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GLAST BURST MONITOR

SIMULATION AND DETECTOR RESPONSE SOFTWARE

FUNCTIONAL SPECIFICATION DOCUMENT

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SIMULATION AND DETECTOR RESPONSE SOFTWARE

FUNCTIONAL SPECIFICATION DOCUMENT

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1. SCOPE

This document defines the functional specifications for the GLAST Burst Monitor (GBM) Simulation (SIM) and Detector Response (DRM) software. This collection of software will serve several different purposes during the course of the GBM mission. In the design phase, simulations will aid in the design and optimization of GBM hardware and flight software systems. In the test/calibration phase, simulations will be used to aid in the analysis and interpretation of calibration data. In the operations phase, simulations will be used to generate detector response functions (with input from calibrations) crucial to the analysis of science data. Because of its varied role, the SIM software is an evolving collection of tools that tracks the development of GBM hardware, flight software, and data analysis software. The SIM software is particularly tied to the development of all GLAST mechanical systems, since detailed mass models are a major source of input that must be updated when the hardware designs change.

2. APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent specified herein. Documents referenced in the following specifications, standards, publications, and procedures are also a part of this specification and are applicable as described to meet the specifications of this document.

Document Number	Title
GBM-SPEC-1031	GBM Mission Operations and Data Analysis Software Functional Specification Document
GBM-PLAN-1023	GBM Ground Software Development Plan
GBM-REQ-1007	GLAST Burst Monitor (GBM) Requirements, Verification, and Compliance (RVC) Document/Database
GBM-MPE-PL-1-1	GLAST Burst Monitor Calibration Plan Document

2.1 Reference Documents

The following documents contain general background information and are for reference only. As such, they do not constitute part of this document, but may be of interest to the reader.

Document Number	Title
n/a	GEANT4 User's Documents. http://wwwinfo.cern.ch/asd/geant4
n/a	GLAST Burst Monitor: A Proposal to NASA for a Burst Monitor for the GLAST Mission, Nov. 1999. http://gammaray.msfc.nasa.gov/gbm/publications/proposal
433-SRD-0001	GLAST Project Science Requirements Doc., Draft, July 2000. http://glast.gsfc.nasa.gov/project/cm/mcdl/

3. SOFTWARE SPECIFICATIONS

3.1 General Specifications

This section addresses general SIM software specifications that are independent of individual program elements. The major components are illustrated in Figure 1.

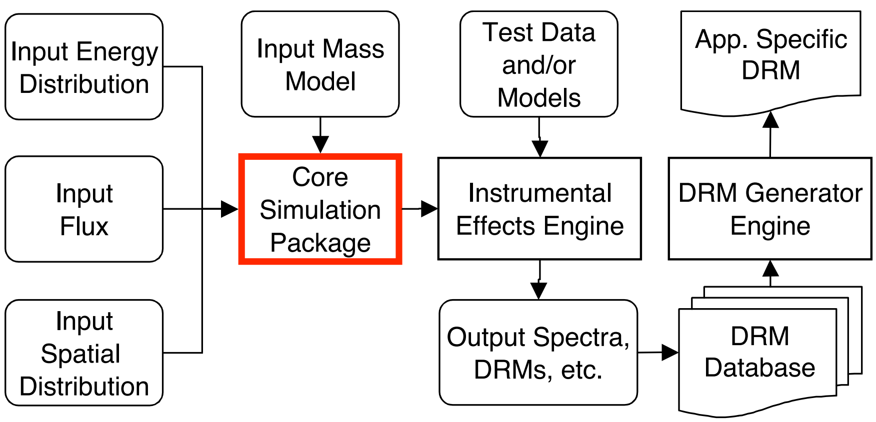

Fig. 1. Major components of SIM software.

3.1.1 Core Simulation Package

The SIM software shall use a general-purpose radiation transport simulation package that includes tools for the definition of complex geometrical mass models, and Monte Carlo simulation of particles through these models.

A trade study shall be performed to identify the core SIM package. This study shall consider at least the following parameters:

(1) Ability to meet required functionality (as defined by the specifications in this document)

(2) Support and maintenance (especially during the GBM operations & analysis phase)

(3) Support by the scientific user community (including gamma-ray astronomy)

(4) Support by the Large Area Telescope (LAT) team

(5) Maturity of code design and implementation

(6) Code availability on different computers and operating systems, particularly UNIX

(7) Ease of use

(8) Ease of customization

(9) Computing performance

A study was performed considering these factors and the GEANT3 package from CERN was chosen for initial prototype (design phase) development because of heritage use and understanding of the code. For all post- design phase development, the GEANT4 package from CERN shall be used. This package exceeds all of the functionality requirements described herein, and will be supported and maintained by its developers (and the scientific community) for the foreseen duration of the GLAST mission. It is also the package being used by the LAT simulation team.

3.1.2 Radiation Transport Physics

In order to simulate the physical response of the GBM detectors, the SIM software shall have the capability to perform Monte Carlo particle transport simulations of primary photons and their secondary photons and electrons. The simulation process shall include at least the following electromagnetic interaction processes (preferably as part of the core simulation package):

(1) Photoelectric absorption, including emission of florescence X rays

(2) Incoherent (Compton) scattering of photons, including scattering form factors

(3) Coherent (Rayleigh) scattering of photons

(4) e^+e^- pair production by photons

(5) Ionization losses of electrons and positrons

(6) Multiple scattering of electrons and positrons

(7) Bremsstrahlung radiation from electrons and positrons

(8) Positron annihilation

The total cross-sections used in the simulations for these processes shall be demonstrated to be accurate to 10% over the energy range 1 keV to 1 GeV.

3.1.3 Input Mass Models

The SIM software shall accept as input descriptions of mass model geometry and composition stored in external data sets. Mass model data sets shall contain all information needed to construct the mass model, such that the SIM software shall be independent of specific mass models.

3.1.4 Input Photon Energy Distributions

The SIM software shall be capable of generating random incident photon energies from at least the following spectral distributions:

(1) Mono energetic

(2) Combination of up to 10 discrete energies with user-specified intensity weighting

(3) An arbitrary tabulated differential spectrum read from a file within a user-specified energy range

(4) Power law with user specified parameters and energy range

(5) Broken power law with user-specified parameters and energy range

(6) Band gamma-ray burst function with user specified parameters and energy range

3.1.5 Input Photon Spatial Distributions

The SIM software shall be capable of generating random incident photon directions from at least the following angular distributions:

(1) A plane-parallel beam from a user-specified direction

(2) An isotropic distribution with user-specified angular limits

(3) A divergent beam emanating from a user-specified location, with user-specified angular limits

(4) An arbitrary angular distribution specified by a tabulated map of flux as a function of direction read from a file in FITS format.

The starting positions shall be randomly selected from a simple, user-specified, surface such as a sphere or cylinder that envelops the region of interest.

3.1.6 Input Flux

The SIM software shall accept as input user-specified incident flux defined as either the total incident flux at a particular energy (in physical units such as photons/cm^2/keV), the total number of incident photons over some energy range, or the total number of detected photons.

3.1.7 Instrumental Effects

The SIM software shall include the capability to simulate instrumental effects unique to individual GBM detectors, such as energy resolution and energy thresholds. Parameters defining such effects shall be read from input data sets. The portion of software that applies instrumental effects shall be made separate from the radiation transport code such that instrumental effects may be applied with different parameters without repeating the radiation transport.

3.1.8 Recorded Data

The SIM software shall include the capability to accumulate and record the energy deposited by incident particles and their secondaries in sensitive components of the mass model. Sensitive components will be defined by the GBM science team as the SIM system is developed. Recorded data shall also include flags to indicate the type of the first interaction (i.e., photoelectric absorption, Compton scatter, etc.) and the mass model component where the interaction took place

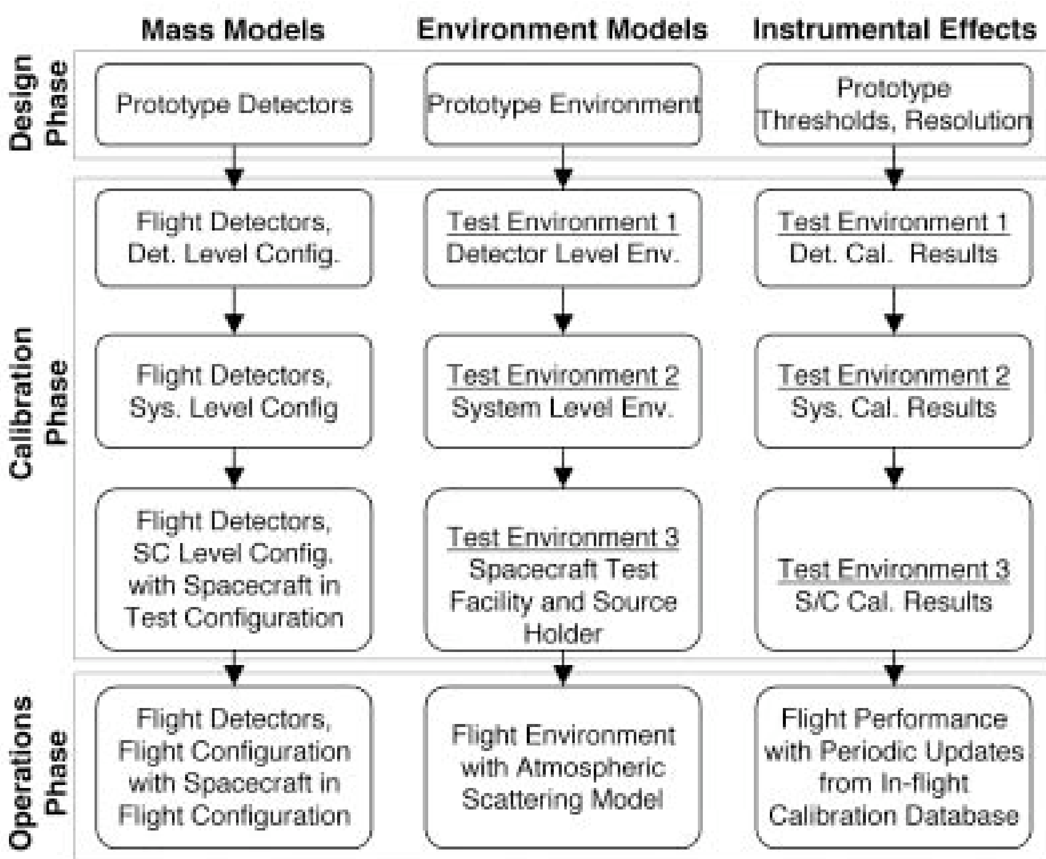

Fig. 2. Development flow of SIM input models.

3.2 Specifications Specific to GBM Design Phase

This section addresses SIM software specifications that are specific to the GBM design phase. The major goal in this phase is to assist in the development of the instrument design.

3.2.1 Design-phase Core Simulation Package

The core radiation transport simulation package used for the design-phase system is not required to be the same as that adopted for later phases of SIM software.

3.2.2 Design-phase Mass Models

The SIM software shall include mass models of the individual GBM detector modules in prototype configuration. These models shall at least include major detector components such as crystals, housings, and PMT assemblies, but not minor components. Dimensions of components shall be accurate to less than 1 mm, and material compositions shall include all species with 10% or greater contribution to the component mass.

3.2.3 Design-phase Environment Models

The SIM environment model during the GBM design phase shall be limited to the individual detectors placed in a uniform surrounding medium, such as vacuum or air.

3.2.4 Design-phase Instrumental Effects Models

For the design phase, SIM software shall include instrumental effects limited to a user-specified detector energy threshold, and a model for the detector energy resolution as a function of energy deposit. In this phase it is not required for the instrumental effects software to be separate from the radiation transport code.

3.3 Specifications Specific to GBM Calibration Phase

The following specifications address SIM support of GBM calibrations. The primary SIM function in this phase is to verify the simulation model through comparison with experimental calibration data (and adjust the model as needed).

3.3.1 Supported Calibrations

The SIM software shall support calibrations of the GBM flight instrument, as defined in the GBM Calibration Plan Document. Specifications for the support of additional calibrations (such as calibrations at different facilities) are limited to those covered here.

3.3.2 Detector-Level Calibrations

In this document, detector-level calibrations refer to those calibrations where detectors are tested independently, with separate data processing systems.

3.3.2.1 Detector Mass Models

The SIM software shall include high-fidelity mass models of the individual GBM flight detector modules in their detector-level calibration configuration. The detector models shall include the mass of all detector components as documented during their fabrication. The elemental mass composition and geometry shall be based on design/fabrication documents. Dimensions of components shall be accurate to less than 0.1 mm, and material compositions shall include all species with 1% or greater contribution to the component mass.

3.3.2.2 Detector Calibration Environment Model

The SIM software shall include models of the detector-level calibration environment sufficient to account for major sources of scattered radiation, such as source holders and mounting fixtures. Where possible, the environment models shall be based on measured (not estimated) properties of the experimental setup.

3.3.2.3 Detector Calibration Instrumental Effects Model

The SIM software shall include instrumental effects models appropriate for conditions during detector-level calibration, including at least energy resolution and thresholds for individual GBM detectors.

3.3.3 System-Level Calibrations

In this document, system-level calibration refers to calibrations where detectors are tested together with a common data processing unit.

3.3.3.1 Detector Mass Models

The SIM software shall include high-fidelity mass models of the individual GBM flight detector modules in their system-level calibration configuration. These models shall be adapted from those used to simulate detector-level calibrations. The elemental mass composition and geometry shall be based on design/fabrication documents. Dimensions of components shall be accurate to less than 0.1 mm, and material compositions shall include all species with 1% or greater contribution to the component mass.

3.3.3.2 System Calibration Environment Model

The SIM software shall include models of the system-level calibration environment sufficient to account for major sources of scattered radiation, such as source holders and mounting fixtures. Where possible, environment models shall be based on measured (not estimated) properties of the experimental setup.

3.3.3.3 System Calibration Instrumental Effects Model

The SIM software shall include instrumental effects models appropriate for conditions during system-level calibration.

3.3.4 On-spacecraft Calibrations

In this document, on-spacecraft calibrations are those calibrations of the GBM system performed after the GBM detectors and LAT hardware are mounted on the GLAST spacecraft.

3.3.4.1 Detector Mass Models

The SIM software shall include high-fidelity mass models of the individual GBM flight detector modules in their on-spacecraft calibration configuration. These models shall be adapted from those used to simulate detector or system-level calibrations. The elemental mass composition and geometry shall be based on design/fabrication documents. Dimensions of components shall be accurate to less than 0.1 mm, and material compositions shall include all species with 1% or greater contribution to the component mass.

3.3.4.2 Spacecraft Mass Model

The SIM software shall include a mass model of the GLAST spacecraft in its configuration during GBM on-spacecraft calibration (with the integrated LAT). The spacecraft/LAT mass model shall at least include all major assemblies, as well as minor assemblies located near the GBM detectors. This model shall be derived from data provided by the spacecraft contractor and/or LAT team. Models of the GBM detectors shall be incorporated into the spacecraft model, including the appropriate mounting hardware.

3.3.4.3 On-spacecraft Calibration Environment Model

The SIM software shall include models of the on-spacecraft-level calibration environment sufficient to account for major sources of scattered radiation, such as source holders and mounting fixtures. Where possible, environment models shall be based on measured (not estimated) properties of the experimental setup.

3.3.4.4 On-spacecraft Calibration Instrumental Effects Model

The SIM software shall include instrumental effects models appropriate for conditions during on-spacecraft calibration.

3.4 Specifications Specific to GBM Operations Phase

In this document, operations phase refers to the operation of the GBM system after successful launch and turn-on when it is part of the GLAST observatory. The SIM software for the mission operations phase is considered part of the GBM Mission Operations and Data Analysis Software. The primary function of the SIM software in this phase is the generation of Detector Response Matrices (DRM) used for analysis of flight science data. Software for this purpose is called “SIM-DRM” software.

3.4.1 Coding Standards

In general, the SIM-DRM software shall abide by the coding standards defined in the GBM Mission Operations and Data Analysis Software Functional Specification Document. However, the programming language used for SIM software is not required to be the same as that used for other data analysis programs.

3.4.2 Maintenance & Configuration Control

The SIM-DRM software and its key input datasets, such as mass models and instrument performance parameters, shall be maintained and configuration controlled in the manner defined in the GBM Mission Operations and Data Analysis Software Functional Specification Document.

3.4.3 Mass Models

3.4.3.1 Detector Mass Models

The SIM-DRM software shall include high-fidelity mass models of the individual GBM flight detector modules in their flight configuration. These models shall be adapted from those used to simulate on-spacecraft calibrations. The elemental mass composition and geometry shall be based on design/fabrication documents. Dimensions of components shall be accurate to less than 0.1 mm, and material compositions shall include all species with 1% or greater contribution to the component mass.

3.4.3.2 Spacecraft Mass Model

The SIM-DRM software shall include a mass model of the GLAST spacecraft in its operational flight configuration (including the LAT). The spacecraft/LAT mass model shall at least include all major assemblies, as well as minor assemblies located near the GBM detectors. This model shall be derived from those used to simulate on-spacecraft calibrations. Models of the GBM detectors shall be incorporated into the spacecraft model, including the appropriate mounting hardware.

3.4.4 Atmospheric Scattering Model

The SIM software shall include a model of the mass distribution of Earth's atmosphere for use in simulating the radiation from cosmic sources that scatters from the earth into the GBM detectors.

3.4.5 Instrumental Effects Models

The SIM software shall include instrumental effects models appropriate for conditions during in-flight operation. These models shall be implemented to allow changes in the instrument performance parameters during the course of the mission.

3.4.6 Detector Response Matrix Generation

3.4.6.1 DRM Definition

The SIM-DRM software shall generate detector response matrices that tabulate the effective detection area of individual GBM detectors as a function of incident and measured photon energy. The definition of energy grid shall be an input parameter.

3.4.6.2 Direct Response

The SIM-DRM software shall compute the response of individual GBM detectors to the flux from cosmic sources at arbitrary directions, including the response from photons and their secondary particles that scatter from the spacecraft into the detectors.

3.4.6.3 Atmospheric Scattering

The SIM-DRM software shall compute the response of individual GBM detectors to the flux from astrophysical sources at arbitrary directions that scatters from Earth's atmosphere into the detectors. The response due to atmospheric scattering shall be computed independently from the direct response.

3.4.6.4 Source Geometry

The SIM-DRM software shall generate detector response matrices for arbitrary Earth–Source–Spacecraft geometry.

3.4.6.5 Changing Detector Aspect

The SIM-DRM software shall have the capability to generate averaged DRMs appropriate for time intervals when the spacecraft/detector aspect or spacecraft–earth–source angle changes by more than 1 degree.

3.4.6.6 Statistical Uncertainty

The SIM-DRM software shall generate DRMs with user-specified statistical uncertainty.

3.4.6.7 DRM Data Format

The SIM-DRM software shall record DRM data files that adhere to the high-level data products standards defined in the GBM Mission Operations and Data Analysis Software Functional Specification Document.

3.4.6.8 DRM Database

The SIM-DRM software shall be used to generate a database of DRMs that cover the full range source directions and Earth-source geometry with a sampling resolution of at least 10 degrees. The response due to atmospheric scattering shall be stored in the database independently from the direct response. This database shall be stored using the CALDB architecture as specified in the GBM Mission Operations and Data Analysis Software Functional Specification Document.

3.4.6.9 DRM Database Interpolation

The SIM-DRM software shall include the capability to generate DRMs for an arbitrary source direction and arbitrary Earth-source geometry by interpolating an existing DRM database. This software shall have the ability to generate DRMs with, or without the response due to atmospheric scattering. The combination of DRM database and interpolation algorithm shall be capable of generating DRMs to a resolution of 0.5 deg with a precision of less than 5% compared to non-interpolated DRMs.

3.4.7 Energy Deposit Spectral Data Generation

The SIM-DRM software shall have the capability to generate, for any GBM detector, energy deposit spectra for cosmic sources at arbitrary (user-specified) directions and Earth-source geometries. The user shall have the option to include direct and/or Earth-scattered response. These spectra shall be recorded in data files that adhere to the high-level data products standards defined in the GBM Mission Operations and Data Analysis Software Functional Specification Document.

4. NOTES

4.1 List of Acronyms

BGO	Bismuth Germanate
Dec.	Declination
deg	degree
DRM	Detector Response Matrix
GBM	GLAST Burst Monitor
GLAST	Gamma-Ray Large Area Space Telescope
GRB	Gamma-Ray Burst
keV	kilo electron Volts
LAT	Large Area Telescope
MB	Megabyte
MeV	mega electron Volts
MSFC	Marshall Space Flight Center
NaI	Sodium Iodide

NASA	National Aeronautics and Space Administration
PMT	Photomultiplier Tube
R.A.	Right Ascension
SC	Spacecraft
SIM	Simulation and detector response
TBR	To Be Resolved
TBD	To Be Defined
UTC	Universal Time (Coordinated)