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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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GLAST BURST MONITOR

Calibration Plan for the GBM

DRAFT, Prior to Baseline

CHECK THE MASTER LIST—
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

GLAST Burst Monitor (GBM) Calibration Plan

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MSFC Form 4140 (Rev. September 1990) **NOTE: After revising the document, file this sheet in document preceding Table of Contents.** Informed 2.6.3

Acronyms and Abbreviations

BGO	Bismuth Germanate
cm	centimeters
cps	counts per second
FWHM	Full-width half-maximum
GBM	GLAST Burst Monitor
GEANT	Geometry and Tracking Monte-Carlo Program
GLAST	Gamma Ray Large Area Space Telescope
GRB	Gamma-Ray Burst
HV	High Voltage
HVPS	High Voltage Power Supply
HWHM	Half-width half-maximum
I&T	Integration and Test
kcps	kilo counts per second
NaI	Sodium Iodide

1. PURPOSE

The calibrations and tests in this GLAST Burst Monitor (GBM) Calibration Plan serve three purposes:

I. To provide performance verification of distinct elements of the GBM detector system, including the flight data system. These verification elements are described in the GBM Verification Plan, GBM-PLAN-1014.

II. To provides calibration data that will be used for orbital operations and in data analysis in order to ensure efficient operation of the flight system and accurate, well-characterized data for subsequent scientific analysis.

III. To provide benchmark data to compare with calculated detector response data which cannot be derived from actual calibration data due to limited resources, schedule, or other physical limitations

This Plan defines the test procedures and identifies the organizations responsible for conducting these calibrations. It includes a summary of each calibration and identifies the person responsible for writing the procedure and the due date for the completed procedure.

These calibrations will be performed on GBM flight detector hardware. It is suggested that procedures for these tests be performed on GBM science model detectors several months before their actual use on flight detectors, in order to streamline the test procedures and avoid schedule delays.

Acceptance tests are intended to verify that the hardware design meets requirements. Functional tests are generally performed numerous times and verify that the flight hardware still performs properly.

2. APPLICABILITY

Verification is in accordance with Marshall Work Instruction 8050.1 within the scope of MPD 1280.1, “Marshall Management Manual” (MMM). This plan will apply to the GLAST Burst Monitor test program and verification for the entire instrument.

3. APPLICABLE DOCUMENTS

3.1 MPD 1280.1, “Marshall Management Manual”
3.2 MPG 8060.1, “Flight Systems Design/Development Control”
3.3 MPG 8040.1, “Configuration Management, MSFC Programs/Projects”

3.4 MWI 7120.2, "Data Requirements Identification/Definition"
3.5 MPG 8730.1, "Inspection and Testing"
3.6 MPG 8730.3, "Control of Nonconforming Product"
3.7 MPG 1280.4, "MSFC Corrective Action System"
3.8 MPG 1440.2, "MSFC Records Management Program"

4. REFERENCES

Schötzig, Ulrich and Heinrich Schrader: Physikalisch-Technische Bundesanstalt PTB-Ra-16/5, Braunschweig, September 1998

5. DEFINITIONS

None

6. INSTRUCTIONS

The Principal Investigator, or his designee, has overall responsibility for developing and implementing a Calibration Plan that will be the basis for verification, tests and calibration of detectors and detector systems for the flight mission. The paragraphs that follow identify activities needed to be performed, either sequentially or concurrently, that will ensure proper calibration of the flight detector system.

7. NOTES - Test Numbering Scheme

GBM-PROC-TP0XX	Miscellaneous tests (a catch-all for tests that defy classification)
GBM-PROC-TP1XX	Detector development tests at MPE (possibly repeated at MSFC) & calibrations
GBM-PROC-TP5XX	Subsystem hardware tests at MSFC (also includes subsystem bench testing at S/C I&T)
GBM-PROC-TP6XX	System level hardware tests at MSFC, including thermal-vac
GBM-PROC-TP8XX	Tests during S/C I&T, including ETE tests
GBM-PROC-TP9XX	On-orbit tests

8. SAFETY PRECAUTIONS AND WARNING NOTES

As specified in the individual procedures. Many of these tests and calibrations require the use of radioactive sources. The handling, use and storage of these sources are subject to federal and state regulations.

9. RECORDS

The Project Manager shall be responsible for maintaining and archiving the following verification-related documentation as Quality Records in accordance with MPG 1440.2.

Verification program documentation will be recorded by reference in the GBM Requirements Database (GBM-REQ-1007). All verification data will be stored in files maintained by the GBM Lead Systems Engineer. The files will be stored in the folders indexed to the GBM Requirements Database in the verification section for each requirement.

Compliance Data, including nonconformances, waivers, and deviations will also be recorded by reference in the GBM Requirements Database (GBM-REQ-1007). The files will be stored in the folders indexed to the GBM Requirements Database in the compliance section for each requirement. All non conformances will be noted by requirement in the database and hardcopies will be stored with the verification and compliance data.

10. PERSONNEL TRAINING AND CERTIFICATION

The calibration test conductor for each test will be assigned by the Principal Investigator, the Co-Principal Investigator, or the Lead Systems Engineer.

11. FLOW DIAGRAM

The flight hardware and test flow diagram is contained in the GBM Verification Plan #1014. A version is also attached herein for convenience, however the reader should note that this may not be a current version.

12. CANCELLATION

None

13. TEST PROCEDURES LIST

	Number	Name	Lead Author	Due	Run
1.	**GBM-PROC-TP100**	**NaI Detector Performance**	**MPE**	**SCDR**	**MPE cal.**
2.	**GBM-PROC-TP101**	**NaI Low Energy Calibration**	**MPE**	**SCDR**	**TBD**
3.	**GBM-PROC-TP105**	**NaI Detector Functional**	**MPE**	**SCDR**	**DJO Qual.**
4.	**GBM-PROC-TP110**	**BGO Detector Performance**	**MPE**	**SCDR**	**MPE cal.**
5.	**GBM-PROC-TP111**	**BGO High Energy Calibration**	**MPE/GJF**	**TBD**	**TBD**
6.	**GBM-PROC-TP115**	**BGO Detector Functional**	**MPE**	**SCDR**	**DJO Qual.**
7.	**GBM-PROC-TP120**	**Detector Magnetic Susceptibility**	**MPE**	**SCDR**	**MPE cal.**
8.	**GBM-PROC-TP605**	**System Linearity**	**Wilson**	**4/1/04**	**EQM testing**
9.	**GBM-PROC-TP610**	**High Rate**	**Wilson**	**1/1/05**	**GBM I&T**
10.	**GBM-PROC-TP630**	**Short Energy Calibration**	**Fishman**	**PER**	**GBM I&T**
11.	**GBM-PROC-TP635**	**Long Energy Calibration**	**Fishman**	**PER**	**GBM I&T**
12.	**GBM-PROC-TP650**	**Short System Functional**	**Meegan**	**PER**	**GBM I&T**
13.	**GBM-PROC-TP655**	**Long System Functional**	**Meegan**	**PER**	**GBM I&T**
14.	**GBM-PROC-TP805**	**S/C Integration Source Survey**	**Fishman**	**10/1/05**	**S/C I&T**

NOTE: SCDR = Systems Critical Design Review

13.1 Test Procedure Outlines

Test No. and Name: GBM-PROC-TP100, NaI Detector Performance
Performed at: MPE
Purpose: Verify requirements for NaI detector resolution, angular response, effective area, and high rate performance.

Requirements verified: 3.3.1.2, 3.3.1.3, 3.3.2.1, 3.3.2.2, 3.3.3.1.
Author: MPE

Summary: The detector is exposed to various radioactive sources covering the energy range of 5 keV to at least 1 MeV. Resolution and relative rates are recorded. Resolution must meet requirement 3.3.2.2. Effective area is measured using sources that have an accurately known intensity, as specified in this Calibration Plan.

These tests consist of the following separate procedures:

TP100-A. Measurement of the Channel-Energy Relation and the Energy Resolution

Energy spectra shall be recorded from the sources listed in Table 2. The sources are to be placed ≥50 cm from the center of the NaI crystal disc, so that they irradiate the crystal nearly uniformly. From the recorded spectra, the channel-energy relation and the energy resolution as a function of the energy can be derived by fitting a Gaussian to the photopeak. At least four of these sources, with widely-spaced energies, shall have their intensity calibrated with an accuracy of 5%, or better. The remaining sources shall have their intensity calibrated with an accuracy of 10%, or better.

The above measurements shall be made with sufficient accuracy to determine the peak energy to within 0.2 PHA channels, the linearity to a level of better than 1%, and the energy resolution to within 0.2%.

TP100-B. Measurement of the Relative Response, the Channel-Energy Relation and the Energy Resolution as a Function of Off-Axis Angle

The dependence of the number of detected counts relative to on-axis shall be measured at several different energies using ^{133}Ba and ^{22}Na (the energies of these sources cover most of the energy range of the NaI crystals). At the same time, measurements shall be made of the channel-energy relation and of the energy resolution on the angle between the normal to the crystal surface of a NaI crystal and the incident direction of the γ-rays in steps of 15° up to an angle of 180° for one azimuth only. (It is assumed that the detectors are nearly axially symmetric.)

TP100-C. Determination of the Photoelectron Yield

The photoelectron yield is closely related to the energy resolution. If one neglects other statistical effects and the broadening of the measured energy distribution due to geometrical effects (like inhomogeneity of the photocathode) and considers only the photoelectron statistics, then the photoelectron yield can be calculated from the energy resolution with the following formula:

$$N \geq \frac{5.545}{(\Delta E / E)^2} \qquad (1)$$

ΔE is the FWHM of the measured energy distribution for a given γ-ray energy E. The $\geq$-sign indicates that the true number of photoelectrons is larger than the number calculated from (1).

If one considers the statistical broadening of the distribution due to the PMT noise, a better value of N can be calculated according to:

$$N = \frac{5.545}{(\Delta E / E)^2} \cdot [1 + (\frac{\sigma_g}{g})^2] \qquad (2)$$

Here g is the gain of the PMT and σ_g is its standard deviation. For the phototube used in the GBM detectors, the additional factor has a value of TBD. However, N is still not the exact number of photoelectrons because of the geometrical broadening, thus N can only be considered as a figure of merit.

N as a function of the various parameters (energy, incidence angle & temperature) shall be determined from the measurements described in sections I.A and I.B, above.

TP100-D. Measurement of the Temperature Dependence of the Channel-Energy Relation and the Energy Resolution (These measurements shall be obtained during thermal-vacuum testing and will become part of that Plan.)

The energy calibration and the resolution of the detectors shall be measured with two well-separated gamma-ray lines as a function of the temperature. The temperature range shall be from +5° C to +35° C (or greater) in steps of 5° C. Two full temperature cycles shall be made. Between the measurements at the different temperatures at least one hour must have passed in order to allow the module to stabilize at a uniform temperature and not to exceed the allowed temperature gradient of 5° C per hour.

These measurements shall be made with sufficient accuracy to determine the peak energy to within 0.2 PHA channels, the linearity to a level of better than 1%, and the energy resolution to within 0.2%.

Table 2. - List of radioactive sources for the calibration of the GBM detectors

Nuclide	Half-life	Transition probabilities	Line energies [keV]
^{55}Fe	2.75 y	24.9 % 28.3 %	5.89 5.96
^{241}Am	432.2 y	11.93 % 18.61 % 35.9 %	13.95 17.54 59.54
^{109}Cd	462.1 d	28.99 % 54.7 % 83.6 % 15.14 % 17.77 % 3.62 %	21.99 22.16 22.10 24.9 25.0 88.03
^{133}Ba	10.5 y	34.6 % 63.4 % 98.0 % 18.7 % 23.0 % 34.06 % 18.33 % 62.05 %	30.63 30.97 30.85 35.0 35.1 81.0 302.85 356.02
^{203}Hg	46.6 d	81.46 %	279.2
^{207}Bi	31.55 y	78 % 32.5 % 22.6 % 60.8 % 38.2 % 13.0 % 16.9 % 97.74 % 74.5 %	7.2 – 8.7 (?) 11.8 72.8 74.2 74.97 84.9 85.4 569.7 1063.66
^{57}Co	271.83 d	51.0 % 57.9 % 9.16 % 85.6 % 10.68 %	6.4 6.48 14.41 122.06 136.47
^{54}Mn	312.15 d	22.7 % 25.8 % 99.975 %	5.4 5.47 834.84
^{60}Co	5.27 y	99.85 % 99.98 %	1173.23 1332.49
^{137}Cs	30.1 y	85.0 %	661.66
^{22}Na	2.6 y	179.8 % 99.94 %	511 1274.54

^{24}Na	14.96 h	99.9932 % 99.871 %	1368.63 2754.01
^{88}Y	106.63 d	17.8 % 34.4 % 52.2 % 94.0 % 99.33 %	14.1 14.17 14.14 898.04 1836.6
^{232}Th	$1.41 \bullet 10^{10}$ y	14.2 % 41 % 10.5 % 17.7 % 43.3 % 11.27 % 30.4 % 25.8 % 15.8 % 35.64 %	12.1 15.2 74.81 77.11 238.63 338.32 583.19 911.20 968.97 2614.53

Table 2: Compiled from Schötzig, Ulrich and Heinrich Schrader: Physikalisch-Technische Bundesanstalt PTB-Ra-16/5, Braunschweig, September 1998 (with one exception only lines with emission probabilities larger than 10 % were included)

Test No. and Name: GBM-PROC-TP101, NaI Low Energy Calibration
Performed at: X Ray Test Facility (PUMA Facility at MPE)
Purpose: Calibration of the NaI detectors at low energies
Summary: Calibrate from 3 keV to 40 keV. Trace out the k-edge of iodine in the detector response. Measure effective area as a function of energy and angle.
Requirements verified: none, but required to meet 3.3.5.
Author: MPE

The purpose of the GBM Low Energy X-ray Calibrations, TP101, is to perform a detailed determination of the performance of the NaI detectors at low energies, that cannot be performed with radioactive sources alone, due to the unavailability of low energy, mono-energetic photon sources, closely spaced in energy. The determination of low-energy spectral measurements from GRBs is an important scientific objective of the GBM. Furthermore, absorbing materials in front of the detectors must be accurately measures since they cannot be modeled with certainty.

The absolute efficiency of all NaI flight detectors and flight spares shall be determined at various closely-spaced, low-energy x-ray energies and incidence angles. The lowest energy shall be ~3 keV, well below the expected low energy response of the GBM NaI detectors. The highest energy measurements of these measurements shall be well above the iodine k-edge (32 keV), where the response is non-linear and even discontinuous. It is recommended that these measurements extend to ~40 keV, if possible.

The x-ray beam characteristics such as the energy spread, beam background, absolute beam flux monitoring, etc., will be factors in completing this section of the GBM-PROC-TP101. These parameters will be developed by MPE, in consultation with personnel of the PUMA X-ray Facility at MPE, when details of that facility are better known in the timeframe of the GBM required calibrations.

The x-ray photon source of PUMA is expected to use a combination of x-ray tubes, and tube target materials, filters of different materials and thicknesses, and possibly a crystal monochrometer.

A flight-like thermal cover is to be installed over the front face of the NaI detector, since this might have a significant effect on the low-energy performance. The number of angular calibrations will be a sub-set of those in the comprehensive, medium energy calibrations of the NaI detectors.

[The low energy response of the detectors will be determined primarily by materials in front of the NaI crystal. While it is a design goal of GBM to have identical materials in each detector, it cannot be well-modeled or easily verified, without these actual measurements.]

Test No. and Name: GBM-PROC-TP105, NaI Detector Functional
Performed at: MPE, MSFC, S/C pre-integration
Purpose: Verify operation of PMT, preamps, and detector electronics.
Summary: The detector is powered up and receipt of background counts is verified. Preamp power is cycled by command. These tests will be made using background radiation or with radioactive sources (optional).
Requirements verified: None
Author: MPE
Use: This procedure will be used at various times during the integration and test flow at MPE, MSFC, and Spectrum Astro, as determined by the test flow and at other times, as specified by the P.I. or the GBM Systems Engineer.

Test No. and Name: GBM-PROC-TP110, BGO Detector Performance
Performed at: MPE
Purpose: Verify requirements for BGO detector resolution, angular response, and effective area.

Summary: The detector is exposed to radioactive sources covering the energy range of 100 keV to at least 2.6 MeV and a range of angles. Resolution and relative rates are recorded. Resolution must meet requirement 3.3.2.2. Effective area is measured using sources that have accurately known intensity, as specified in the Calibration Plan.

Requirements verified: 3.3.2.1, 3.3.2.2, 3.3.3.1.
Author: MPE

TP110-A. Measurement of the Channel-Energy Relation and the Energy Resolution

Energy spectra shall be recorded from the sources listed in Table 2 (with principal radiation >100 keV). The sources are to be placed ≥50 cm above the cylindrical surface of each BGO crystal lying in the middle plane perpendicular to the cylindrical axis located halfway between the two PMTs. From the recorded spectra, the channel-energy relation and the energy resolution as a function of the energy can be derived by fitting a Gaussian to the photopeak. At least four of these sources, with widely-spaced energies, shall have their intensity calibrated with an accuracy of 5%, or better. The remaining sources shall have their intensity calibrated with an accuracy of 10%, or better.

The above measurements shall be made with sufficient accuracy to determine the peak energy to within 0.2 PHA channels, the linearity to a level of better than 1%, and the energy resolution to within 0.2%.

TP110-B. Measurement of the Relative Response, the Channel-Energy Relation and the Energy Resolution as a Function of Off-Axis Angle

The same measurements shall be performed with the BGO crystals as the NaI detectors with the difference that the angle shall lie in one arbitrary plane defined by a radius and the cylindrical axis of the BGO detector. (On-axis refers to a radius at the BGO detector centerline.) Again, 15° steps up to an angle of 90° shall be applied. Only two radioactive sources, ^{137}Cs and ^{24}Na, shall be used.

The above measurements shall be made with sufficient accuracy to determine the response of the detector to a level of better than 1%, relative to the on-axis measurement. The energy-resolution measurement should be made with an accuracy of better than 0.2%.

TP110-C. Determination of the Photoelectron Yield

The photoelectron yield is closely related to the energy resolution. If one neglects other statistical effects and the broadening of the measured energy distribution due to geometrical effects (like inhomogeneity of the photocathode) and considers only the photoelectron statistics, then the photoelectron yield can be calculated from the energy resolution with the following formula:

$$N \geq \frac{5.545}{(\Delta E / E)^2} \qquad (1)$$

ΔE is the FWHM of the measured energy distribution for a given γ-ray energy E. The ≥-sign indicates that the true number of photoelectrons is larger than the number calculated from (1).

If one considers the statistical broadening of the distribution due to the PMT noise, a better value of N can be calculated according to:

$$N = \frac{5.545}{(\Delta E / E)^2} \cdot [1 + (\frac{\sigma_g}{g})^2] \quad (2)$$

Here g is the gain of the PMT and σ_g is its standard deviation. For the phototube used in the GBM detectors, the additional factor has a value of TBD. However, N is still not the exact number of photoelectrons because of the geometrical broadening, thus N can only be considered as a figure of merit.

N as a function of the various parameters (energy, incidence angle & temperature) shall be determined from the measurements described in sections I.A and I.B, above.

TP110-D. Measurement of the Temperature Dependence of the Channel-Energy Relation and the Energy Resolution (These measurements shall be obtained during thermal-vacuum testing and will become part of that Plan.)

The energy calibration and the resolution of the detectors shall be measured with two well-separated gamma-ray lines as a function of the temperature. The temperature range shall be from +5° C to +35° C (or greater) in steps of 5° C. Two full temperature cycles shall be made. Between the measurements at the different temperatures at least one hour must have passed in order to allow the module to stabilize at a uniform temperature and not to exceed the allowed temperature gradient of 5° C per hour.

These measurements shall be made with sufficient accuracy to determine the peak energy to within 0.2 PHA channels, the linearity to a level of better than 1%, and the energy resolution to within 0.2%.

Test No. and Name: **GBM-PROC-TP111, BGO High Energy Calibration**
Performed at: Duke University Free-Electron Laser facility
Purpose:
Summary: Determine the BGO detector linearity from 2 MeV to 35 MeV.

Author: Fishman/Lichti

Purpose: To test for non-linearity and saturation effects in a science model BGO crystal and PMT at high energy deposits and to determine the performance of the BGO detectors at energies higher than that achievable with radioactive sources. (These tests will not be used to verify the detector off-diagonal elements, since the calibration set-up will be very different from the flight configuration on the spacecraft.) In particular, non-linearities in BGO crystal light output and PMT response at high energies (but not high rates) shall be performed. These effects cannot be performed with radioactive sources alone, due to the unavailability of energies higher than ~2.6 MeV.

The determination of high-energy spectral measurements from GRBs is a scientific objective of the GBM, however, it is noted that spectral measurements above ~2 MeV from GRBs will be limited by counting statistics, rather than by energy calibration accuracy. Furthermore, the GBM detector response matrices (DRMs) will be developed the required accuracy at these high energies to the required resolution. These calibrations will be performed at least six months prior to launch on the flight spare BGO detector, so that test results may be included in the DRMs.

The Duke University Free-Electron Laser Facility (DFELF) will be used for the GBM High Energy Gamma-Ray Calibrations. That facility is being utilized for tests of the MPE Mega Project, over roughly the same energy range, ~2 to 35 MeV, as required for the GBM BGO detectors. To avoid GBM hardware and schedule risk, it is planned to use the GBM BGO Flight Spare Unit for the high energy gamma-ray calibrations. The tests shall be performed at the following energies: 2, 4, 8, 10, 12.5, 15, 17.5, 20, 25, 30, 35 MeV. At each energy, the peak channel, energy resolution shall be determined so that an overall linearity (or non-linearity) curve may be derived with an accuracy of 2%, or better.

Test No. and Name: GBM-PROC-TP115, BGO Detector Functional
Performed at: MPE, MSFC, S/C pre-integration
Purpose: Verify operation of PMT, preamps, and detector electronics.
Summary: The detector is powered up and receipt of background counts is verified. Preamp power is cycled by command. These tests will be made using background radiation or with radioactive sources (optional). (This procedure will be almost identical to PROC-TP-105, NaI Detector Functional.)

Requirements verified: None
Author: MPE
Use: This procedure will be used at various times during the integration and test flow at MPE, MSFC, and Spectrum Astro, as determined by the test flow and at other times, as specified by the P.I. or the GBM Systems Engineer.

Test No. and Name: GBM-PROC-TP120, Detector Magnetic Susceptibility
Performed at: MPE
Purpose: Measure change in gain due to magnetic field variations.
Summary: Detector is placed in a Helmholtz coil. Gain is measured at a range of applied magnetic field intensity, up to 1.5 gauss, and for various directions of the magnetic field with respect to the PMT axis.
Required for 3.3.3 analysis
Author: MPE

Procedure: Magnetic-Field Susceptibility

The effects of magnetic fields on three NaI and one BGO detectors shall be investigated at the detector level in three orthogonal directions and for field strengths from –2 G to + 2G in steps of no less than 0.5 G. The magnetic fields are to be generated with three Helmholtz coils perpendicular to each other. For this investigation a ^{22}Na source shall be used which shall be placed in the same geometrical arrangement as described in section 4.1. For each of these 25 measurements a pulse-height spectrum with sufficient counts so that the peak channel can be determined to within 0.2%.. The magnetic shielding shall shield the magnetic fields up to |2| G so effectively that the impact on the peak position is <1% and on the resolution <0.2%. The measurements shall be capable of measuring these changes.

Test No. and Name: GBM-PROC-TP121, Detector Gain vs. HV
Performed at: MPE, may be duplicated at NSSTC & Spectrum Astro
Required for Orbital Operations and Lifetime Assessment

The gain vs. PMT HV shall be measured for each PMT of each detector in order to provide a rough estimate of the total lifetime of the PMTs, as determined by the aging (reduced gain) expected with time, as observed from similar type PMTs in orbit. Using the peaks at 32 keV and 662 keV from ^{137}Cs, the peak position shall be determined as the high voltage is varied in increments of 50v over a range +/- 200 v. from the nominal setting. These measurements shall be made with sufficient accuracy to determine the peak energy to within 0.2 PHA channels.

Test No. and Name: GBM-PROC-TP605, System Linearity
Performed at: MSFC
Purpose: Verify that the detector electronics and DPU meet the requirement for linearity.
Summary: This test will use a combination of radioactive sources and a sliding pulser on the test input for the EQMs, and will use only radioactive sources for the flight detectors. The output channel linearity is recorded.
Requirements verified: 3.3.4.
Author: Wilson

Test No. and Name: **GBM-PROC-TP610,**
Performed at: MSFC
Purpose: Verify that GBM system meets the requirement for deadtime and gain stability at high rates.
Summary: Radioactive sources are used to subject the detectors to high individual rates and subject the DPU to high combined rates. The deadtimes and gain changes are measured as a function of rate.
Requirements verified: 3.4.2.2.2.
Author: Fishman

<u>High Rate Tests - Summary</u>:

1. Linearity Calibrations at High Count Rates Using a Pulse Generator
   The preamplifier (FEE) of each detector shall be calibrated via its test input for system linearity over the full operational amplitude range at different counting rates up to a count rate of 300,000 cts/s. At least 5 different amplitudes spread equally over the amplitude range shall be applied. The input pulses shall be generated randomly with a pulse generator. The effects of overload pulses on a recorded pulse-height spectrum up to an equivalent energy of 2 GeV shall also be tested via this test input.

2. Linearity Calibrations at High Count Rates Using Radioactive Sources
   The influence of the counting rate on the stability and linearity has to be tested for each detector by measuring the pulse-height spectrum of a line of a weak γ-ray source while a set of strong sources is moved on axis towards and away from the detector crystal (with this set of sources the shape of an average GRB shall be simulated). From the measured pulse-height spectrum of the weak source the peak position and the width of the distribution shall be determined as a function of the overall count rate up to a count rate of 100,000 counts/s starting at a counting rate of 10,000 cts/s with increments space approximately a factor of 1.5 apart. For the measurements with the NaI crystals an ^{55}Fe source and a ^{22}Na source and for the measurements with the BGO crystals an ^{88}Y source shall be used as the weak γ-ray source.

Detector Response Matrices (DRMs) – Generation Plan – In a Separate Document, Prepared by R.M. Kippen

Summary: Detector-Response Matrices (DRMs)

The DRM Generation Plan shall outline the steps leading to the generation of GBM DRMs in outline and block diagram form. Details of the generation are left to the discrimination of the GBM investigators. Note: These DRMs, while they play a critical role in the scientific data analysis, are not required for GBM detector performance verification.

A comprehensive set of detector-response matrices shall be developed for both detector types. These DRMs will be produced by Monte Carlo calculations using a high-fidelity radiation-transport code like GEANT 4 with a high-resolution mass model for the detectors and the entire spacecraft. The energy range of these calculations shall be from 5 keV to 40 MeV. Details of these calculations will provided in a separate plan, to be developed under the direction of Dr. R.M. Kippen/LANL, GBM Co-I. Data from the calibrations described herein will be used in the verification of these DRMs.

Test No. and Name: GBM-PROC-TP630, Short Energy Calibration
Performed at: MSFC, Performed at times indicated in the test flow and at other times requested by the P.I.; System-level test.
Purpose: Measure gains and verify that detector performance has not changed at selected times in the test flow.
Summary: One or two low intensity sources are positioned approximately 20cm in front of each detector. Resolution and gain are measured for the detectors. The sources and the accumulation times are left to the discretion of the P.I., Co-P.I., or the test conductor.
Requirements verified: none.
Author: Fishman

Test No. and Name: GBM-PROC-TP635, Long Energy Calibration
Performed at: MSFC, S/C pre and post integration; System-level test.
Purpose: Measure peak position and resolution of each detector over a wide range of energies so that a calibration curve can be obtained. Determine PMT gain coefficients.
Summary: About 6 to 10 low intensity radioactive sources are positioned 20cm in front of each detector. At least three values of HV are used (nominal, above nominal, and below nominal). Peak positions and resolution are measured. Gain vs. HV is determined.
Requirements verified: 3.1.1.3.
Author: Fishman

Test No. and Name: GBM-PROC-TP805, S/C Integration Source Survey
Performed at: S/C I&T, Following GBM integration on the spacecraft
Purpose: Purpose: To quantitatively determine the amount of scattered gamma radiation from spacecraft (and LAT) into the GBM detectors at various angles of incidence, including backside detector angles and at several discrete energies.

Summary: Several radioactive sources (2 to 10 mCi) will be positioned at various positions around the spacecraft over a period of about 4 days.
Requirements verified: none, but required for 3.3.5.

Author: Fishman

- **Test Procedures: This Element of the Cal. Plan is under development jointly by NSSTC & Spectrum Astro.**

Summary:

Two isotopes are to be used in this survey: ^{57}Co and ^{22}Na

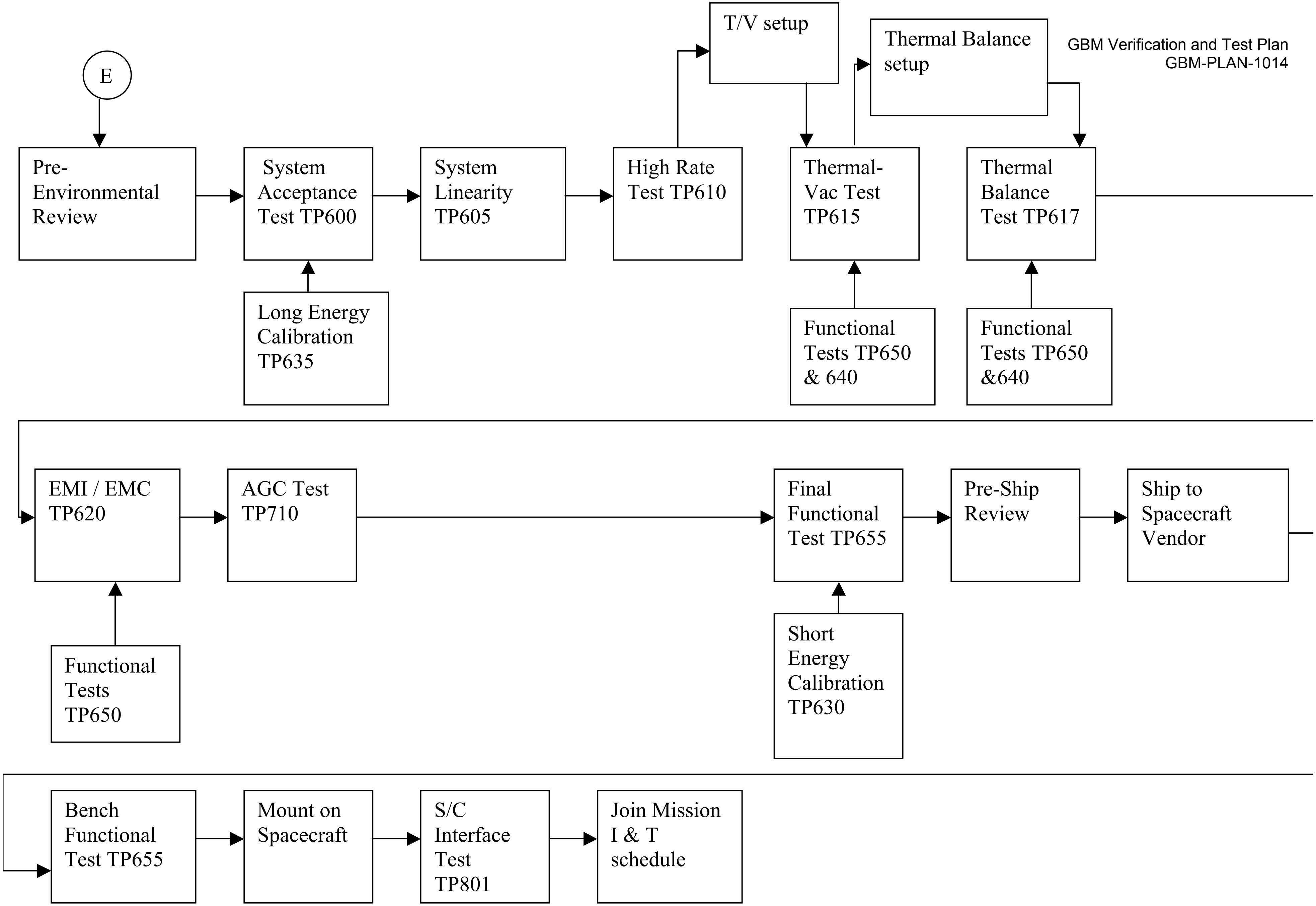
Radioactive source strength: ~10 milliCuries, each

Source handing and placement: To be performed by SpectrumAstro (or their sub-contractor.

Special precautions: Area roped-off with warning signs. Radiation training and use of film badges by test personnel handling the sources and near the spacecraft during the tests. (These sources are not harmful to humans or spacecraft components, but they should be handled only by trained personnel.)

Tests to be performed:

A. Measurement of the Channel-Energy Relation and of the Energy Resolution, for all detectors (As in Section I.A.)
B. Scattering tests: Spectra shall be accumulated for three sources at twelve positions around the spacecraft. Sufficient counts shall be accumulated so that the statistical errors are less than 2% at the peak energy and in scattered energy bands of width 50 keV or less.
C. Source locations: Sources shall be placed and collimated so that at least four detectors are illuminated at a distance of no less than 1.5 meters. Twelve different locations on one side of the spacecraft shall be used, spaced by at least 30 degrees from each other. The strong source shall be shielded by a thick Pb shield in a manner to minimize illumination of room materials other than the in the direction of the spacecraft.


E
Pre-Environmental Review
System Acceptance Test TP600
Long Energy Calibration TP635
System Linearity TP605
High Rate Test TP610
T/V setup
Thermal-Vac Test TP615
Functional Tests TP650 & 640
Thermal Balance setup
Thermal Balance Test TP617
Functional Tests TP650 &640
EMI / EMC TP620
Functional Tests TP650
AGC Test TP710
Final Functional Test TP655
Short Energy Calibration TP630
Pre-Ship Review
Ship to Spacecraft Vendor
Bench Functional Test TP655
Mount on Spacecraft
S/C Interface Test TP801
Join Mission I & T schedule