GAMMA-RAY LARGE AREA
SPACE TELESCOPE
(GLAST)

SCIENCE TOOLS DATABASES
REQUIREMENTS

VERSION 1.1

AUGUST 26, 2002
DRAFT VERSION 0.4
Prepared by:

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Concurrence:

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Approval:

__________________________________  _______________________

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**DOCUMENT TITLE:** Science Tools Databases Requirements

**DOCUMENT DATE:** August 26, 2002

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1 Purpose

This document describes the requirements for databases to be used with the science analysis tools for the GLAST mission. These databases have been identified by the SSC-LAT Working Group (SLWG). The analysis software will make queries of the databases, through specially devised access utilities. These databases will be populated by data generated from the LAT IOC and the GBM IOC.
## 2 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Expansion</th>
</tr>
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<tbody>
<tr>
<td>API</td>
<td>Application Program Interface</td>
</tr>
<tr>
<td>DBMS</td>
<td>Database Management System</td>
</tr>
<tr>
<td>GBM</td>
<td>GLAST Burst Monitor</td>
</tr>
<tr>
<td>GIOC</td>
<td>GBM IOC</td>
</tr>
<tr>
<td>GRB</td>
<td>Gamma-Ray Burst</td>
</tr>
<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center</td>
</tr>
<tr>
<td>GLAST</td>
<td>Gamma-ray Large Area Space Telescope</td>
</tr>
<tr>
<td>HEASARC</td>
<td>High Energy Astrophysics Science Archive Research Center</td>
</tr>
<tr>
<td>IOC</td>
<td>Instrument Operations Center</td>
</tr>
<tr>
<td>LAT</td>
<td>Large Area Telescope</td>
</tr>
<tr>
<td>LHEA</td>
<td>Laboratory for High Energy Astrophysics</td>
</tr>
<tr>
<td>LIOC</td>
<td>LAT IOC</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>SAA</td>
<td>South Atlantic Anomaly</td>
</tr>
<tr>
<td>SSC</td>
<td>Science Support Center</td>
</tr>
<tr>
<td>SLWG</td>
<td>SSC LAT Working Group</td>
</tr>
<tr>
<td>SWG</td>
<td>Science Working Group</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
</tr>
<tr>
<td>TBR</td>
<td>To Be Reviewed</td>
</tr>
</tbody>
</table>
3  Glossary

3.1  Level 1 Data

Level 1 data result from “automatic” pipeline processing of Level 0 data. This processing applies the instrument calibration to remove instrument artifacts and convert the instrument measurements to physical units. If appropriate, Level 1 processing also converts celestial coordinates to J2000, the mission’s standard representation. Level 1 data are generally the starting point for scientific analyses.

In LAT Level 1 processing, the Level 0 data, describing the interactions within the LAT, will be analyzed to identify and characterize the interacting particle (e.g., photons, electrons, protons, etc.). Thus tracks will be fitted to the hits in the tracker and calorimeter, the particle trajectories and energies will be estimated, and the event will be classified. The Level 1 data for an event will include not only the parameters from the analysis of the tracks, but also the time, the spacecraft ephemerides, etc. Other LAT Level 1 data will include histories of the instrument live time and exposure, as well as instrument response functions relevant to the observation.
4 Applicable Documents

- “GLAST Large Area Telescope Flight Investigation: An Astro-Particle Physics Partnership Exploring the High-Energy Universe,” P. Michelson, PI.
- GLAST DPWG (Data Products Working Group) Report, Draft 2/15/02, S. Digel
- LAT IOC (Instrument Operations Center) System Specification
- GLAST Level I Requirements Document
- Operations Concept Document, 433-OPS-0001
- Science Requirements Document, 433-SRD-000
- Project Data Management Plan (PDMP), 433-PLN-0009
- LAT Science Analysis Software Requirements Document, LAT-SS-20.0
- LAT Science Analysis Software Management Plan, LAT-MD-360.1
- LAT Event Summary Database Requirements Document [Event Database Requirements Draft](http://glast.gsfc.nasa.gov/ssc/Event_Database_Requirements_Draft)
5 Requirements

These requirements relate to the databases used by the GLAST science analysis tools. There are a total of 6 databases identified as D1-D6 by the Science Tools Working Group. The first of these, D1, is the LAT level 1 event summary database and is covered in a separate document (LAT Event Summary Database Requirements Document). D4 is a placeholder for astronomical catalogs external to the GLAST project, and D3 is the Calibration database (CALDB) designed and maintained by the HEASARC. We will design and implement the structure of the information inside D3, but the database Management system will be maintained by the HEASARC. As such, D4 and D3 are outside the scope of this document as we only consider requirements on the databases themselves here.

The three databases covered by this document are: D2 – the pointing, livetime, and mode history database, D5 – the LAT point source catalog, and D4 the pulsar ephemerides compilation.

The requirements in the next few sections cover the databases themselves. An attempt was made to try to avoid specifying implementation details and concentrate on just what the database has to do.

The first subsection will introduce the databases. The next section will discuss all the general requirements (with the exception of access related requirements) on the databases. The third section focuses on the access requirements. The final section in the document covers requirements specific to individual databases. The appendix lists the expected contents and data sizes for the databases for informational purposes.

5.1 Introduction

The databases covered here are D2, D5, and D4 as defined by the SLWG. D2 holds information regarding the spacecraft pointing history, the LAT detector livetime, and the instrument modes selected over the lifetime of the mission. D5 is a catalog of point sources identified by the LAT team as being important for gamma ray science. The final catalog is a compendium of pulsar characteristics that are relevant for gamma ray analyses.

In the next two subsections are general requirements that must be met by all three databases. The common elements among them are the main drivers in this requirements document. These are relatively simple databases, so the requirements are not too stringent. It is hoped that a single type of database management system can be used for all databases, which would minimize maintenance complexity for the project.

It is expected that a DataBase Management System (DBMS) will be used to maintain the integrity of the data through ingest and retrieval. However we do not preclude the
possibility of using some system based on flat files (e.g., a Berkeley database system or a custom made management tool) if all the requirements can be met.

5.2 General Requirements

5.2.1 Searchability

Must be able to search on times, integers, and reals.

5.2.2 Database handling capacity

Must be able to store and search the entire 10 years worth of mission data, information, or results.

5.2.3 Operating Systems

The database system must be able to run on hardware and operating systems commonly available in the LAT IOC, the SSC, and the HEASARC (e.g., Linux).

5.2.4 Maintenance

Must be relatively easy to maintain. Less than 0.2 FTE per database system summed over the three databases here.

5.2.5 Assumption by the HEASARC

The databases shall be maintained by (at least) the HEASARC after the GLAST mission ends

5.2.6 Database system independence

The database system must not require the use of special proprietary features to meet the requirements in this document, as this could make changing to a different database system later a problem. For example, the database should not need a special dialect of SQL (see § 5.2.9.1).
5.2.7 Update and backup search concurrency

Must be able to update and backup the database concurrent with searching.

5.2.8 Database Backup

The database must have tools available for incremental and full backup of the data contents.

5.2.9 DBMS specific requirements

The following requirement applies if a DBMS system is preferred over some other way to archive the data.

5.2.9.1 SQL version

If a DBMS, must use SQL close to ANSI standard SQL (currently SQL99) to be compatible with §5.2.6

5.3 Access Requirements

5.3.1 Accessibility

Must be accessible through an API in a standard GLAST programming language (e.g., Perl, C++, and Java).

5.3.2 Administrator account

There must be at least one way to restrict write privilege and configuration control to an administrator account.

5.3.3 Remote access

The database must be remotely accessible for queries and data retrieval.

5.3.4 Read Only Web queries
Must be able to restrict some remote database connections to be read only queries.

5.4 Database Specific Requirements

5.4.1 D2. Pointing, livetime, and mode history

5.4.1.1 Functional Description

This is the database of pointing and observation history that is needed to calculate exposures. It contains information about the orientation, location, and operation of the LAT for regular time intervals, ~30 s. The information also includes entries whenever instrument mode changes are made. The analysis tools do not directly access the database. Instead, it receives queries from, and passes data to, the Pointing/livetime history extractor (U2 – see the SLWG description).

5.4.1.2 Inputs

Must be able to ingest spacecraft livetime history tables generated by the LIOC for roughly 5 hour periods delivered 5 times per day.

5.4.1.3 Output

The database must be able to deliver a table with all selected rows.

5.4.1.4 Queries required

The database must be able to select rows by time intervals, filtered by other fields in the row.

5.4.1.5 Performance requirements

5.4.1.5.1 Ingest Speed

Must be able to ingest a newly delivered 5-hour data table in < 1 minute.

5.4.1.5.2 Request speed
A standard search is the expected average user query.

5.4.1.5.2.1 Standard Search

The standard search for D2 is to get 6 months worth of consecutive data, which constitutes about 40 Mb of data (TBR).

5.4.1.5.2.2 Service time

Must be able to service a standard search request in < 1 minute.

5.4.1.5.2.3 Number of service requests

Must be able to service > 1500 standard search requests in a day.

5.4.1.5.3 Update speed

Must be able to input a re-processed 5-hour data table in < 5 times the time it takes to ingest a brand new table. This allows time to find and delete the old entries before inserting the new values into the database.

5.4.1.5.4 Restore speed

Must be able to rebuild the database from input files in < 1 day.

5.4.2 D5. LAT point source catalog

The information in this catalog is under the control of the LAT team.

5.4.2.1 Functional Description

This is the online form of the point source catalog. It is not directly accessed by the analysis tools, but instead receives queries from, and passes data to, the Catalog Access tool (U5 see the SLWG description document).

5.4.2.2 Input
Must be able to ingest the latest complete source catalog updated when necessary by LIOC

5.4.2.3 Output

Must be able to output tables with all fields for selected rows.

5.4.2.4 Queries required

- Select all entries specified by 2 dimensional region of the sky filtered by selections on other fields (e.g. frequency).
- Search source by name.
- Search by 2-D coordinates.

5.4.2.5 Performance requirements

5.4.2.5.1 Ingest Speed

10 Mb of LAT point source data must be able to be ingested and ready for searching in <10 minutes.

5.4.2.5.2 Request speed

A standard search is the expected average user query.

5.4.2.5.2.1 Standard Searches

5.4.2.5.2.1.1 Named source

The data in the table for a given source is retrieved by source name or 2-dimensional coordinates.

5.4.2.5.2.1.2 Region query

A standard region search fetches all sources in an area twice (TBR) the size of a standard event point source search. This is to ensure that there are no strong sources near the edge of the search region that could affect the analysis.
5.4.2.5.2.2 Service time

Must be able to service either type of standard search in < 1 minute.

5.4.2.5.2.3 Number of service requests

Must be able to satisfy > 1500 service requests per day.

5.4.2.5.3 Update speed

Must be able to update tables of refined point source entries at < 5 times the ingest rate,

5.4.2.5.4 Restore speed

Must be able to recreate the database from the input tables in < 1 day.

5.4.3 D4. Pulsar ephemerides

5.4.3.1 Functional Description

This is the radio pulsar timing information to be maintained during the LAT mission for assigning pulsar phases to gamma rays. The user does not directly access it, but instead the Pulsar Analysis tool A3 (see the SLWG description document) will perform the query. (If the pulsar ephemerides are implemented in a true database system, then a front-end interface tool, equivalent to the Data Extractor for the gamma-ray data, will be what communicates directly with the database.) The database will also receive queries from, and pass data to, the Catalog Access tool (U5).

5.4.3.2 Inputs

Must be able to ingest new pulsar ephemerides on update.
Must also be able to ingest tables with varying numbers of pulsar ephemerides.

5.4.3.3 Output

Must be able to output tables with all fields for selected rows. Output may be two tables for single and binary pulsars.
5.4.3.4 Queries required

- Must be able to select by 2 dimensional region of the sky, filtered by other parameters.
- Must be able to select individual pulsar records by source name or 2-D coordinates.
- Must be able to select by pulsar period. (TBR).

5.4.3.5 Performance requirements

5.4.3.5.1 Ingest Speed

Must be able to ingest 1 Mb worth of pulsar ephemerides tables in < 1 minute.

5.4.3.5.2 Request speed

A standard search is the expected average user query.

5.4.3.5.2.1 Standard Searches

5.4.3.5.2.2 Named source

Retrieve pulsar record from pulsar name or from 2-D coordinates.

5.4.3.5.2.3 Region search

Retrieve records for all pulsars in a level 1 event summary database standard search area (a 15 degree radius circle).

5.4.3.5.2.4 Service time

Must be able to perform either standard search of the database in < 1 minute

5.4.3.5.2.5 Number of service requests

Must be able to service >1500 standard requests per day.

5.4.3.5.3 Update speed
Must be able to load an updated database in < 5 times the ingest speed.

5.4.3.5.4 Restore speed

Must be able to restore the database from input data files in < 1 hour.

6 Appendix: Expected Database Characteristics

Listed here are the contents and data sizes anticipated for the databases covered in this document. This information can and will be modified as the Science Tools Working Group continues to refine the detailed specification of these databases.

6.1 D2: Pointing, Livetime, and mode history database

6.1.1 Contents

The provisional contents of the database, defined in the report of the Data Products Working Group as LS-005 and augmented here to include the SAA flag and positions of the sun and moon, are as follows:

<table>
<thead>
<tr>
<th>Contents</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 starting time of interval (Mission Elapsed Time)</td>
<td>s</td>
</tr>
<tr>
<td>2 ending time of interval (Mission Elapsed Time)</td>
<td>s</td>
</tr>
<tr>
<td>3 position of S/C at start of interval (x,y,z inertial coordinates)</td>
<td>km</td>
</tr>
<tr>
<td>4 viewing direction at start (LAT +z axis), 2 angles</td>
<td>dimensionless</td>
</tr>
<tr>
<td>5 orientation at start (LAT +x axis), 2 angles</td>
<td>dimensionless</td>
</tr>
<tr>
<td>6 zenith direction at start, 2 angles</td>
<td>dimensionless</td>
</tr>
<tr>
<td>7 LAT operation mode</td>
<td>dimensionless</td>
</tr>
<tr>
<td>8 Livetime</td>
<td>s</td>
</tr>
<tr>
<td>9 SAA flag</td>
<td>dimensionless</td>
</tr>
<tr>
<td>10 S/C longitude</td>
<td>deg</td>
</tr>
<tr>
<td>11 S/C longitude</td>
<td>deg</td>
</tr>
<tr>
<td>12 S/C altitude</td>
<td>km</td>
</tr>
<tr>
<td>13 direction of the sun, 2 angles</td>
<td>Deg</td>
</tr>
<tr>
<td>14 direction of the moon, 2 angles</td>
<td></td>
</tr>
</tbody>
</table>

The positions of the sun and moon are included here solely to facilitate cuts on their positions in the generation of exposure. They are both gamma-ray sources (the sun impulsively) and both of course shadow sources they pass in front of.
6.1.2 Data Sizes

- Table to ingest \( \sim \) 60kb
- 1 year data size \( \sim \) 100 Mb
- 10 year data size \( \sim \) 1000 Mb
- Number of rows in 1 year \( \sim \) 1 M rows (30s resolution)

6.2 D5: LAT point Source Catalog

6.2.1 Contents

The provisional contents of the database, defined in the report of the Data Products Working Group as LS-008, are as follows:

<table>
<thead>
<tr>
<th>Contents</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  source name (“telephone number”)</td>
<td>dimensionless</td>
</tr>
<tr>
<td>2  RA</td>
<td>Deg</td>
</tr>
<tr>
<td>3  Dec</td>
<td>Deg</td>
</tr>
<tr>
<td>4  th68 semimajor, semiminor axis, and position angle</td>
<td>Deg</td>
</tr>
<tr>
<td>5  th95 semimajor, semiminor axis, and position angle</td>
<td>Deg</td>
</tr>
<tr>
<td>6  flux (&gt;100 MeV, avg. for the time interval of the catalog)</td>
<td>cm-2 s-1</td>
</tr>
<tr>
<td>7  flux uncertainty, 1 sigma (as above)</td>
<td>cm-2 s-1</td>
</tr>
<tr>
<td>8  Photon spectral index (avg)</td>
<td>dimensionless</td>
</tr>
<tr>
<td>9  variability index</td>
<td>dimensionless</td>
</tr>
<tr>
<td>10 significance (avg)</td>
<td>dimensionless</td>
</tr>
<tr>
<td>11 significance (peak)</td>
<td>dimensionless</td>
</tr>
<tr>
<td>12 peak flux (for time interval above?)</td>
<td>cm-2 s-1</td>
</tr>
<tr>
<td>13 peak flux uncertainty</td>
<td>cm-2 s-1</td>
</tr>
<tr>
<td>14 time of peak flux (wrt reference date)</td>
<td>S</td>
</tr>
<tr>
<td>15 interval of time</td>
<td>S</td>
</tr>
<tr>
<td>16 flux history</td>
<td>cm-2 s-1</td>
</tr>
<tr>
<td>17 flux uncertainty, 1 sigma (as above)</td>
<td>cm-2 s-1</td>
</tr>
<tr>
<td>18 start times of flux history entries</td>
<td>S</td>
</tr>
<tr>
<td>19 end times of flux history entries</td>
<td>S</td>
</tr>
<tr>
<td>20 candidate counterparts</td>
<td>dimensionless</td>
</tr>
<tr>
<td>21 Degrees of confidence for the counterparts</td>
<td>dimensionless</td>
</tr>
<tr>
<td>22 flags (confusion, low latitude,…)</td>
<td>dimensionless</td>
</tr>
</tbody>
</table>

6.2.2 Data Size

- Expected catalog size \( \sim \) 10 Mb
• Data size after 1 year ~ 10 Mb
• Data size after 10 years ~ 50 Mb (TBR)

6.3 D4: Pulsar Ephemerides

6.3.1 Contents

The provisional contents of the database, defined based on the pulsar timing files used for EGRET are given below. Note that for generality and consistency with format provided by pulsar observers, times in this file should be specified in MJD rather than Mission Elapsed Time. The second table below contains the additional information required for binary pulsars, but these two tables could be combined.

### Parameters for any pulsar

<table>
<thead>
<tr>
<th>Contents</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pulsar name</td>
<td>dimensionless</td>
</tr>
<tr>
<td>2 Right Ascension (J2000)</td>
<td>deg</td>
</tr>
<tr>
<td>3 Declination (J2000)</td>
<td>deg</td>
</tr>
<tr>
<td>4 Start of interval of validity for timing info (MJD)</td>
<td>days</td>
</tr>
<tr>
<td>5 End of interval of validity (MJD)</td>
<td>days</td>
</tr>
<tr>
<td>6 Infinite-frequency geocentric UTC arrival time of a pulse (MJD)</td>
<td>days</td>
</tr>
<tr>
<td>7 Pulsar rotation frequency</td>
<td>Hz</td>
</tr>
<tr>
<td>8 First derivative of pulsar frequency</td>
<td>Hz(^2)</td>
</tr>
<tr>
<td>9 Second derivative of pulsar frequency</td>
<td>Hz(^3)</td>
</tr>
<tr>
<td>10 Root-mean-square radio timing residual (periods)</td>
<td>dimensionless</td>
</tr>
<tr>
<td>11 Source of timing information</td>
<td>dimensionless</td>
</tr>
<tr>
<td>12 Flag for binary pulsars</td>
<td>dimensionless</td>
</tr>
</tbody>
</table>

### Orbital parameters for binary pulsars

<table>
<thead>
<tr>
<th>Contents</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pulsar name</td>
<td>dimensionless</td>
</tr>
<tr>
<td>2 Orbital period</td>
<td>s</td>
</tr>
<tr>
<td>3 Projected semi-major axis</td>
<td>s (light travel time)</td>
</tr>
<tr>
<td>4 Orbital eccentricity</td>
<td>dimensionless</td>
</tr>
<tr>
<td>5 Barycentric time (TDB scale) of periastron (MJD)</td>
<td>days</td>
</tr>
<tr>
<td>6 Longitude of periastron</td>
<td>deg</td>
</tr>
<tr>
<td>7 First derivative of longitude of periastron</td>
<td>deg per Julian year</td>
</tr>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

### 6.3.2 Data Sizes

- Expected catalog size ~ 1 Mb (1000 pulsars entries of 1 kb each)
- Data size after 1 year ~ 1 Mb
- Data size after 10 years ~ 5 Mb (TBR)