of analyzing LAT data**
  - **The LAT will primarily operate in scanning mode**
  - **Enormous FOV (>2 sr)**
  - **Response functions, in particular the PSF, depend on arrival direction in instrument coordinates**
  - **Response functions will also depend on other parameters, such as conversion plane in the tracker**
  - **So a given region will be observed *with many different response functions***





Design Considerations (2)

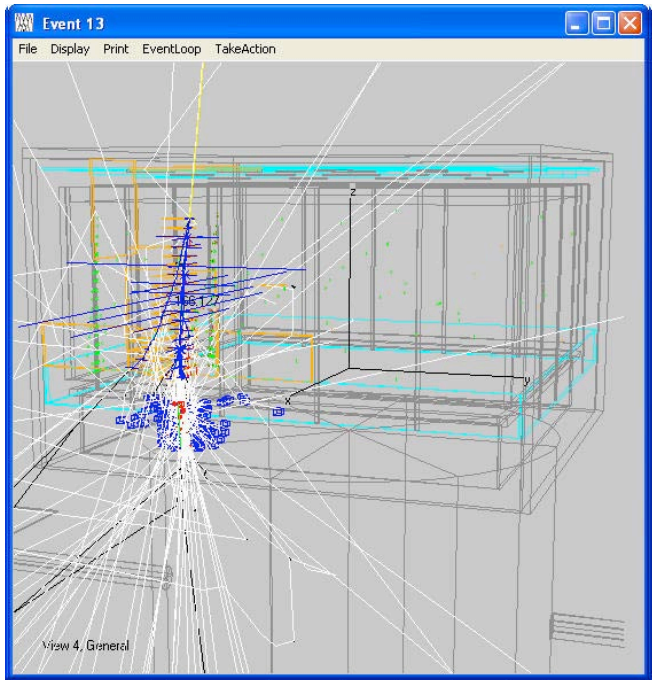


One day's worth of LAT gamma rays

- Fluxes of celestial sources are low (~1 _/minute for a bright source), and the celestial background relatively bright (~2.5 Hz over the FOV)
- Earth albedo _-ray intensity is even brighter (30 Hz if stare at limb)
- Charged particle background is extremely intense (few kHz rate)
- Relatively very poor angular resolution, especially on consideration of the tails and the density of sources

Design Considerations (3)

- Complicated data – and reconstruction and classification of events – underlay making the LAT a 'Telescope'
- As for previous high-energy gamma-ray astronomy missions, the core high-level analysis will be model fitting, i.e., parametric analysis
  - The analysis relies on an abstract characterization of the LAT – via its response functions
  - Models have discrete sources plus interstellar diffuse emission and isotropic emission
  - Mixing of instrument coordinates with coordinates on the sky, owing to scanning, is one motivation to pursue unbinned likelihood analysis



T. Usher

- Scanning operation also strongly influences database design (as will be discussed later)

Definition Process

- The process formally began in January, 2000, with a meeting at SLAC (before the GSSC was constituted)
- The data products the analysis environment will use were defined by the GLAST-wide Data Products Working Group (mid-2001 to early 2002).
- GSSC-LAT Software Working Group established in March, 2002 to define the analysis environment. 3 LAT and 3 SSC members, co-chaired by S. Digel and D. Band, and representation from HEASARC (J. Peachey)
- Workshop at SLAC in June, 2002, reviewed the proposed analysis environment (~30 attendees LAT+GSSC)
- Definition of analysis environment guided by use cases, anticipation of science possible with LAT data, and expertise analyzing high energy astrophysics data
- A formal review of our plans was made; see http://www-glast.slac.stanford.edu/ScienceTools/reviews/sept02/

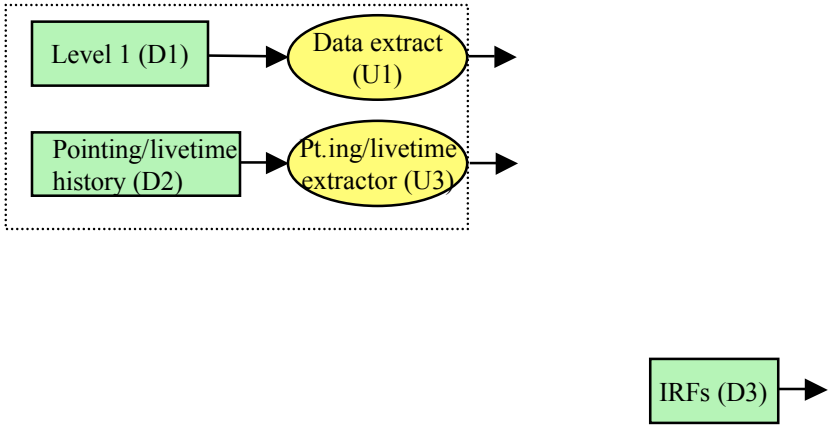
More on Definition

- We are not attempting to reinvent the wheel
  - Compliance with standards for high-energy astrophysics analysis facilitates software reuse
  - Ideally, we'll reuse the kind of software that we don't have to maintain, like Xspec
  - Other most likely candidates for reuse are tools for timing analysis

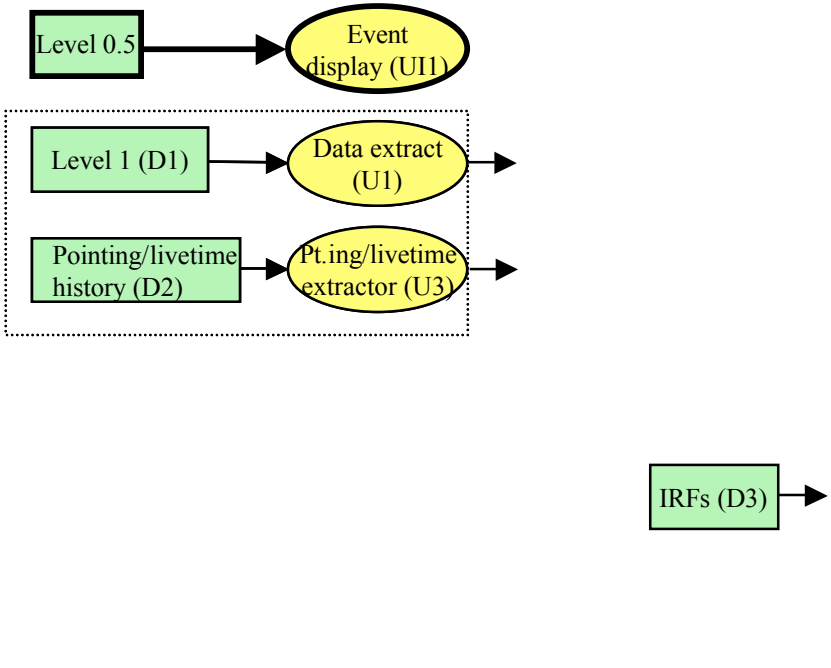
Walkthrough of the SAE

- Schematic illustration of the data flow and how the tools relate to each other. Not all inputs (e.g., from user) are explicitly indicated
  - Detailed descriptions of each component are available
- The tool's identification scheme (letter + number) is for convenience; the distinction between U & A can be subtle
  - D – database (in a general sense)
  - U – utility (supporting analyses)
  - A – analysis tool
  - O – observation simulation
  - UI – user interface (common aspects to utilities & analysis tools)
- Common data types that can pass between tools are defined but not included in the diagram
- User Interface aspects of the SAE--such as Image/plot display, Command line interface & scripting, and GUI & Web access--are not shown explicitly in the diagram

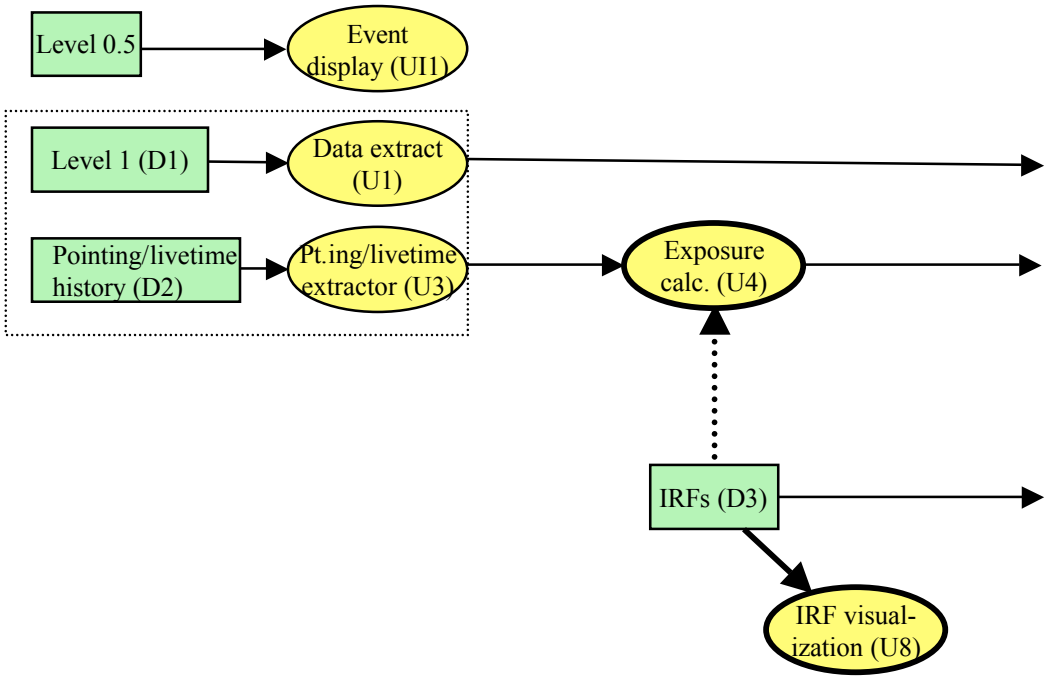
Event Data, Pointing & Livetime History, and Response Functions



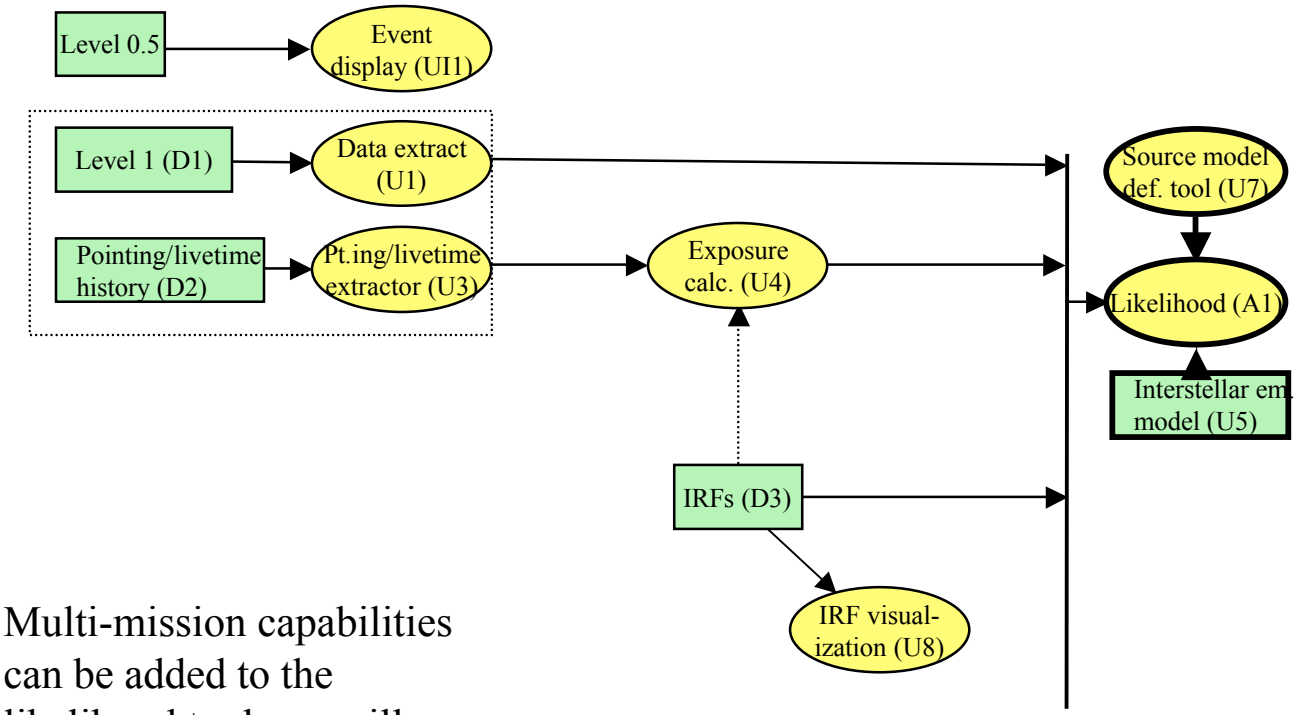
Event Display



Exposure

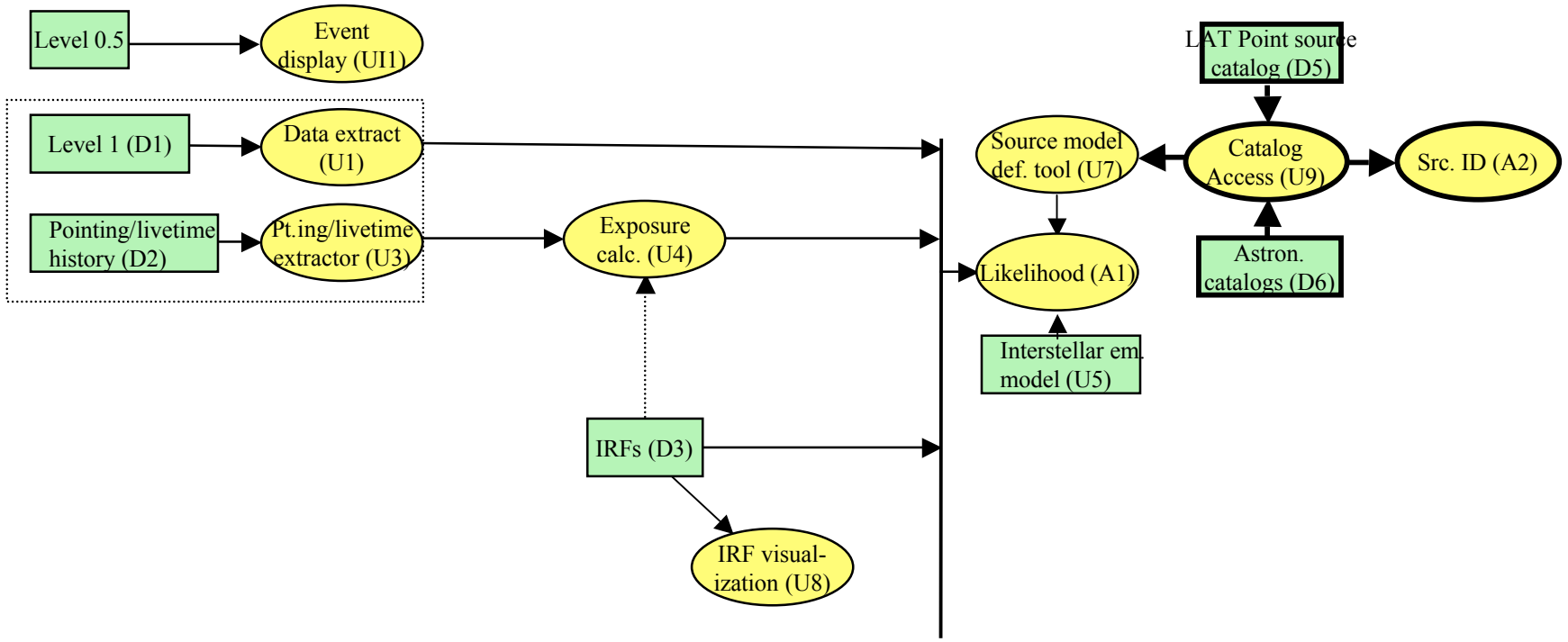

Level 0.5
Event display (UI1)
Level 1 (D1)
Data extract (U1)
Pointing/livetime history (D2)
Pt.ing/livetime extractor (U3)
Exposure calc. (U4)
IRFs (D3)
IRF visual-ization (U8)

Likelihood Analysis

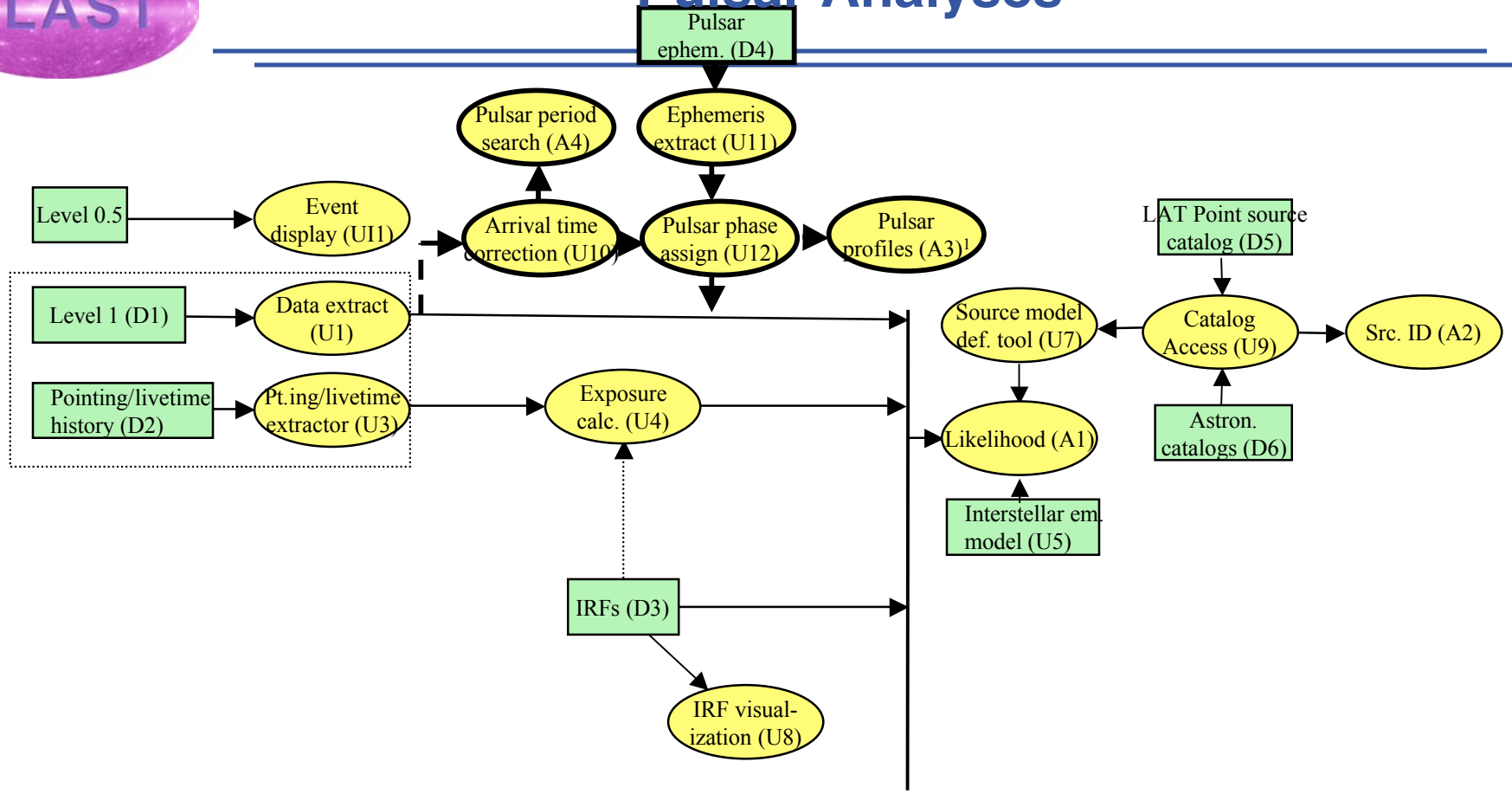


Multi-mission capabilities can be added to the likelihood tool; we will study whether such analysis is computationally feasible.

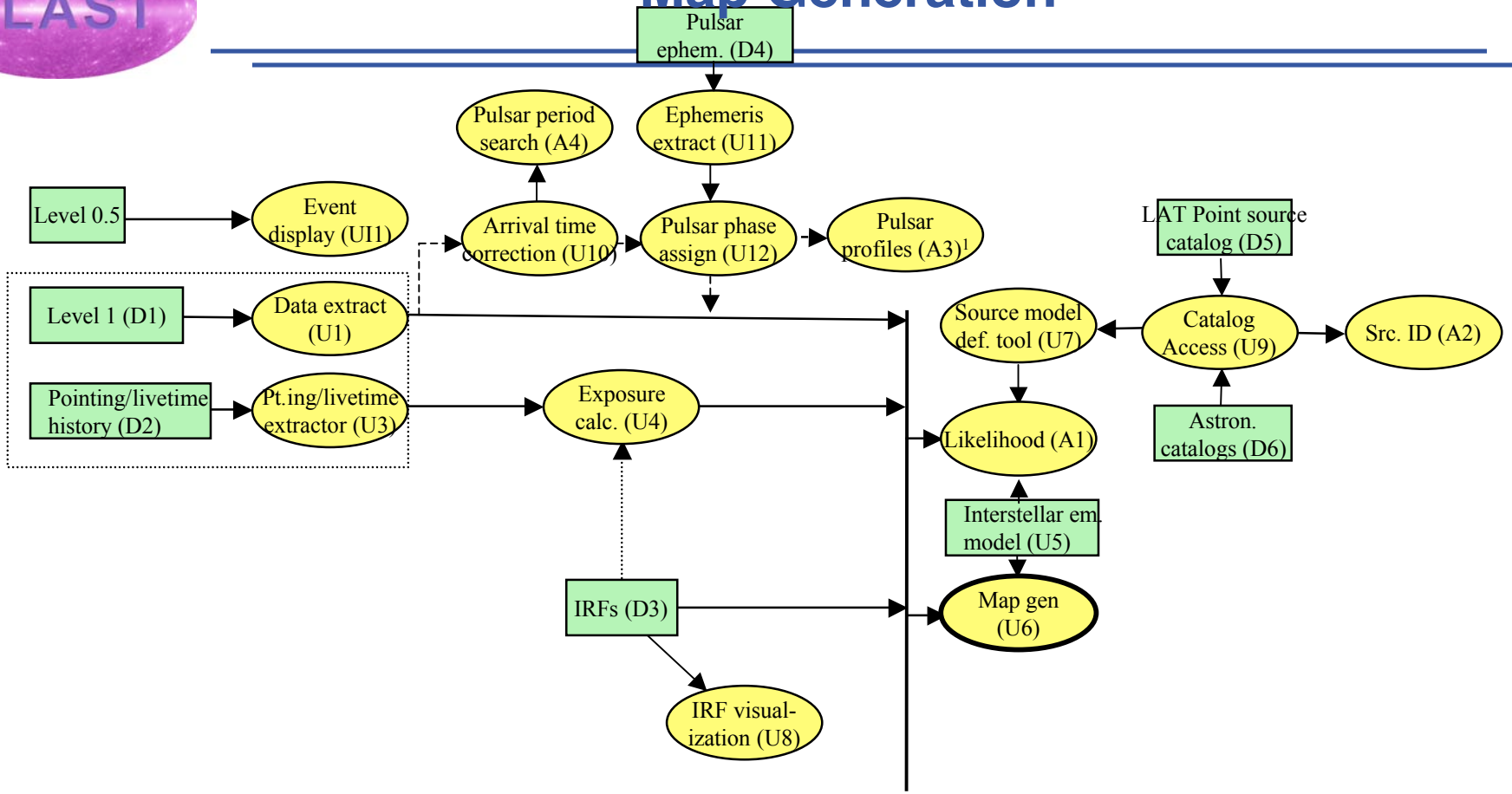
Point Source Catalog, Astronomical Catalogs, & Source Identification



Pulsar Analyses

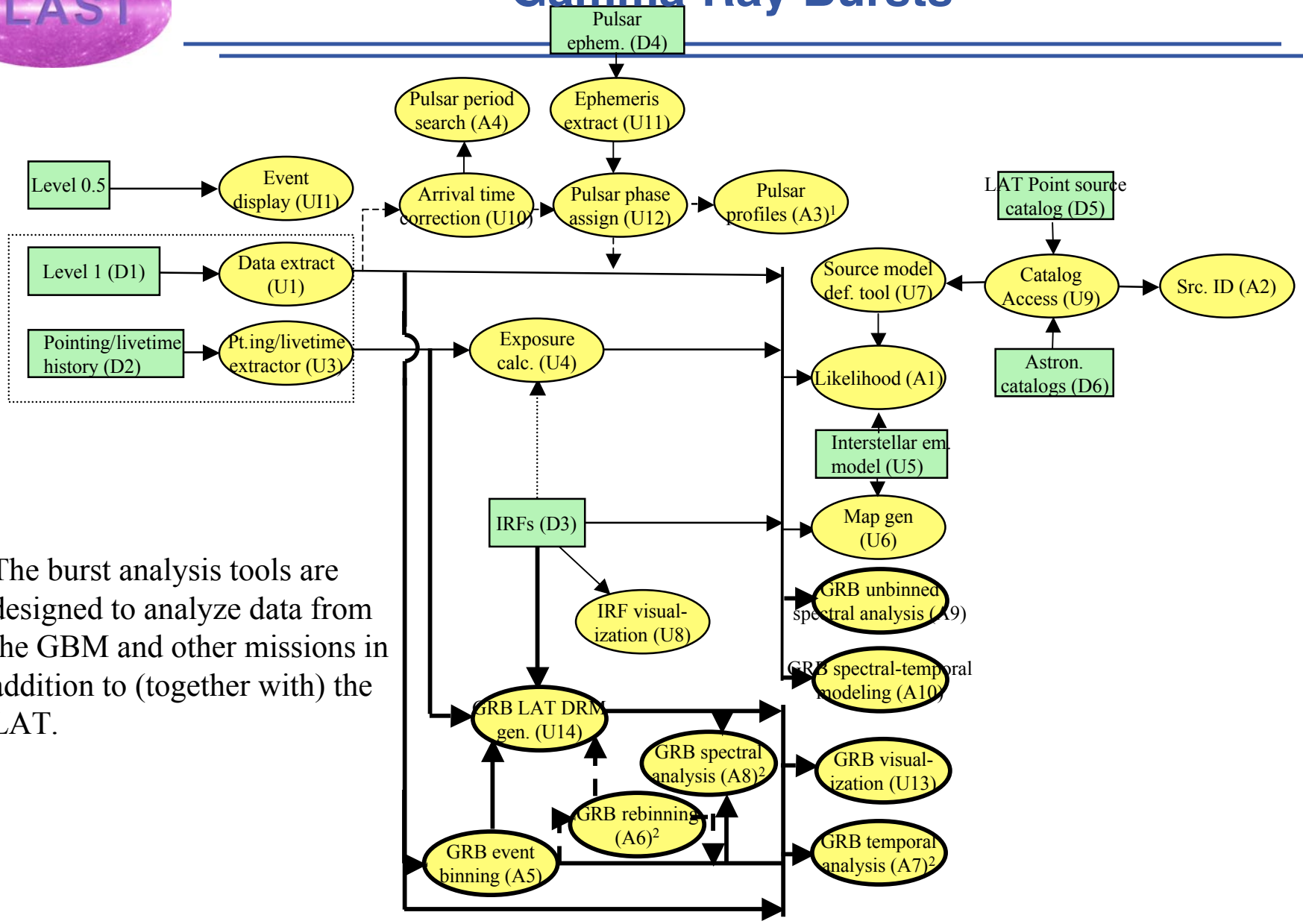


Map Generation

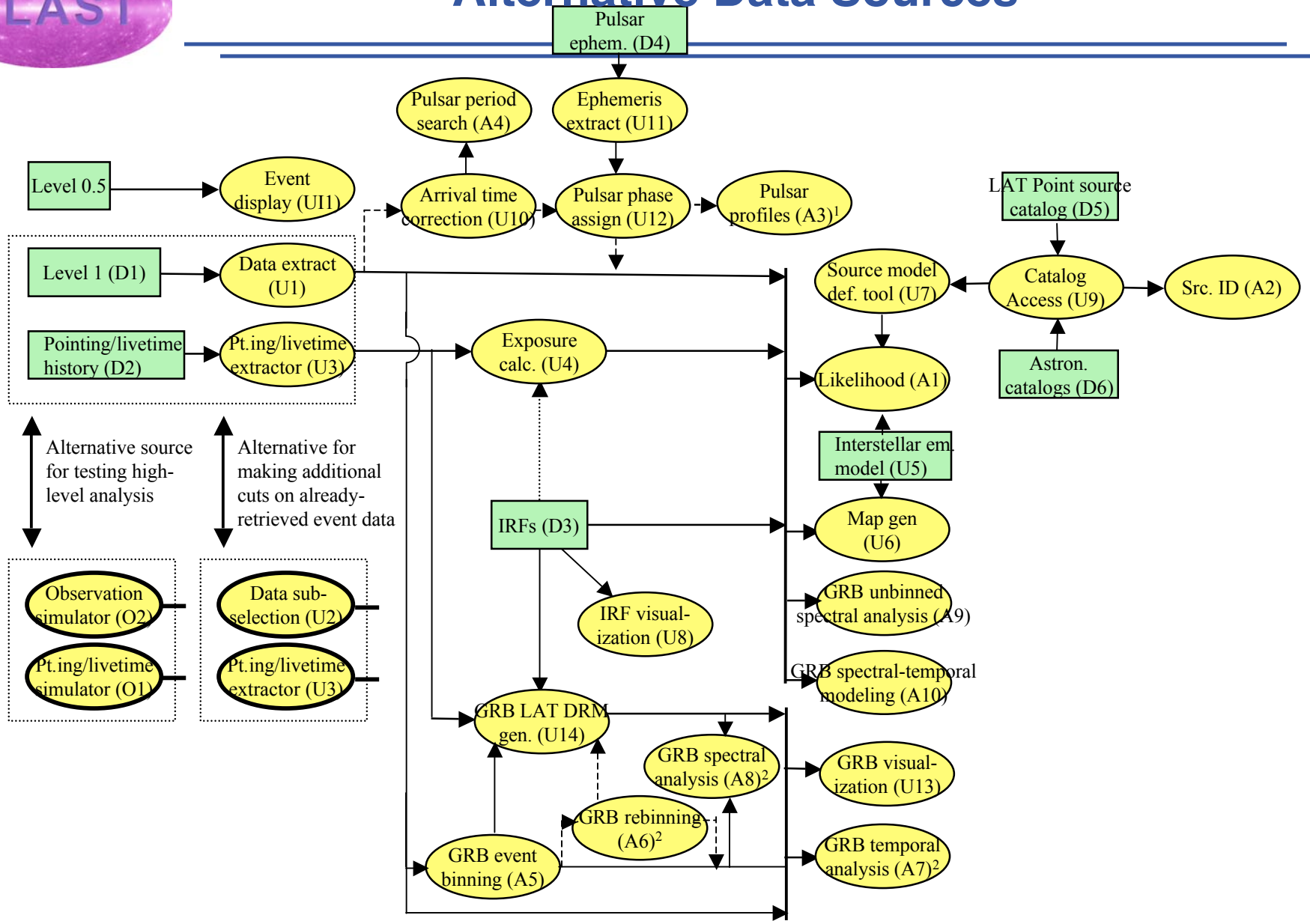


Gamma-Ray Bursts

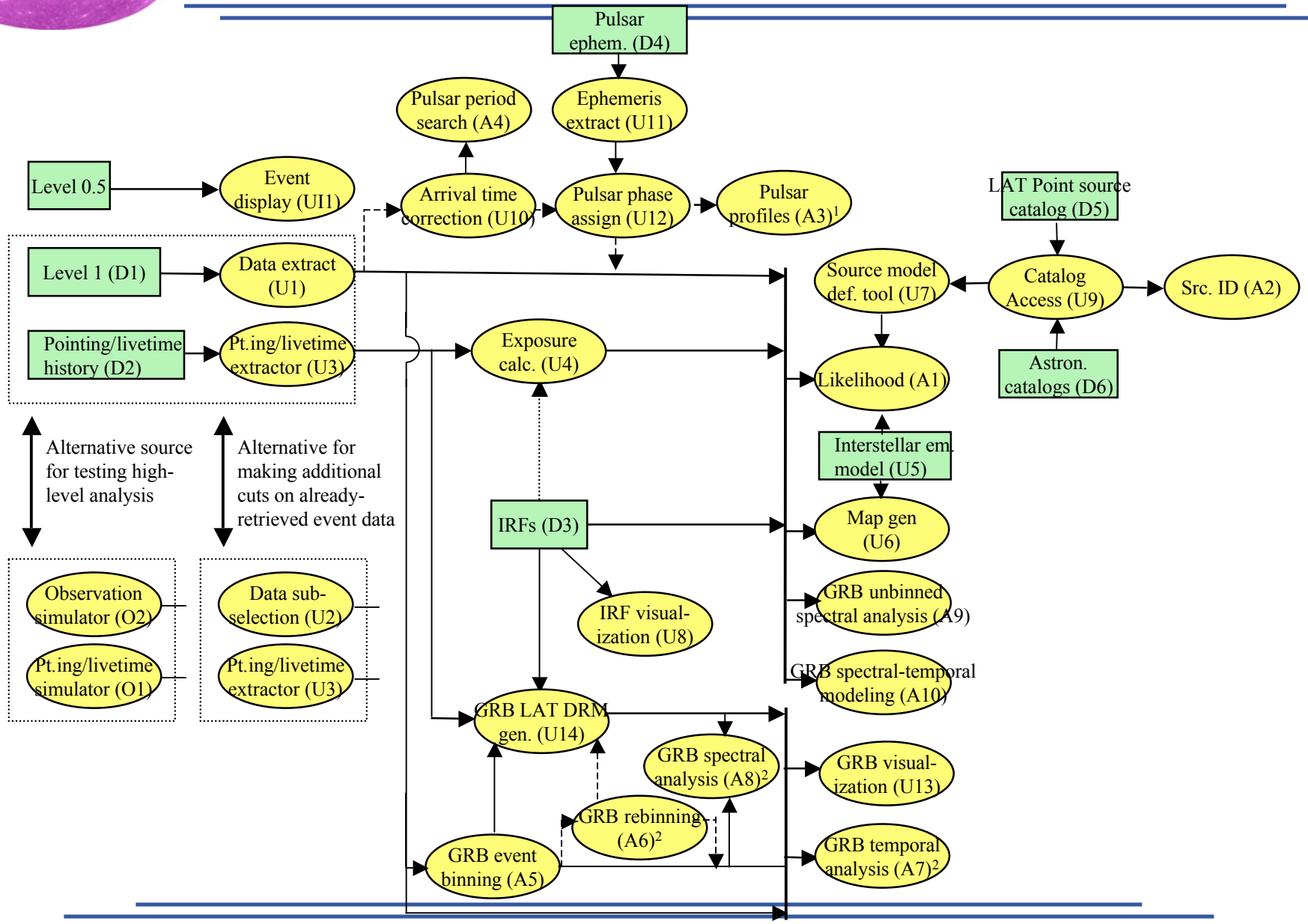
The burst analysis tools are designed to analyze data from the GBM and other missions in addition to (together with) the LAT.



Alternative Data Sources



All Together



Sequence of an Analysis: Gamma-Ray Point Source

- Define region of sky, time range, etc. of interest
  - Typical minimum size (based on PSF sizes) radius ~ 15°
- Extract gamma-ray data (U1 accessing D1)
  - Applying selection cuts, including zenith angle
  - Typical data volume (per year): 1 _ 10^6 _-rays, 10^8 bytes
- Generate exposure (U3 accessing D2)
  - May better be called livetime accumulation, or precomputation for likelihood analysis
  - Matches cuts applied to gamma-ray data
  - Potential tabulation ~ 700 grid points on sky _ 15 energies _ 15 inclinations _ 15 zenith angle limits ~ 2.5 _ 10^6 values ~ 10^7 bytes
- Define the model to be fit to the data (U7)
  - Facilitated by candidate source catalog, intensity map and data visualization within U7
  - Models may be considered as a table of parameters, or an XML file, human-readable, including parameters for interstellar emission model
  - Typically will contain ~dozens of point sources
- Fit the model to the data, generating, e.g. 'TS maps' and confidence regions or spectral fits (A1)
  - Model may need refinement, iteration within A1

Software Infrastructure

- Core - Reusing much of the infrastructure from the development of the instrument simulation (GLEAM)
  - Windows & Linux will be supported
  - New software will be written in C++ (VC++ and gnu tools)
  - Coding, documentation standards are defined, long-standing CVS repository
- Tools
  - Will be FTOOLS (i.e., HEASARC standards compliant)
    - FITS in/FITS out, CALDB for IRFs
    - User interface mediated by PIL (or PIL++ developed by HEASARC which includes hooks for GUIs)
  - Intermediate files, e.g., for exposure calculations, also will be in FITS
  - Plotting (and probably GUI) will be via abstract interfaces to the corresponding ROOT classes
  - Image display is via DS9 (TBR - if Tcl/Tk dependence is not a problem)

Infrastructure (2)

- Testing
  - Nightly builds, test procedures
  - Code reviews
  - Data Challenges with simulated data and real users
    - Three ~annual large scale evaluations of science tools with simulated data
    - DC1 is to start in December & has a science tools component

Data Challenge 1

- Schedule
  - Kickoff workshop, probably December 15-17, at SLAC
  - Interim reports, mid-January
  - Close out meeting in early March
- For science tools, test of (limited functionality), distribution, documentation
  - Scope – A single day's worth of simulated data, processed through Gleam, with astrophysical sources (including interstellar emission)
  - Audience – LAT team, GSSC, and interested, generally knowledgable, review committee-caliber scientists…
- Functionality to be tested
  - D1/D2 & related utilities – ingest and query support
  - A1 – limited likelihood analysis (e.g., no zenith angle cuts, no GUI for source model definition, no scripting)
- Status: Getting there

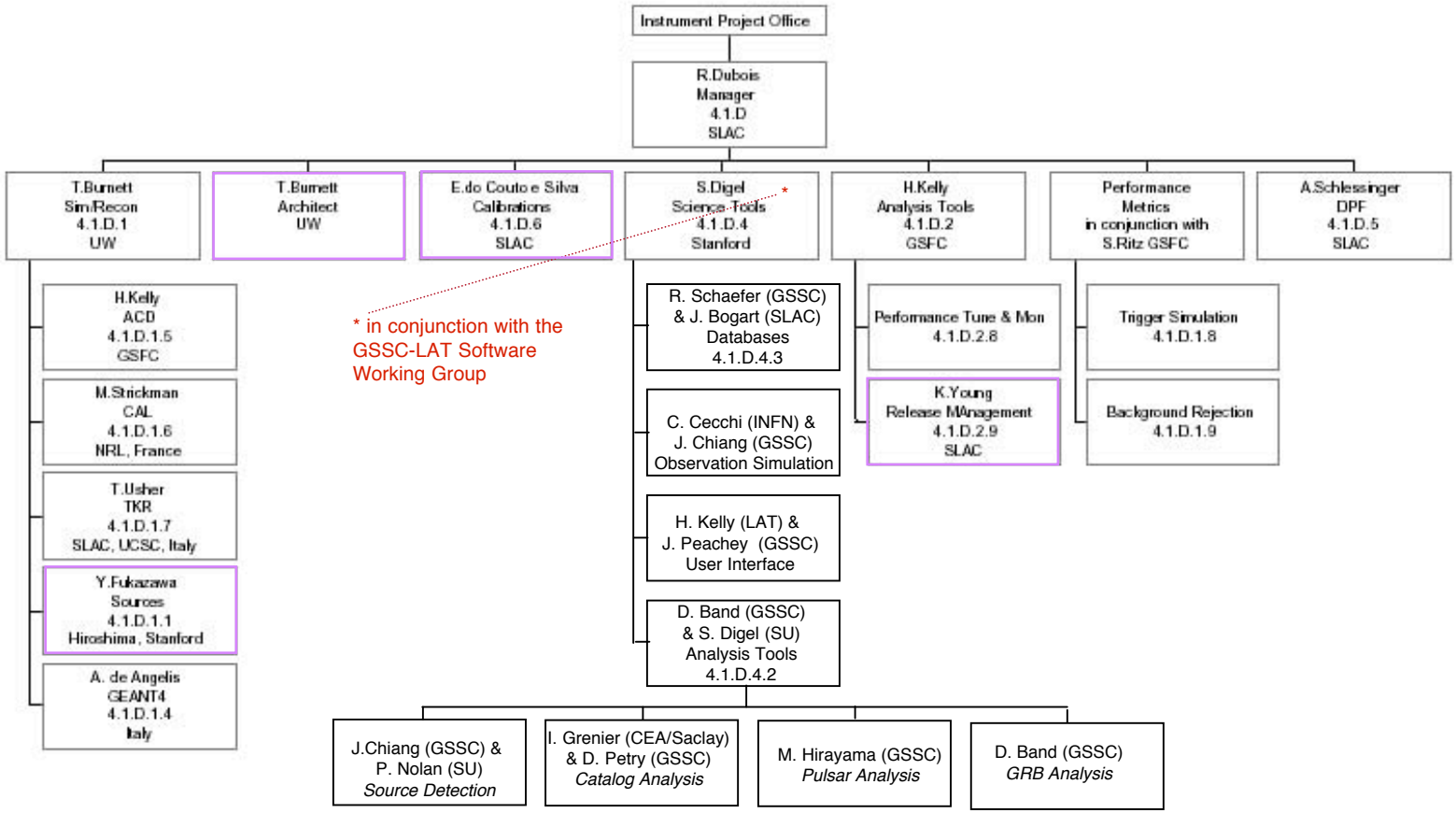
Post DC1 – From Here to Reality

- Response functions – definitions have not converged yet, and we will probably have some latitude in event classification
- Further areas of development for source analysis
  - Full generality can be computationally tough; tradeoffs regarding detail in definition of response functions need to be explored
  - Nonparametric tool (e.g., something useful for quicklook) could help get optimizations off on the right foot; Bayesian Blocks, wavelets, and Independent Component analysis are among the methods being investigated
  - Expectation Maximization algorithm is being investigated for making source model fitting more efficient for larger models
  - Quantitative interpretation of likelihood ratios for upper limits or source detection in unbinned likelihood analysis
  - Zenith angle cuts, a dimension that must be handled carefully, e.g., for exposure calculations
  - Allowance for moving sources, e.g., the moon and sun

Highlights of Development Schedule for 2004

- **Other post-DC1 work planned:**
  - **Pulsar tools – timing corrections**
  - **GRB temporal analysis**
  - **User interface – source model definition tool and catalog access, analysis scripting**
  - **Beefing up high-level simulators (and tests with EGRET data)**

Organization: Science Tools within LAT SAS



- Science Tools also relates to *Architect, Calibrations, Release Management,* and *Sources* boxes of the LAT instrument simulation effort
- GSSC is integrally involved in the development effort

Science Tools Labor

- Currently about half from the GSSC and the rest contributed across the LAT collaboration
- Active contributions, or signs of life, from SU/SLAC, UW, GSFC, CEA/Saclay, IN2P3/LLR, INFN/Perugia, Pisa, Trieste, & Udine
  - Many LAT people are doing other things, like building the LAT

Operations

Commanding

- Commands from the IOCs for their instruments will pass through the GSSC on their way to the MOC. The MOC will uplink commands to the spacecraft.
- The GSSC will evaluate the impact of the commands on the science timeline. If the impact is unacceptable, the GSSC will request that the IOC reschedule the command.
- High priority commands will be passed directly to the MOC.
- GSSC vetting of commands will not begin until after the first year. During Phase 1 the LAT will survey the sky, and the instrument teams will be calibrating their instruments.

Targets of Opportunity (ToOs)

- Scientists will request a ToO through a form on the GSSC website (as is the case for RXTE). The request will be transmitted immediately to the Project Scientist.
- The Project Scientist will request that the GSSC evaluate the ToO's feasibility and impact on the science timeline.
- If the Project Scientist declares a ToO, the GSSC will have 2 hours to send the MOC a ToO order, and the MOC will have 4 hours to uplink the ToO command.
- Since the GSSC will not command the spacecraft directly, the GSSC can generate the ToO order remotely.
- If the MOC is not staffed when the ToO order arrives, a member of the flight operations team that staffs the MOC must come in to uplink the command.
- ~1 ToO per month is anticipated

Timeline

- In Phase 2 the GSSC is responsible for the science timeline.
- Before each GI cycle the Timeline Committee (representing the Project, the IOCs and the GSSC) will determine which highly rated GI-proposed observations can be performed.
  - It is anticipated that survey mode will predominate as the most efficient observing strategy.
- The GSSC will construct a weekly science timeline to implement the GI observations, and will accommodate the IOCs' commands.
- The resulting science timeline will be sent to the MOC where it will be merged into the mission timeline (e.g., including the telemetry up and downlinks).
- If a ToO or an autonomous repoint (in response to a burst) disrupts the timeline, the GSSC will create and send the MOC an updated timeline.

Timeline, continued

- GLAST will have solar panel and radiator constraints.
- For efficiency we will keep the Earth out of the central part of the LAT's FOV.
- We are considering TAKO, a scheduling tool that will be used by Swift, Astro-E2, and RXTE.

GSSC Operations Software (1/2)

Tool	Purpose	Candidate
Proposal Ingestor	Process proposals submitted by GIs.	Recycled XTE software including RPS
Planning Tool	Designs schedules for optimum sky coverage.	D. Davis simulator.
Scheduling Tool	Generates observation schedule transmitted to MOC.	Tako (or Spike or STK software).
External TOO Requester	Method for general community to request a TOO observation.	Web based software based on XTE RPS?
TOO Orderer	Sends TOO order to MOC.	Custom software + DTS.
Schedule Deliverer	Delivers new or updated schedule to MOC.	DTS + “glue” scripts.
MOC Product Receiver	Ingests into GSSC regular MOC products such as as flown timeline etc.	DTS + “glue” software.

GSSC Operations Software (2/2)

Tool	Purpose	Candidate
MOC Alert Receiver	Similar to Product Receiver but for “exceptional” events (e.g. auto repoint)	DTS + “glue” software.
GCN Receiver	Receives and archives GCN notices produced by BAP	Custom scripts.
"As Flown Timeline" Processor	Reformats and archives MOC's as flown timeline.	Custom software/scipts.
Observing Plan Sky Coverage Monitor	Monitor as flown timeline to determine uniformity etc. of sky coverage. Interacts with Planning Tool.	Custon software. Possible D. Petry candidate.
IOC Command Ingestor	Processes commands from IOCs (reads wrappers), ,may page.staff.	DTS + custom scripts + Pager Tool.
General Archive Accessor	General access to timelines and TBD others.	XTE software from G. Romeo..
Pager Tool	Alerts GSSC staff if urgent action required (e.g. commands from IOC)	Reuse of XTE commercial & custom system.

GSSC Data Processing

- Periodically the GSSC will produce and post on its website sky maps and exposure maps of the entire sky, with blow ups of regions of interest (e.g., the Galactic Center). These maps will:
  - Assist investigators in choosing regions and time periods to analyze.
  - Aid GI proposers in designing observation plans.
  - Guide the Project in maintaining uniform exposure.
- At the beginning of the mission the LAT team will monitor and post light curves for ~20 strong sources; possibly the GSSC will take over this task later in the mission.

Ingest and GSSC Database Operations

- GSSC receiving 21 types of science data to be archived from 3 sources (2 IOCs, and MOC)
- GSSC role to retrieve data, validate it, archive it, and make it searchable/available to Guest Investigators.
- These data ingested by automated pipelines (no hand feeding required)
  - Single Pipeline manager will supervise all processes.
  - 21 databases described in the Database Architecture Document.
- GSSC databases will be searchable via the web.

GSSC Ingest Pipeline

- Data Flow managed by Pipeline Manager
- Pipeline Manager
  - Determines when new data arrives
  - Makes immediate backup of new data
  - Identifies processing needs by data type
  - Checks available processing resources
  - Schedules for processing
  - Processes data. Includes:
    - Generates any metadata
    - Reformats data if necessary
    - Extracts information into new files
    - Populates databases with new information
    - Notifies Archive Manager that new data is to be archived onto permanent media.
  - Tracks each processing step with a database.
  - Logs time tagged processing information to a file.
  - Notifies operations staff when serious errors occur
- Provides reliable, timely ingest of data into SSC access system.
- Looking at COTS and home grown options for doing this.

Databases

- Three types of databases
  - Metadata which points to information in files (e.g., prepackaged FITS data for popular sources, level 0 data)
  - Self contained databases - containing data and metadata (e.g., command history)
  - Hybrids of the above two (event and spacecraft pointing databases)

- Type 1 in common usage in HEASARC
- Type 2 can be flat files or a DBMS system such as MySQL.
- Type 3 custom made with performance and simplicity as the most important design criteria.

- Since type 3 is different, we will look a little more closely at the design

Event Database Design

- GLAST LAT event database requirements
  - Goal: Search 10 years worth of event lists by 2-D area (2-D area cuts are a little tricky, cuts on other parameters easy)
  - Standard Search: Retrieve all events which originated from a 15° circle (~ 99% confidence off-axis PSF width) within a yearlong time interval with an arbitrary start time
  - Performance criteria: Standard search for photons must be done in < 60 seconds
- Did trade studies to find the fastest search methods:
  - Winner was row-filtering FITS files with CFITSIO. (see also http://wiki.astrogrid.org/bin/view/Astrogrid/DbmsEvaluations)
- Database searches event lists stored in FITS format
- To improve speed, parallelize search with a Linux cluster
- Technically a Beowulf cluster, but a particularly simple configuration

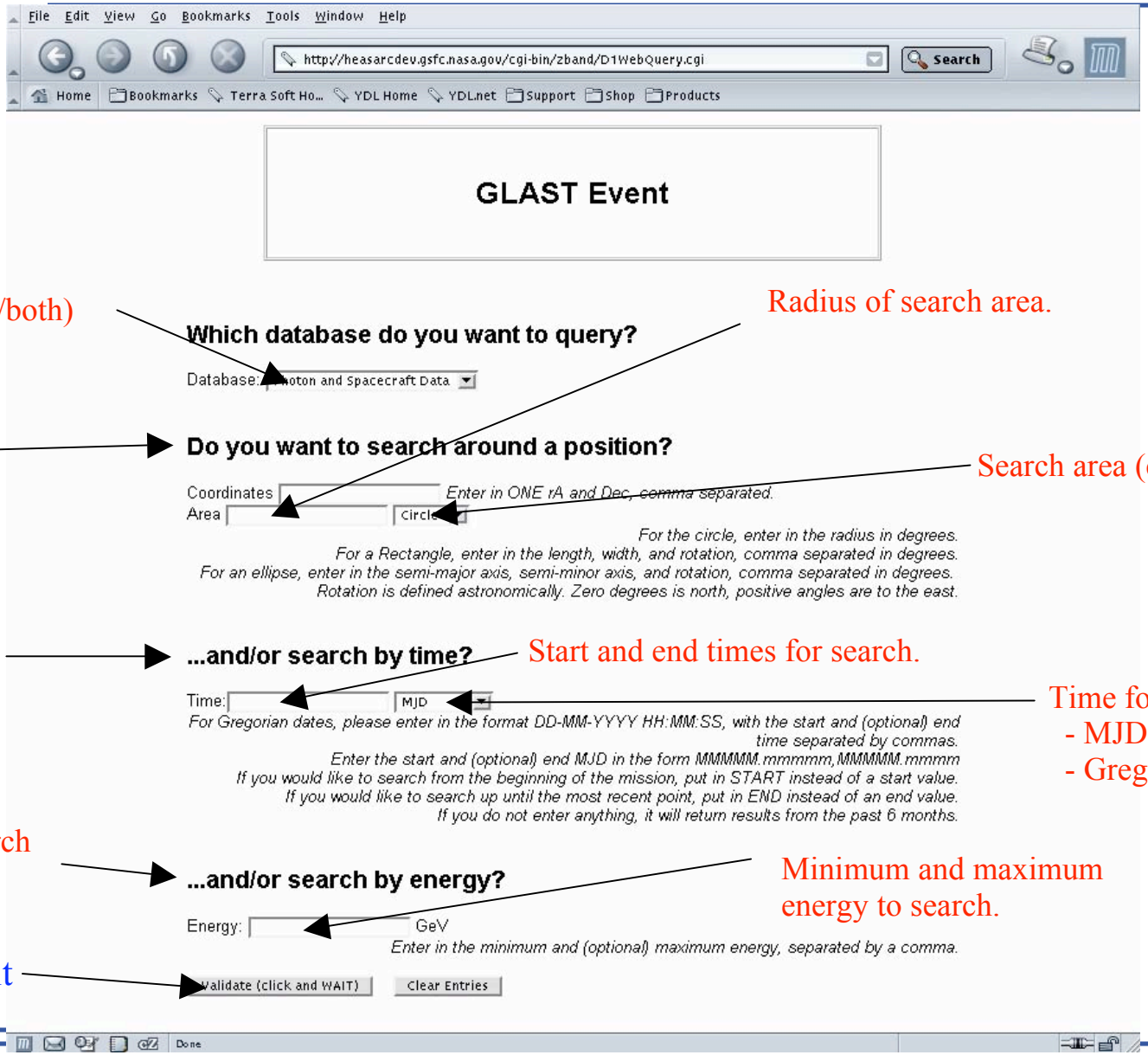
Data Challenge 1 Databases

- Prototypes of the hybrid databases created for Data Challenge 1 (testing starts Dec. 15, 2003).
- Access system created for photon and spacecraft pointing databases.
- Current status: Moving web pages and data ftp area to a location accessible to the LAT collaboration for DC1.

Prototype Database Web Interface

- One interface for both Event (D1) and Spacecraft (D2) Databases
- Basic search functionality (Note: Spacecraft database is only searched by time)
  - Choice of Database
  - Position – circular regions of adjustable radius with center in RA/Dec (J200))
  - Time – start and end time in MJD or UTC (Gregorian)
  - Energy – minimum and maximum energy in GeV (or MeV)
  - Future:
    - More types of area selections
    - More keywords searchable.
    - Separate complete event database (not only photons)

DB query page layout (prototype)



Database selection (photon/spacecraft/both)

Radius of search area.

Position search

Search area (circle)

and/or Time search

Start and end times for search.

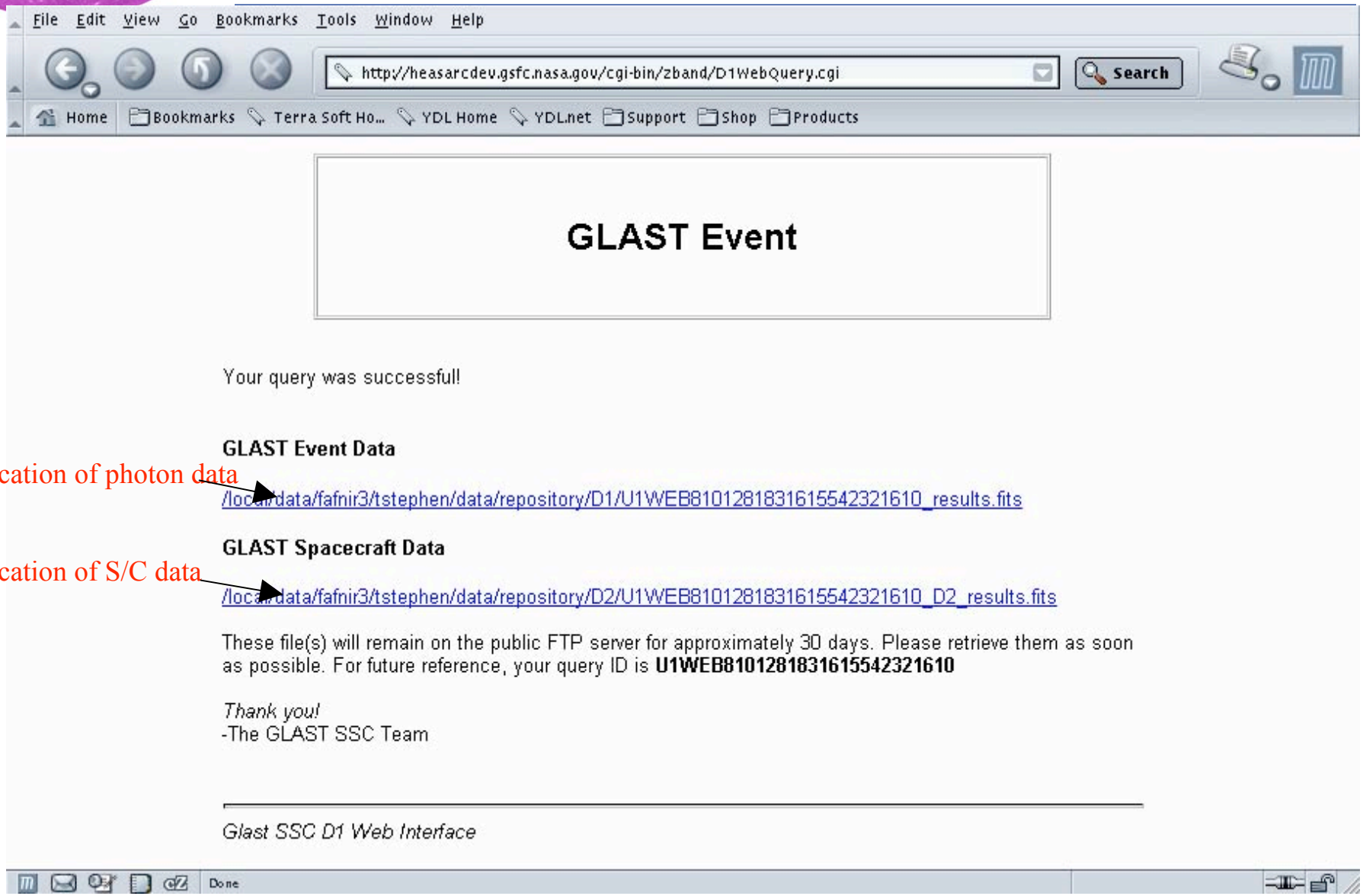
Time format:
- MJD
- Gregorian (UTC)

and/or Energy search

Minimum and maximum energy to search.

Click to submit

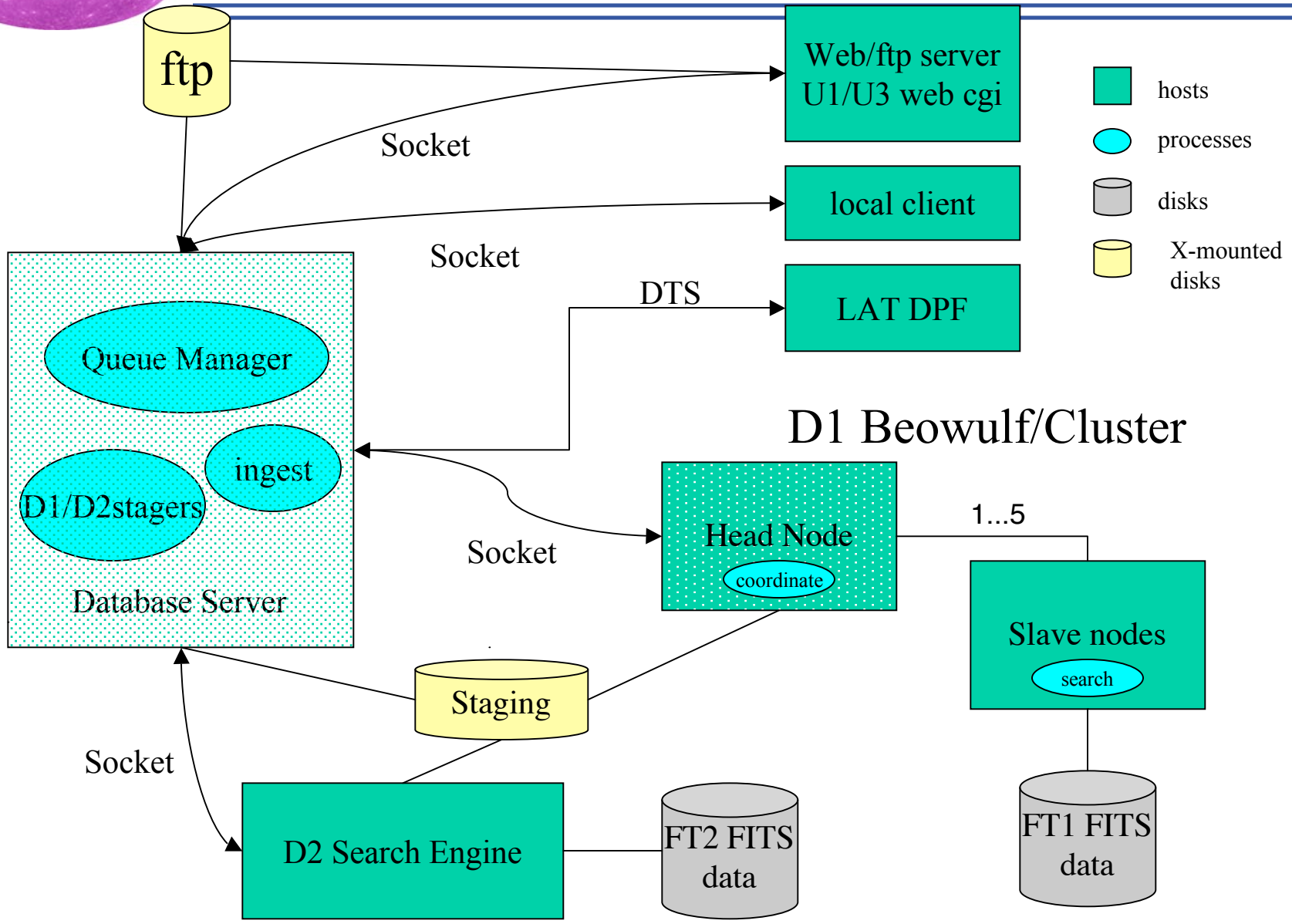
DB Results Web Page (prototype)



Location of photon data

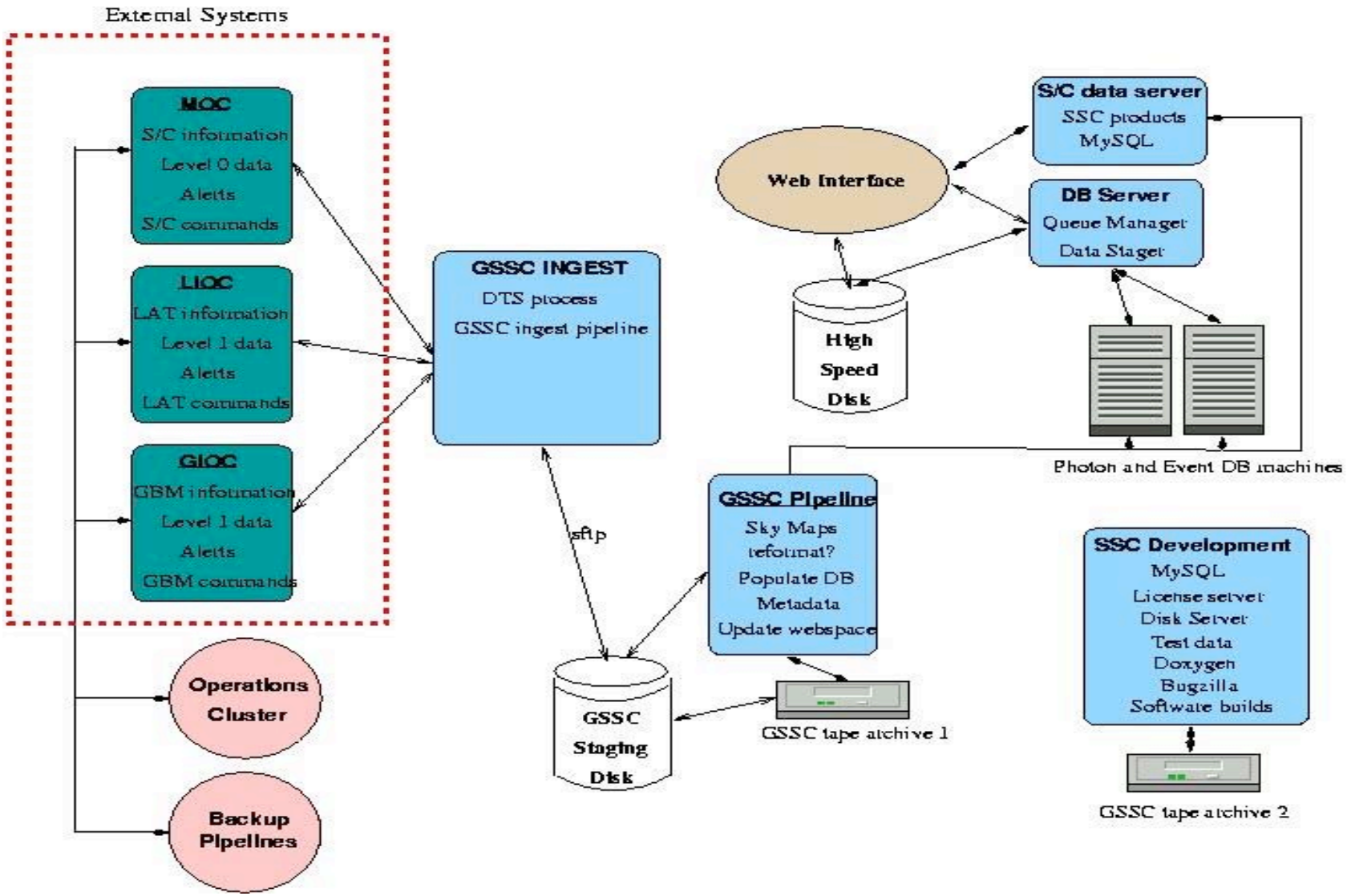
Location of S/C data

Database Access Architecture

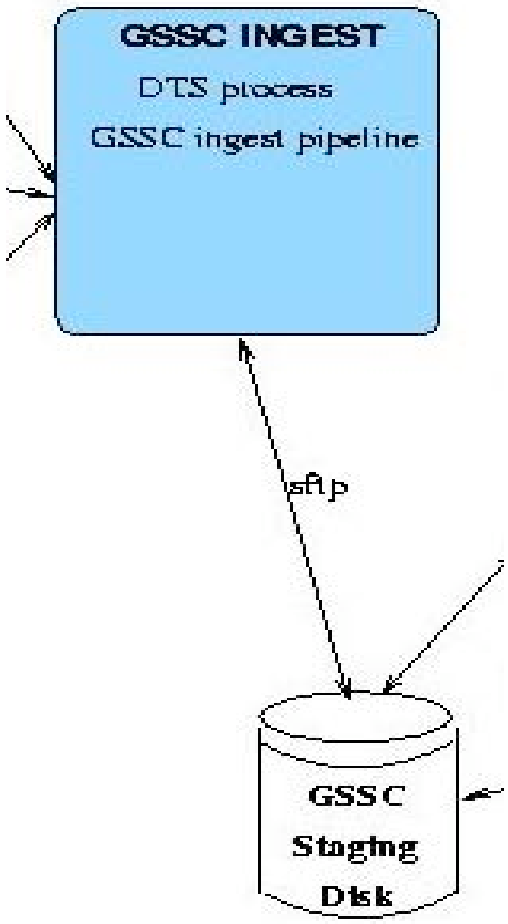


Database and Ingest Status

- Databases and data access well under way (working prototypes > 3 years before launch)
- Other databases should be easier to create and access with a web interface.
- Ingest pipeline management software will be evaluated after Data Challenge 1 (early 2004)
- Don't anticipate problems with any of the processing.
  - Should be straightforward to implement
  - However many types of data that need processing programs written, so there is still a lot of work to do.
    - GIOC 4 data types sent to GSSC
    - LIOC 10 data types sent to GSSC
    - MOC 7 data types sent to GSSC
- Expect ingest pipeline will be complete in early 2006.

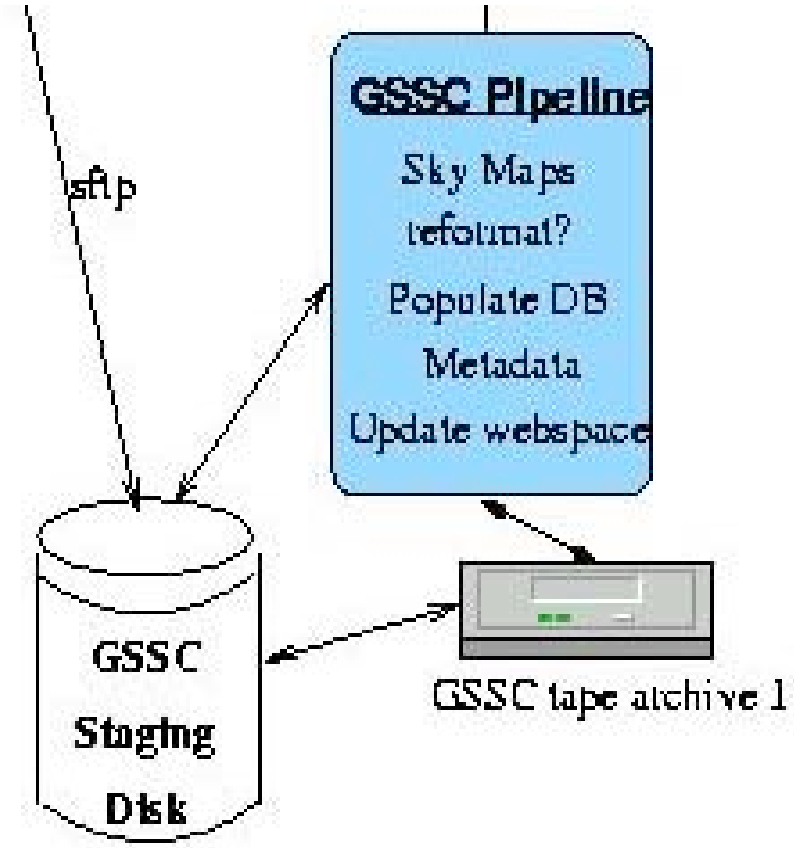

External Systems
MOC
S/C information
Level 0 data
Alerts
S/C commands
LIOC
LAT information
Level 1 data
Alerts
LAT commands
GIOC
GBM information
Level 1 data
Alerts
GBM commands
Operations Cluster
Backup Pipelines
GSSC INGEST
DTS process
GSSC ingest pipeline
sftp
GSSC Staging Disk
GSSC Pipeline
Sky Maps reformat?
Populate DB
Metadata
Update webspace
GSSC tape archive 1
Web Interface
High Speed Disk
S/C data server
SSC products
MySQL
DB Server
Queue Manager
Data Stager
Photon and Event DB machines
SSC Development
MySQL
License server
Disk Server
Test data
Doxygen
Bugzilla
Software builds
GSSC tape archive 2

GSSC Ingest



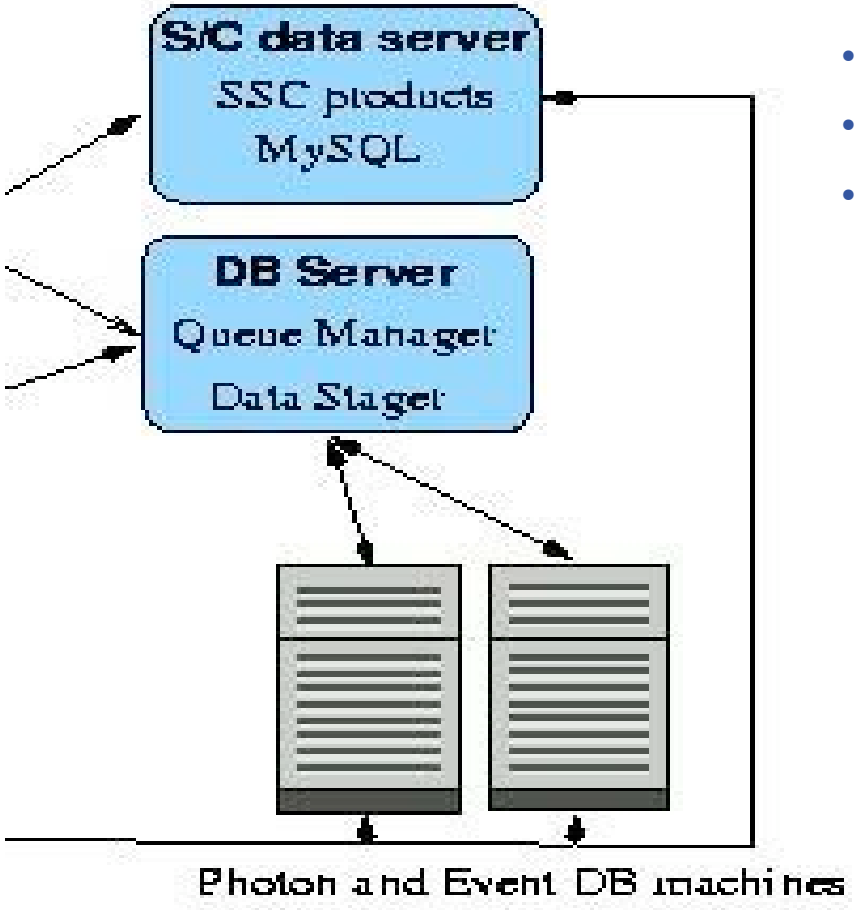
- Receives data from the IOC's
- Runs in a secure enviroment
- Logs all data transfers and errors
- Notifies operator in the case of a major problem

GSSC Pipeline

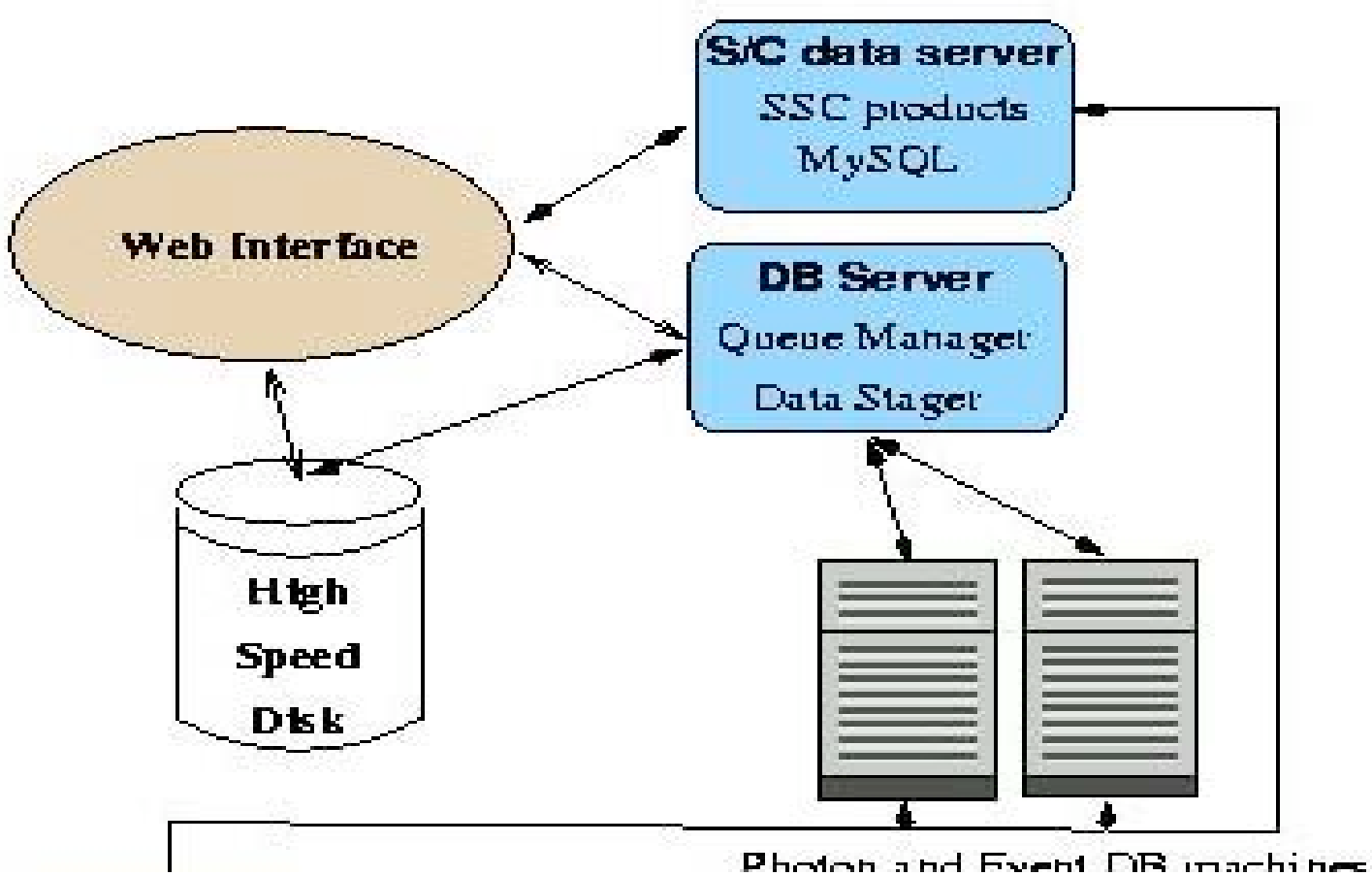


- Performs standard GSSC processing
- Loads Databases (public and local)
- Generates Metadata
- Produces GSSC products

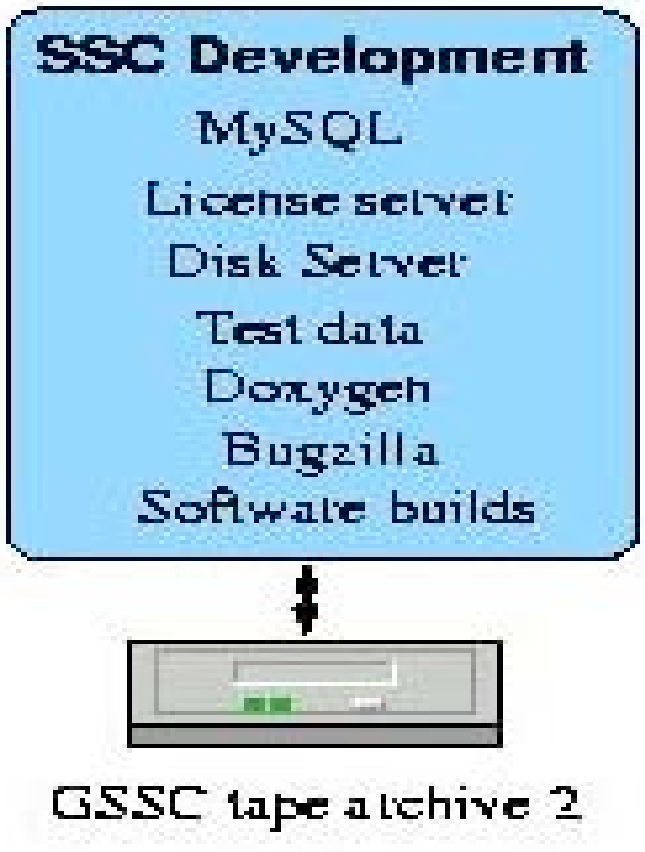
GSSC Data Servers



- Event and photon data
- burst products
- Skymaps
- S/C data
- Timelines


S/C data server
SSC products
MySQL
Web Interface
DB Server
Queue Manager
Data Stager
High
Speed
Disk

GSSC Development

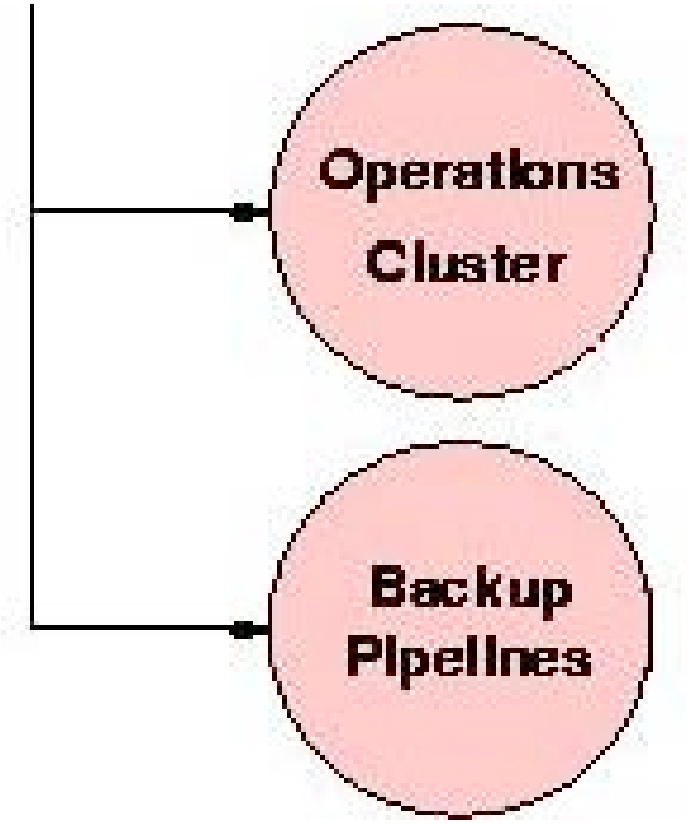


- Software development
- Software testing
- Software builds
- License server
- Doxygen
- Bugzilla

Computer System

- Security
  - Operational computers have a higher level of security
  - A Firewall exists between the web site and all GSSC computers
  - DTS runs on a system isolated from the Web and other GSSC computers and data transfer will be via sftp
  - Secure communications will be used between all components
- GSSC System Operations
  - Each component of the system can run independently of the others
  - Processing will run in a “chain” - the successful end of one will trigger the next stage
  - Logging will be recorded for all data received and processed
  - A central utility will monitor progress of data ingest and will notify an operator in the case of problems or failures
  - Backups will be maintained for all processing stages

Operations and Backup Pipeline



- Operations cluster
  - Robin Corbet
- Backup Pipeline
  - To be finalized

Testing

- We will subject our internal software to extensive testing, and the software will be placed under formal configuration management before the formal testing.
- Informal testing of external links will take place before the formal ground system tests.
  - For example, we will set up DTS to transfer data files from the LIOC to the GSSC as part of Data Challenge 1 before the link is formally tested as part of the ground system.
- The GSSC will participate in a series of ground system tests: Ground Readiness Tests (GRTs) testing the links between ground elements; End-To-End tests (ETEs) starting with the spacecraft; and mission simulations. Our operations software and computer system releases are scheduled for these tests.

External Test Schedule

- GRT1 (11/1/04): Ingest Level 0 data from MOC
- GRT2 (4/1/05): Preliminary test of command and activity schedule flows to and from other GS components
- GRT3 (6/15/05): Clean-up from GRTs 1 & 2.
- GRT4 (9/1/05): Ingest Level 1 data from IOCs
- GRT5 (11/15/05): Full command and activity schedule system
- GRT6 (2/15/06), GRT7 (5/1/06): Clean-up
- 6 2-day End-to-end (ETE) tests (11/11/05, 1/31/06, 3/15/06, 5/25/06, 7/14/06, 9/1/06): Early tests may not involve GSSC
- Mission Simulations

Operations Release Schedule

- **Software—Driven by Ground Readiness Tests (GRTs)**
  - **Release 1 (6/30/04), tied to GRT1 (11/1/04)—ingest of Level 0 data from MOC:**
    - **a) scripts to move data from MOC to GSSC;**
    - **b) creation of GSSC database;**
    - **c) scripts to ingest data into GSSC database**
  - **Release 2 (1/15/05), tied to GRT2 (4/1/05)—preliminary command and schedule tools:**
    - **a) command passing from IOCs to GSSC, and from GSSC to MOC**
    - **b) timeline creation and passing to MOC**
    - **c) ToO order creation and passing to MOC**
  - **Release 3 (5/1/05), tied to GRT4 (9/1/05)—ingest of Level 1 data from IOCs:**
    - **a) scripts to move data from IOCs to GSSC**
    - **b) creation of GSSC databases**
    - **c) software to ingest data into GSSC databases**
  - **Release 4 (8/1/05), tied to GRT5 (11/15/05)—completion of command and schedule tools**

Operations Release Schedule (con't)

- **Software driven by Launch Readiness**
  - **Release 5 (3/1/06), tied to first NRA release---GSSC internal operations tools complete**
    - **a) Ingest system complete for all data products.**
    - **b) GSSC web site able to serve observation simulator tools**
    - **c) Production databases and data backup system operational.**
  - **Release 6 (12/1/06) Tied to Launch (12/1/06)--GSSC Web site ready to for business**
    - **a) GSSC Web site able to distribute analysis tools**
    - **b) GSSC web site ready for timelines**
    - **c) GSSC website fully ready to display information about data products**
    - **d) Archive system complete**
    - **e) LAT and GBM backup pipelines operational**

Computer System Release Schedule

- **Computer System—Driven by GRTs**
  - **Phase 1 (3/1/04)—Single processor system tied to Beowulf database system**
  - **Phase 2 (1/15/05)—Preliminary multiprocessor system**
  - **Phase 3 (3/1/06)—Complete multiprocessor system**

Schedule

A recapitulation of milestones presented above

Reviews

- Ground System Requirements Review (7/03)
- Users' Committee Meeting (10/03)
- GSSC Peer Review (11/03)
- Ground System Design Review (5/04)
- Mission Operations Review (4/05)
- Operations Readiness Review (7/06)

Analysis software

- Release 1 (12/15/03)—basic capabilities such as accessing the principal databases, fitting source models with the likelihood tool, binning burst counts into spectra, creating burst response matrices and fitting burst spectra.
- Release 2 (12/15/04)— completion of basic capabilities, especially the addition of graphics to the tools. Basic pulsar tools.
- Release 3 (3/06)— completion of tools. Integration of analysis of GBM data.

GI Program Schedule

	Cycle 1	Subsequent Cycles
NRA Development	T_0-18 months	T_0-14 months
HQ Review of NRA	T_0-14 months	T_0-12 months
NRA Release	T_0-10.5 months	T_0-9 months
Proposal Deadline	T_0-7.5 months	T_0-6 months
Peer Review	T_0-4.5 months	T_0-4 months
Notification of Rejections	T_0-4 months	T_0-3.5 months
Timeline Meeting	T_0-3.5 months	T_0-3 months
Request Funding Prop.	T_0-3 months	T_0-2.5 months
Funding Proposal Due	T_0-1.5 month	T_0-1 month
Funding Decision	T_0-1 month	T_0-0.5 month
Beginning of Cycle	T_0=L+60 days	T_0
End of Cycle	T_0+1 year	T_0+1 year

Operations Software Release Schedule

- Release 1 (6/30/04)—ingest of Level 0 data from MOC:
  - a) scripts to move data from MOC to GSSC;
  - b) creation of GSSC database;
  - c) scripts to ingest data into GSSC database
- Release 2 (1/15/05)—preliminary command and schedule tools:
  - a) command passing from IOCs to GSSC, and from GSSC to MOC
  - b) timeline creation and passing to MOC
  - c) ToO order creation and passing to MOC
- Release 3 (5/1/05)—ingest of Level 1 data from IOCs:
  - a) scripts to move data from IOCs to GSSC
  - b) creation of GSSC databases
  - c) software to ingest data into GSSC databases
- Release 4 (8/1/05)—completion of command and schedule tools

Operations Software Release Schedule (con't)

- Release 5 (3/1/06), tied to first NRA release---GSSC internal operations tools complete
  - a) Ingest system complete for all data products.
  - b) GSSC web site able to serve observation simulator tools
  - c) Production databases and data backup system operational.
- Release 6 (12/1/06) Tied to Launch (12/1/06)--GSSC Web site ready to for business
  - a) GSSC Web site able to distribute analysis tools
  - b) GSSC web site ready for timelines
  - c) GSSC website fully ready to display information about data products
  - d) Archive system complete
  - e) LAT and GBM backup pipelines operational

Computer System

- Phase 1 (3/1/04)—Single processor system tied to Beowulf database system
- Phase 2 (1/15/05)—Preliminary multiprocessor system
- Phase 3 (3/1/06)—Complete multiprocessor system

Operations Software Release Schedule

- Release 1 (6/30/04)—ingest of Level 0 data from MOC:
  - a) scripts to move data from MOC to GSSC;
  - b) creation of GSSC database;
  - c) scripts to ingest data into GSSC database
- Release 2 (1/15/05)—preliminary command and schedule tools:
  - a) command passing from IOCs to GSSC, and from GSSC to MOC
  - b) timeline creation and passing to MOC
  - c) ToO order creation and passing to MOC
- Release 3 (5/1/05)—ingest of Level 1 data from IOCs:
  - a) scripts to move data from IOCs to GSSC
  - b) creation of GSSC databases
  - c) software to ingest data into GSSC databases
- Release 4 (8/1/05)—completion of command and schedule tool