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Document Title **CAL Flight Module Vibration Test Procedure**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter Flight Module Vibration Test Procedure

DOCUMENT APPROVAL

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
01	12 August 2004	Initial Release

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1 INTRODUCTION

1.1 PURPOSE

This test procedure contains the requirements and procedures for the structural environment test of the Qualification Module (QM) and each Flight Modules (FM) of the GLAST Calorimeter (CAL) Module. The test results will be presented in a separate test reports upon completion of each test.

1.2 OBJECTIVE

The objective of this test is to verify the design and workmanship of the GLAST CAL Module FM in accordance with the Large Area Telescope (LAT) Program Instrument Performance Verification Plan, LAT-MD-00408. The design will be qualified by subjecting the QM to a protoflight test program. Workmanship of the subsequent FMs will be verified via an acceptance test program. Qualification and acceptance is accomplished by subjecting CAL Module to test levels that exceed the maximum expected launch and ascent dynamic environments. The fundamental frequency of the CAL Module will be verified by subjecting it to low-level random vibration. The environments are simulated by random vibration, sine vibration and sine-burst test.

1.3 OVERVIEW

Structural environment testing will be done at the Vibration Laboratory of the Naval Research Laboratory, Washington, D.C. It will consist of the standard technique of attaching the test article to either the slip table or vertical head expander and conducting a series of vibration tests of various levels and types. Overall responsibility will lie with the test director.

2 APPLICABLE SPECIFICATIONS

Documents required to perform this test will accompany the test article, including the As-Built Configuration List (ABCL) and traveler control sheets. The applicable documents cited in this standard are listed in this section only for reference. The specified technical requirements listed in the body of this document takes precedence over the source document is listed in this section.

2.1 GOVERNMENT SPECIFICATIONS

The following specifications, standards and handbooks form a part of this document to extent specified herein.

Number	Title
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components

2.2 NON-GOVERNMENT SPECIFICATIONS

Number	Title
LAT-MD-00408	LAT Program Instrument Performance Verification Plan
LAT-MD-01370	CAL Comprehensive and Limited Performance Test Definition
LAT-PS-04237	CAL Module Handling Procedure
LAT-SS-00788	LAT Environmental Specification
LAT-SS-01345	CAL Module Verification & Environmental Test Plan
LAT-TD-01888	CAL Module – Engineering Module (EM) Vibration Test Report
SAI-TM-2378	Pre-Test Analysis Report for CAL EM3 Module (11 Feb 2003)
N/A	Instrumentation Manuals

2.3 DRAWINGS

Number	Title
LAT-DS-00916	Calorimeter Module, GLAST

2.4 ORDER OF PREFERENCE

In the event of a conflict between this document and the technical guidelines cited in other documents referenced herein, the technical guidelines of this document would take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3 TEST DECRIPTION

3.1 TEST OBJECTIVE

The objective of this test is to qualify the design and workmanship of the GLAST CAL Module by verifying the fundamental frequency and subjecting it to test levels that exceed the maximum expected launch and ascent dynamic environments.

3.2 TEST METHODOLOGY

The structural environmental test is divided into four tests, which are performed on each of the three axes of the QM and FM: the transverse axes (X and Y) and the thrust axis (Z). The four test activities of the structural environmental test are:

- Frequency Survey – to subject the test article to a low-level random vibration environment to define a pre-test and post-test signature of the test article (QM and FM).
- Random Vibration Test – to subject the test article to the dynamic environment defined by the protoflight (QM) and acceptance (FM) random vibration acceleration spectral density.
- Sinusoidal Vibration Test - to subject the test article to the dynamic environment defined by the protoflight (QM) and acceptance (FM) sinusoidal vibration spectrum.
- Sine-Burst Test - to subject the test article to a protoflight static-equivalent acceleration level (QM)

The fundamental frequency of the test article will be verified by evaluating the frequency response function measured while subjecting the test article to a low-level random vibration environment. This activity will define the pre-test signature of the test article prior to subjecting it to the test environments. Review of the accelerometer data will determine locations with high response.

The next test in the test flow is the random vibration test. The random vibration test is also divided into three phases. The first phase is to subject the test article to the –12 dB of the full random vibration level to verify notching criteria. The second phase is to subject the test article to an intermediate random vibration level (–6 dB) and the third phase is to subject it to the full random vibration level. Notching of the vibration levels in the second and third phase will be done, if required.

Following random vibration test activities, the test article will be subjected to a sinusoidal vibration test following random vibration test activities. The first phase is to subject the test article to the –12 dB of the full sinusoidal vibration level to verify notching criteria. The second phase is to subject the test article to an intermediate vibration level (–6 dB) and the third phase is to subject it to the full sinusoidal vibration level. Notching of the vibration levels will be done, if required.

Only the QM test article will be subjected to a protoflight static-equivalent acceleration level by means of a sine-burst test.

A final low-level random vibration run following the sine-burst test (for QM) or the sinusoidal vibration test (for FM) defines the post-test low-level signature of the test article. Comparison of the frequency response functions before and after this test will determine if there is any structural change to the test article.

A Comprehensive Performance Functional Test (LAT-MD-01370) of the test article will conclude the test. Results of the CPT will be compared to the reference CPT conducted prior to entry of the CAL Tower Module into the environmental test program.

3.3 TEST ARTICLE DESCRIPTION

The test article is the GLAST CAL Tower Module as documented in the as-built configuration list (ABCL). The Tower Module consists of the CAL Module (LAT-DS-00916) with the Tower Electronics Module/Power Supply (TEM/TPS) Assembly (LAT-DS-00995) attached to the CAL Module base plate by means of four rigid stand-offs. The total weight of this unit is approximately 230 lbs.

There are no deviations from the flight configuration with the exception of:

- A Mass Simulator representing the proper mass (27.56 lbs) and centers of gravity (5.23 in from the CAL-Grid interface) of the SIU electronics box attached to the TEM/TPS Assembly. It attaches to the TEM/TPS Assembly using the same TPS-SIU bolted interface.
- Electrical Harness from the TPS is removed.
- The TEM/TPS Assembly is version EM2, rather than Flight.

The GLAST CAL Module in flight configuration is shown in Figure 3-1.

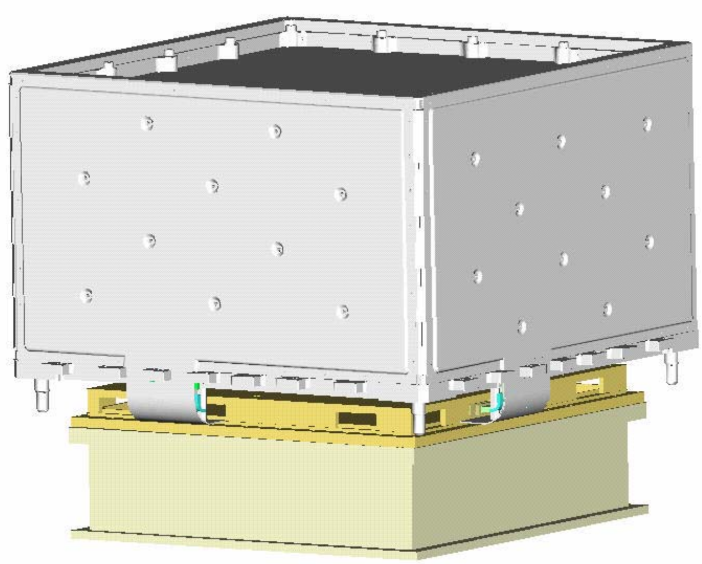


Figure 3-1: CAL FM in Flight Configuration with TEM/TPS

4 TEST RESPONSIBILITIES

4.1 TEST PERSONNEL

Test personnel are defined below. Responsible points of contact for this test procedure are listed in Table 4-1.

Table 4-1 – Test Personnel

Role	Name	Telephone Number
Project Representative	Eric Grove	202-767-3112
Test Director	Paul Dizon	202-404-7193
Test Conductor, Primary	Bob Haynes	202-767-0705
Test Conductor, Electrical Subsystem	Jim Ampe	202-404-1464
Test Conductor, Science Subsystem	Eric Grove	202-767-3112
Instrumentation/Data Support	Jim Layher	202-767-0705
Analysis Support	Jon Shaw	301-902-4260
	Jim Haughton	202-767-4689
	Chuck Williams	202-767-6696
Quality Assurance Support	Nick Virmani	301-902-4344

4.1.1 Project Representative

The Project Representative represents the GLAST project and will have the responsibility to ensure that no violations of project procedures or CAL handling procedures take place.

4.1.2 Test Director

The Test Director (TD) will have primary responsibility for directing test activities, maintaining the log, documenting the test schedules, coordination of resources, and preparation and close-out of all Problem Reports (PRs) and Non-Conformance Material Reports (NMRs). The TD will also have the primary responsibility for all data collection and evaluation during the test for the final test report. The TD will be responsible for coordinating the inputs from the Test Conductors and Quality Assurance representatives, developing the as-run test file, and for executing the as-run test approval sheet. This includes assuring that all PRs and NMRs have been properly prepared and correctly executed.

4.1.3 Test Conductor

The Test Conductor(s) will be responsible for a specific activity being conducted. The Primary Test Conductor will also be responsible for the entire laboratory, installation and check-out of instrumentation, data acquisition, and data reduction. The other TC(s) will be responsible for executing their specified test procedures. The TC(s) is also responsible for the preparation, operation of test equipment, and the scheduling of daily activities mentioned in the test procedure.

4.1.4 Support Personnel

Support Personnel are responsible for specific activities supporting installation of instrumentation, managing data, and providing real-time data analysis support.

4.2 CONFIGURATION VERIFICATION

Upon completion of the test setup, the Test Director, Test Conductor and Quality Assurance representative must inspect and approve the test configuration and test conditions, prior to the start of the testing and at any key phases of the test.

4.3 TEST DISCREPANCY RESOLUTION

In event of a test discrepancy, which indicates the potential of damage to equipment, a failure of the test article, or a failure of test equipment, testing will be stopped and the condition of the hardware and test setup preserved.

If a test discrepancy occurs, the test will be interrupted and the discrepancy verified. The Test Conductor and Test Director will determine which report (PR or NMR) needs to be prepared and executed. If a discrepancy is verified, a PR will be opened and dispositioned by the Test Director in accordance with LAT-SS-00971, CAL Program Quality Assurance Plan.

In conducting the failure analysis, the Test Director can select and re-run in any sequence, any portion of the full functional test within this procedure. Any test steps, conditions, or procedures that are not a portion of this approved test procedure that needs to be included must first be approved by the TD and QA and a PR generated before they are performed. The results are to be included or referenced in the PR and included in the as-run appendix.

If the discrepancy is dispositioned as a failure of the test article, then a NMR will be opened and dispositioned in accordance with LAT-SS-00971, CAL Program Quality Assurance Plan.

5 GENERAL TEST PROGRAM REQUIREMENTS

5.1 TEST SETUP

5.1.1 Test Location

The structural environmental test will be conducted in the Vibration Test Laboratory of the Payload Check-Out Facility, Building A-59, of the Naval Research Laboratory, Washington, D.C.

5.1.2 Test Article Configuration

The CAL Tower Module will be mounted in the upright position onto a two-piece vibration test fixture. The two-piece test fixture consists of a CAL base plate adapter and the primary fixture, which mounts directly to the slip table of the vibration table. An As-Built Configuration List (ABCL) will be generated for the test article in its test configuration.

5.1.3 Test Equipment

The following test equipment and systems will be used in the execution of this test:

- Test Article: GLAST CAL Tower Module (LAT-DS-04536) - (CAL Module, EM-2 TEM-TPS electronics box, SIU mass simulator)
- Test Article Support: CAL Vibration Test Fixture (LAT-DS-01314)
  CAL Vibration Test Fixture Interface Plates (LAT-DS-01518, LAT-DS-01519)
  CAL Lift Fixture Assembly (LAT-DS-04138)
- Accelerometers: Endevco Model TBD Piezoelectric Tri-Axial Accel
- Charge Amplifiers: Endevco Model 2775A Charge Amplifiers
  Unholtz Dickie Model D22 Charge Amplifiers
- Vibration Test System: GenRad Model 2550 Vibration Control System
  Ling Model 8096B Power Amplifier
  Ling Model SSW-1340-230s Switching Unit
- Data Acquisition System: Hewlett Packard VXI Data Analysis System
- CAL Electrical Ground Test Equipment

Any substitution of the designated test equipment will require the approval of the TD and/or the TC, and QA. Such substitutions will be noted as part of the test data and submitted with the test report.

The test fixture, as shown in Figure 5-1, supports the CAL Tower Module in the upright position. Since the CAL Tower Module must be removed from the test fixture each time the assembly is re-oriented for each axis test, the CAL Tower Module is attached to the test fixture via bolt-on interface plates, as shown in Figure 5-2. These plates are attached to the tabs of the CAL Module base plate. Because there are 56 fasteners connecting the CAL Tower Module to the interface plates, the bolt-on feature of the plates facilitates the re-orientation process. After the interface plates are installed onto the base plate of the CAL Module, the shear pins are secured via shear plates, as shown in Figure 5-3.

Based on pre-test analysis (SAI-TM-2378, CAL-EM Pre-test Analysis by Chia Chung Lee, 11 Feb 2003) the stiffness of this fixture has been tailored to filter the high frequency loads and effectively protect the CDE crystals.

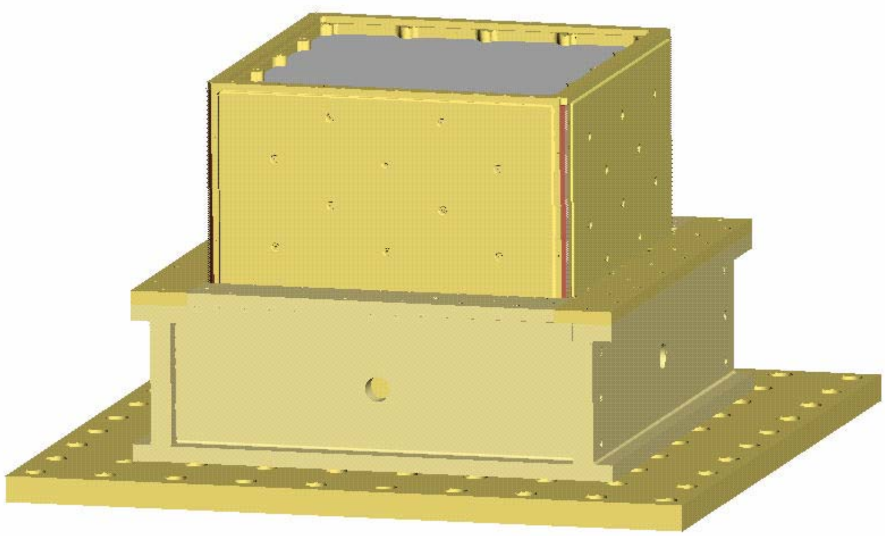


Figure 5-1: Test Fixture with FM CAL Module

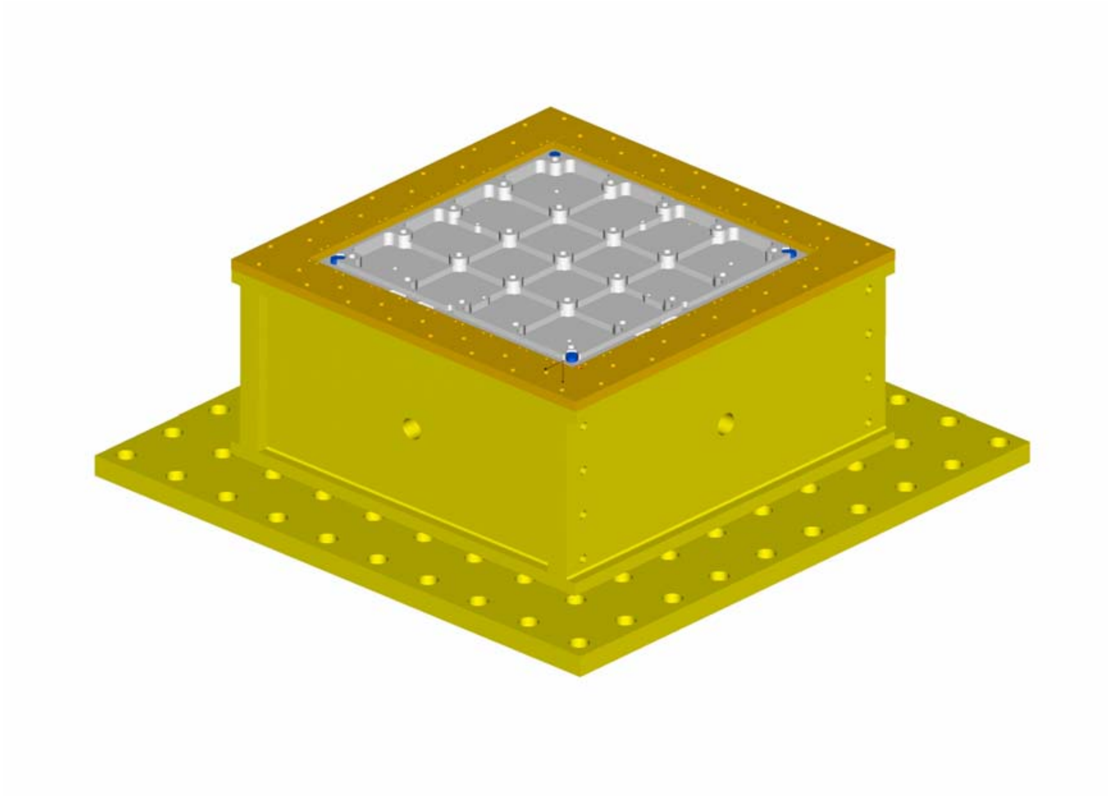


Figure 5-2: Test Fixture Showing Interface Plates

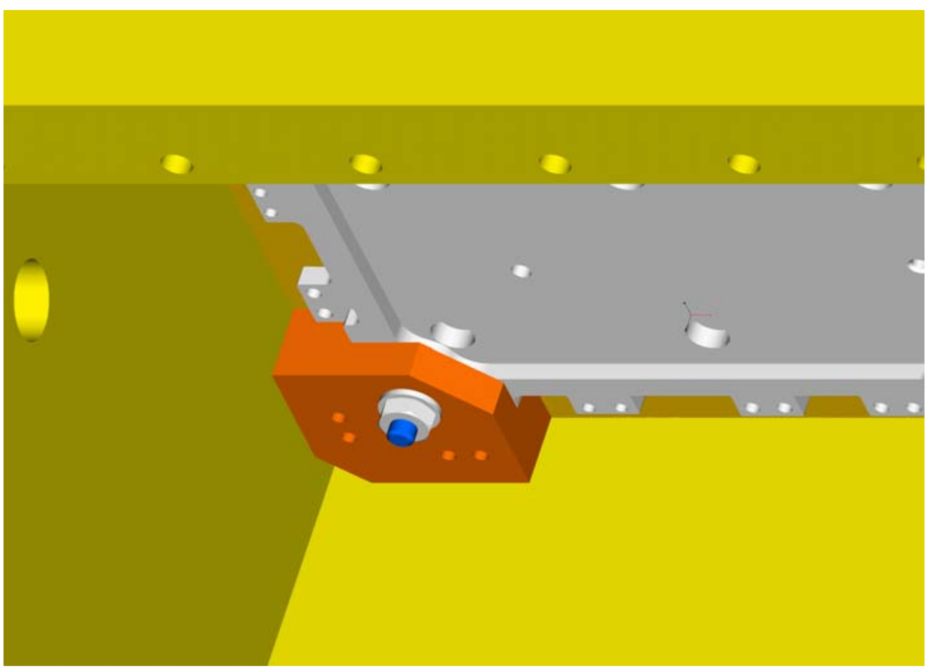


Figure 5-3: Test Fixture Showing Shear Plate Interface

5.1.4 Handling and Control of Equipment

Handling of the CAL Tower Module will be under the direction of the TD and/or TC. The following equipment must be used for the proper and safe handling of the CAL Tower Module:

- Proper FM Grounding Strap for Electrostatic Discharge (ESD) Control
- Grounding Wrist Straps for ESD Control
- Gloves

Unless directly connected to the GASU, the CAL Tower Module must be connected to a certified ground strap at all times. All personnel must wear gloves and ground straps when in contact with the CAL Tower Module.

The following equipment must be used for the proper and safe transportation of the CAL Tower Module:

- Shipping Container
- CAL Hoist Fixture Assembly

The CAL Tower Module is transported to and within the Vibration Facility inside its Shipping Container. The shipping container is wheeled and is also used as a transportation dolly. The CAL Tower Module will be moved and positioned on the shaker table via the facility crane. Interface between the CAL Tower Module and the crane is via the CAL Hoist Fixture Assembly.

5.2 INSTRUMENTATION AND DATA ACQUISITION

5.2.1 Instrumentation

Eight tri-axial accelerometers will be used to measure the acceleration response of the CAL Tower Module. These accelerometers are attached at points of interest or at points expected to have high acceleration response where notching may be necessary. Furthermore, six tri-axial accelerometers will be attached at each corner of the CAL Tower Module-test fixture interface plane and the vibration table for shaker control.

Table 5-1 lists the accelerometers that are to be used in this series of testing. All accelerometers are to be aligned with the CAL coordinate system shown in Figure 3-1. Accelerometer locations are illustrated in Figure 5-4.

Some of these accelerometer channels will have to be monitored during the random vibration testing of the CAL. The goal is to response limit components with known limitations such that random vibration levels do not exceed EM component test levels.

Random vibration levels at the base plate interface will be monitored by four tri-axial accelerometers (ID 09 – ID 12) located near four corners of the base plate. Two tri-axial accelerometers will be used for standard control at the shaker table (ID 13 – ID 14).

5.2.2 Calibration

Standard vibration laboratory calibration techniques will be used. Prior to testing, the accelerometers will be calibrated by comparison against a "Standard Accelerometer" traceable to the National Institute of Standards and Technology.

5.2.3 Data Acquisition

All data will be acquired through the VXI Data Acquisition System. The data will be stored on the HP VXI computer in digital format with a sampling rate appropriate for a 2000 Hz minimum bandwidth.

5.2.4 Data Reduction

Time history data will be stored and analyzed on the HP VXI using SDRC/IDEAS test software. Frequency response functions will be generated and stored. All data will be analyzed over the 10 to 2000 Hz frequency range. In addition, response power spectral densities and cumulative G_{rms} and Force RMS plots for each channel will be generated to monitor the response levels during testing. Finally, all data plots will contain test description, test date, and name and channel number.

Table 5-1 – Accelerometer Locations (QM)

Accelerometer ID	Channel ID	Location	Degree of Freedom
1	01X 01Y 01Z	-X Side Panel – Center	X Y Z
2	02X 02Y 02Z	-X Side Panel – Top	X Y Z
3	03X 03Y 03Z	-Y Side Panel – Center	X Y Z
4	04X 04Y 04Z	-Y Side Panel – Top	X Y Z
5	05X 05Y 05Z	+Z Structure	X Y Z
6	06X 06Y 06Z	+Z Top Frame	X Y Z
7	07X 07Y 07Z	Aft Surface of SIU Mass Simulator	X Y Z
8	08X 08Y 08Z	+X, +Y Interface Plate - Test Fixture	X Y Z
9	09X 09Y 09Z	+X,-Y Interface Plate - Test Fixture	X Y Z
10	10X 10Y 10Z	-X,+Y Interface Plate - Test Fixture	X Y Z
11	11X 11Y 11Z	-X,-Y Interface Plate - Test Fixture	X Y Z
12	12X, 12Y, or 12Z	Vibration Fixture (Control) - Top Corner	X, Y, or Z
13	13X, 13Y, or 13Z	Vibration Fixture (Control) - Top Corner	X, Y, or Z

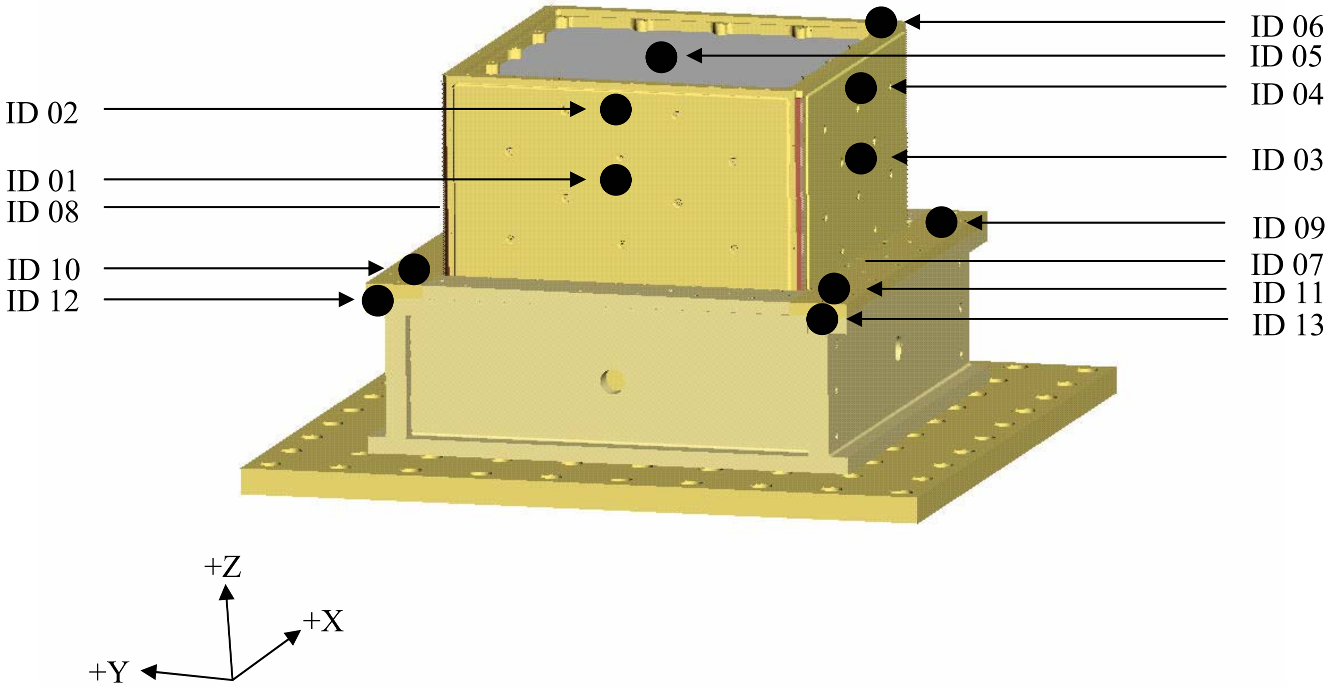


Figure 5-4: Accelerometer Locations (QM)

5.2.5 Test Log

The Test Conductor will maintain a test log of the daily activities during the test. The test log shall contain at a minimum the date and time of each test activity, a brief description of the activity, a description of any deviation from the planned procedure, and any other information known to be significant to the test, such as photographs. Furthermore, the Test Director shall maintain a master copy of the procedure. All deviations from the procedure shall be noted as “red lines” in this master copy.

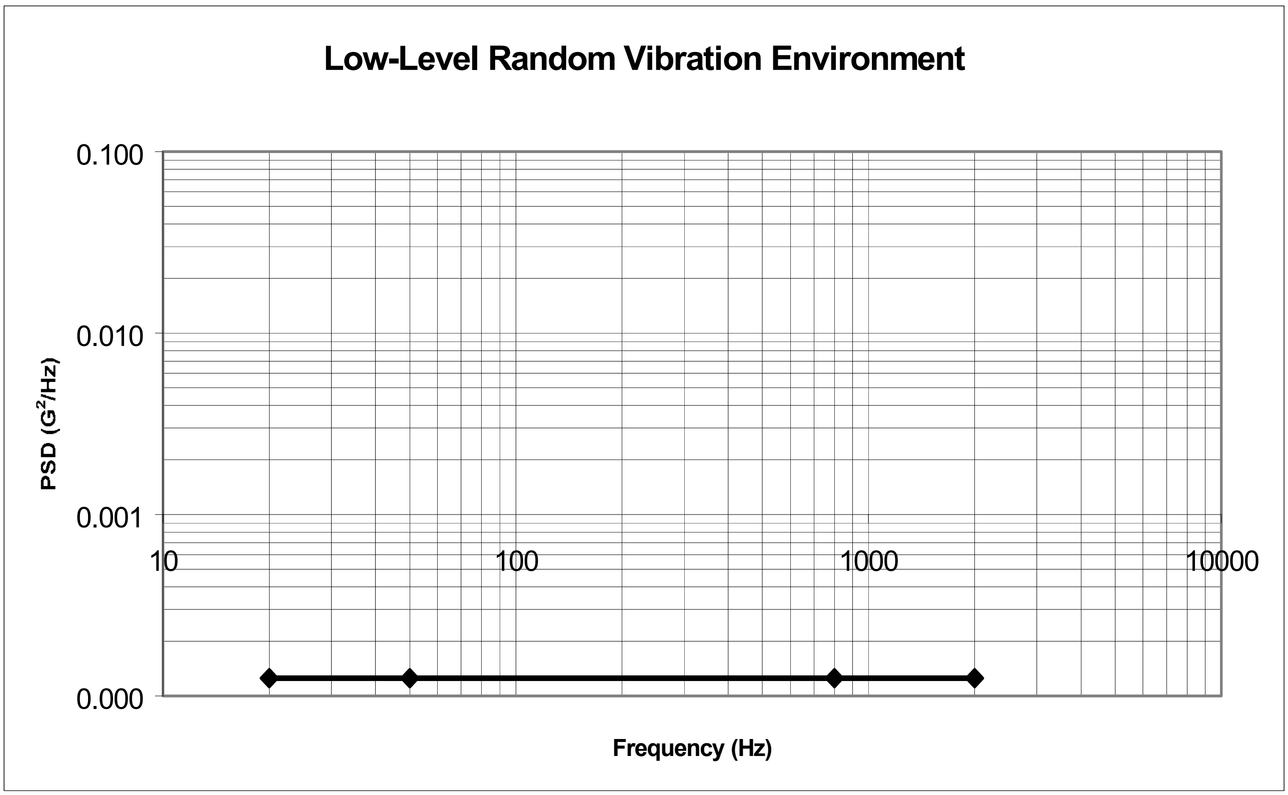
5.2.6 Test Report

The results of the test will be documented in a separate test report after completion of the testing. The report shall contain all test data, photographs, a complete description of the test and a description of any deviation from this procedure.

6 TEST LEVELS

6.1 LOW-LEVEL RANDOM VIBRATION FOR FREQUENCY SURVEY

All three axes of the CAL Tower Module will be independently subjected to low-level random vibration for frequency identification and system characterization before and after the test activities. Figure 6-1 contains the low-level random vibration spectrum to be used.



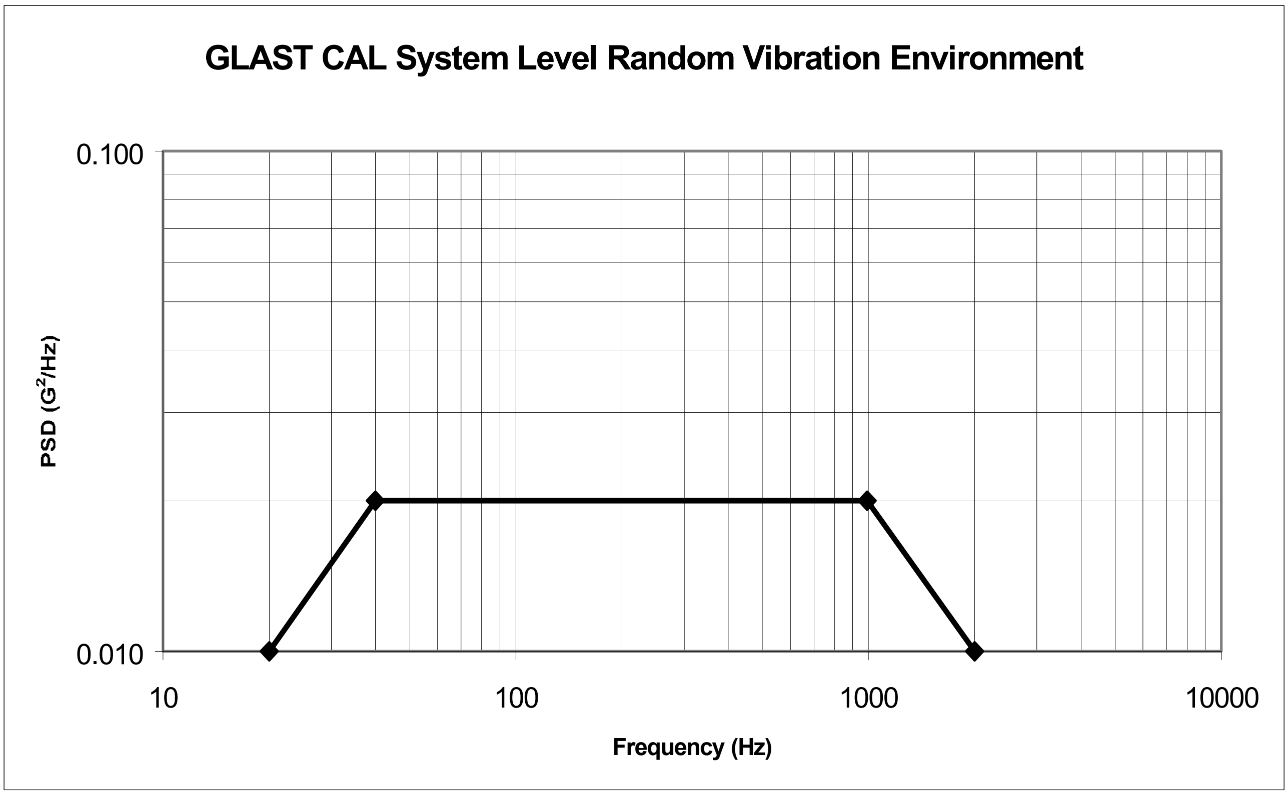
0.5 gRMS	
Frequency (Hz)	g^2/Hz
20	0.000125
50	0.000125
800	0.000125
2000	0.000125

Levels Apply to all Horizontal and Vertical Axes

Figure 6-1: Low-Level Random vibration Environment

6.2 RANDOM VIBRATION TEST LEVEL

Each axis of the CAL Tower Module will be independently subjected to the random vibration environment shown in Figure 6-2. The structure will be subjected to –12 dB and –6 dB random vibration levels preceding the full-level random vibration test. The spectrum may be tailored to keep primary structural and major component responses below the responses seen during the EM random vibration test.



Acceptance/Protoflight Levels 5.8 gRMS	
Frequency (Hz)	g^2/Hz
20	0.010
40	0.020
990	0.020
2000	0.010

Test Duration: 1 minute per axis

Levels Apply to all 3 Axes

Figure 6-2: GLAST CAL System Level Random Vibration Environment

6.3 SINUSOIDAL VIBRATION TEST LEVEL

All three axes of the CAL Tower Module will be independently subjected to the sinusoidal vibration environment shown in Table 6-1, which is specified in Table 21 of the LAT Environmental Specification, LAT-SS-00778. The structure will be subjected to –12 dB and –6 dB vibration levels preceding the full-level sinusoidal vibration test. The spectrum may be tailored to limit primary structural and major component responses.

Table 6-1: GLAST CAL System Level Sinusoidal Vibration Test Level

LAT CAL Acceptance Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	2 g	4
	25 - 35	4.72 g	4
	40 - 50	1.68 g	4
Lateral (X&Y)	5 - 15	2.16 g	4
	15 - 25	0.96 g	4
	25 - 35	0.96 g	4
	35 - 43	1.2 g	4
	43 - 50	1.52 g	4
LAT CAL Protoflight Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	2.5 g	4
	25 - 35	5.9 g	4
	40 - 50	2.1 g	4
Lateral (X&Y)	5 - 15	2.7 g	4
	15 - 25	1.2 g	4
	25 - 35	1.2 g	4
	35 - 43	1.5 g	4
	43 - 50	1.9 g	4

Notes: (1) Quarter and Half Level Tests will be performed before testing at full levels
(2) Input levels should be notched to that interface forces or response accelerations do not exceed flight loads predictions
(3) Linear acceleration transition from 2.5g's at 20 Hz to 5.9g's at 25 Hz.
(4) Linear acceleration transition from 5.9g's at 35 Hz to 2.0g's at 40 Hz.

6.4 SINE BURST TEST LEVEL

All three axes of the QM CAL Tower Module will be independently subjected to a static-equivalent qualification acceleration level using a sine-burst test level defined in Table 6-2, which is specified in Table 4 of the LAT Environmental Specification, LAT-SS-00778. Initial sine-burst runs at lower levels will precede the actual full-level sine-burst test. As these lower level runs are incrementally increased, response data will be reviewed.

Table 6-2: GLAST CAL System Sine Burst Test Level (QM Only)

Axis	Frequency	Acceleration	Cycles
X (Transverse)	25 Hz	± 7.5	5
Y (Transverse)	25 Hz	± 7.5	5
Z (Thrust)	25 Hz	± 8.5	5

The input levels shown in Table 6-2 may be modified, based upon review of response data from the sine-burst test at the –6 dB level.

6.5 LIMITING ACCELERATIONS

Notching criteria used for this test is based on test results from the CAL Module EM Vibration Test (LAT-TD-01888). Responses will be limited to prevent them from exceeded the responses observed during the EM test. Levels will be automatically controlled using response limiting. Accelerometers at the interface will also be monitored to prevent amplification due to the test fixture.

Expected notching criteria may change based on responses observed during the –6 db and –12 db vibration events. If so, any changes to the control and/or response limit levels would be verified prior to running at full level vibration.

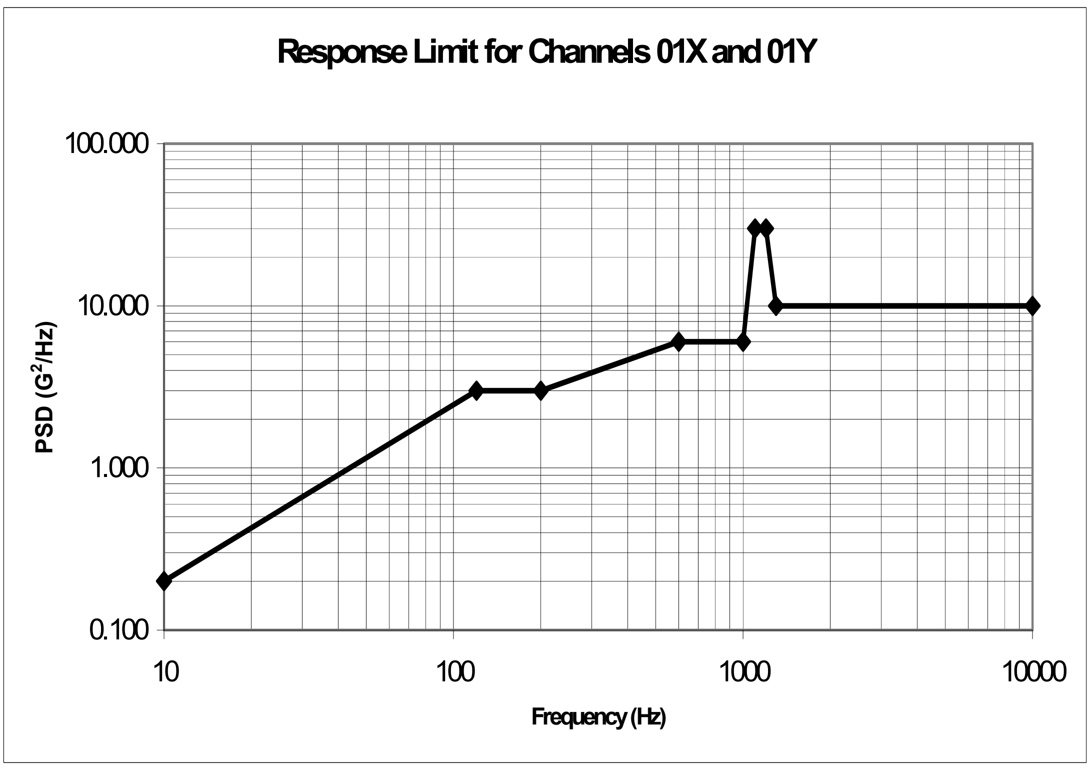


Figure 6-3: Response Limit for Channels 01X and 01Y

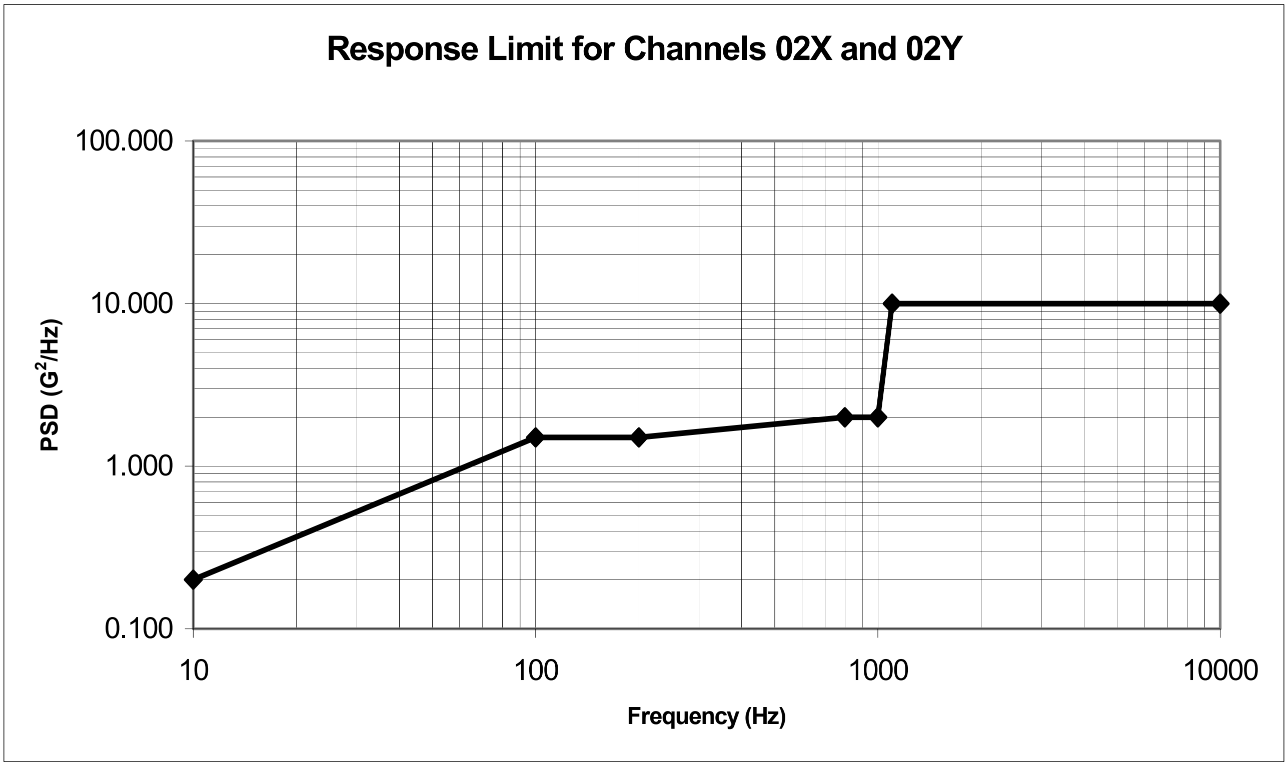


Figure 6-4: Response Limit for Channels 02X and 02Y

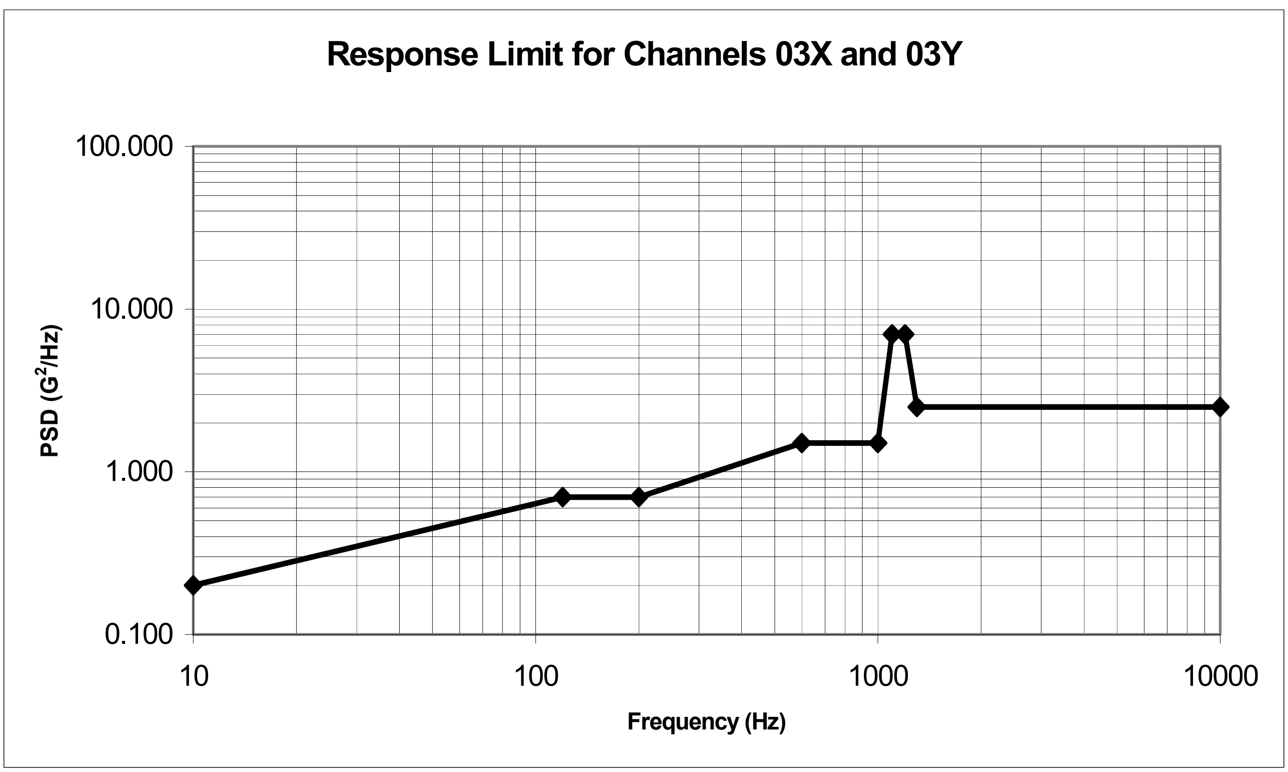


Figure 6-5: Response Limit for Channels 03X and 03Y

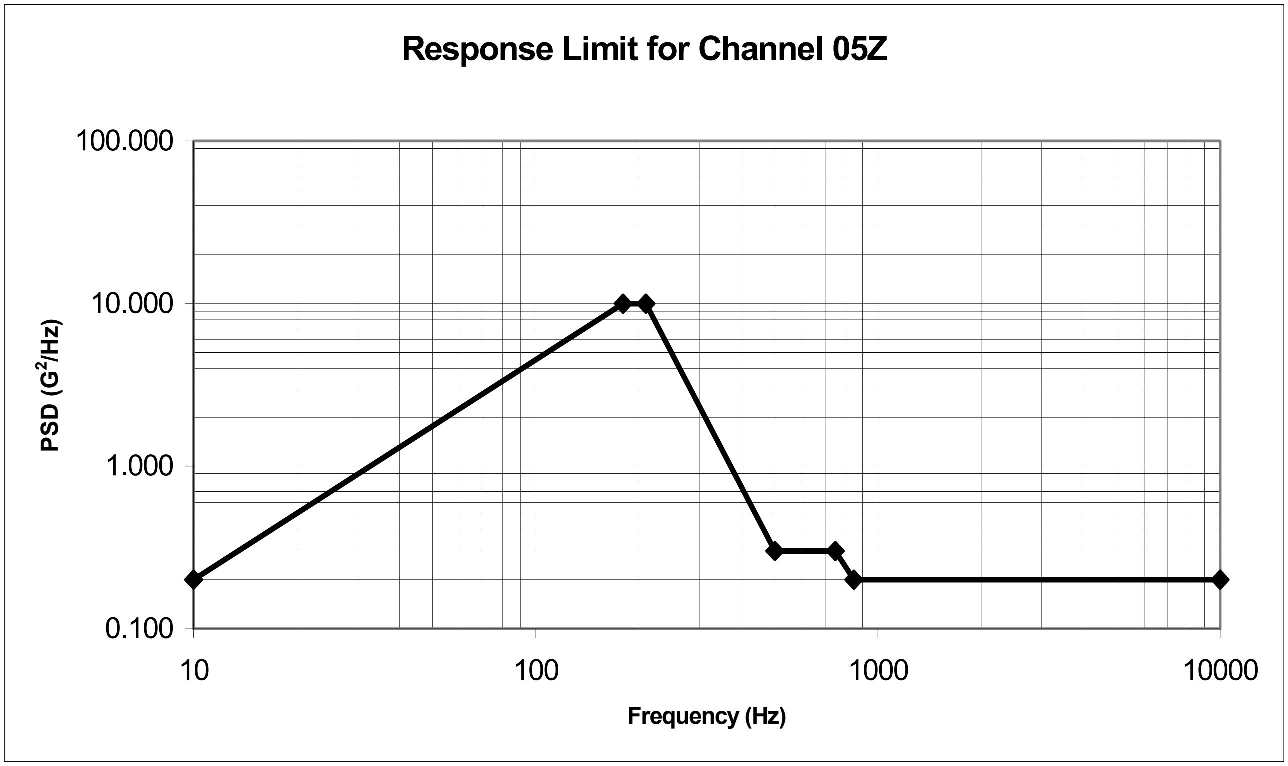


Figure 6-6 : Response Limit for Channel 05Z

7 TEST PROCEDURE

The test procedure is divided into several sections covering:

- Installation and characterization of the test fixture
- Handling and installation of the test article into the test fixture
- Environmental test flow for each axis
- Functional Performance Testing

7.1 INSTALLATION AND CHARACTERIZATION OF THE TEST FIXTURE

Prior to integrating the test article onto the test fixture, the test fixture will be characterized using the same structural environments, as described in Section 6. Ability of the shaker to control the table will be verified.

7.1.1 Installation of the Test Fixture onto the Shaker

Installation of the Test Fixture onto either the Slip Table or Expander Head uses the following procedure:

1. Attach the hoist rings to the Test Fixture
2. Attach the lift straps to the Test Fixture
3. Attach the free ends of the lift straps to the hook of the overhead crane
4. Using the overhead crane lift the Test Fixture and position it over the Slip Table (or Expander Head) of the Shaker.
5. Orient the Test Fixture into position and lower it onto the Shaker.
6. Remove lift straps from the hook of the overhead crane
7. Secure the Test Fixture onto the Slip Table (or Expander Head) with 5/16 in socket-head fasteners and tighten to 350 in-lb
8. Remove the lift straps and hoist rings from the Test Fixture

7.1.2 Test Fixture Structural Environment Test Flow

Subject the Test Fixture to the structural environments, as described in Section 6, to characterize the Test Fixture and verify the ability of the shaker to control the table.

Run #	Test Description	Frequency (Hz)	Test Level	Duration	Comments
1	Low-Level Random Vibration (Pre-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Identify modal frequency
2	Random Vibration (-12 dB, -6 dB)	Input: 20 Hz –2000 Hz	See Section 6.2	As Required for Data	Verify Notching Criteria
3	Random Vibration (Full Level)	Input: 20 Hz –2000 Hz	See Section 6.2	1 Minute (minimum)	Notch if Required
4	Sinusoidal Vibration (-12 dB, -6 dB)	Input: 5 Hz – 15 Hz, 15 Hz – 25 Hz, 25 Hz – 35 Hz, 35 Hz – 43 Hz, 45 Hz – 50 Hz	See Section 6.3		Verify Notching Criteria
5	Sinusoidal Vibration	Input: 5 Hz – 15 Hz, 15 Hz – 25 Hz, 25 Hz – 35 Hz, 35 Hz – 43 Hz, 45 Hz – 50 Hz	See Section 6.3		Notch if Required
6					
7					
8	Low-Level Random Vibration (Post-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Compare Pre and Post FRFs

7.2 HANDLING AND INSTALLATION OF THE TEST ARTICLE

The following handling procedures will be used when moving the test article to and from the test fixture, or when re-orienting the test article for test activities pertaining to a particular axis.

CAUTION – ESD PRECAUTIONS - CAUTION

Ensure that certified ground strap is connected to the test article at all times.

Wrist-strap must be connected to certified ground during all handling operations involving the test article

7.2.1 Installation of Test Article into the Test Fixture

1. Attach certified grounding strap to the CAL Tower Module.
2. Attach personal wrist strap to the CAL Tower Module
3. Remove the CAL Tower Module from the Shipping Container per LAT-PS-04237 and suspend it above the Container
4. Move the Shipping Container away from the suspended CAL Tower Module
5. Move a Work Table underneath the suspended CAL Tower Module
6. Lower the CAL Tower Module onto the table
7. Remove the protective covers from the tabs of the CAL Module base plate

   NOTE: Once the protective covers are removed from the tabs of the base plate, care must be taken to prevent damage to the mating surfaces of the tabs
8. Attach the Vibration Fixture Interface Plates (LAT-DS-01518, LAT-DS-01519) to the tabs of the CAL Module base plate using 6-32 and 8-32 socket-head cap screws. Tighten fasteners to specified torque values:
   - 6-32 Socket-Head Cap Screw 15-17 in-lb
   - 8-32 Socket-Head Cap Screw 28-31 in-lb
9. Lift the CAL Tower Module Assembly from the work table and suspend it high enough to remove the CAL Handling Fixture
10. Remove the four 5/16-18 socket head cap screws which secure the Handling Fixture Base Plate (LAT-DS-5952) to the Handling Fixture Posts (LAT-DS-01524)
11. Remove the Handling Fixture Posts from the shear pins of the CAL Module base plate.

12. Install the Shear Plate over each shear pin and secure to the interface plates with 8-32 socket-head cap screws. Tighten fasteners to 28-31 in-lb. This final assembly (CAL Tower Module with interface and shear plates) becomes the test article.
13. Install the SIU Mass Simulator onto the base of the TEM-TPS using 8-32 socket-head cap screws. Tighten fasteners to 28-31 in-lb.
14. Move the overhead crane to suspend the test article over the Vibration Test Fixture on the shaker.
15. Orient the test article so that its test axis is pointing in the test direction according to the particular test flow (Section 7.3) and lower into the Vibration Test Fixture
16. Secure the Interface Plates onto the Vibration Test Fixture using ¼-20 socket-head cap screws. Tighten fasteners to 112-124 in-lb.
17. Remove MJ4 socket-head cap screws securing the CAL Lifting Fixture Hoist Plate (LAT-DS-02795) to the top frame of the CAL Module.
18. Using the overhead crane, lift the CAL Lifting Fixture Assembly (LAT-DS-04138) from the test article.

7.2.2 Removal of the Test Article from the Test Fixture

1. Verify that certified grounding strap is connected to the CAL Tower Module.
2. Attach personal wrist strap to the CAL Tower Module
3. Using the overhead crane, position the CAL Lifting Fixture Assembly (LAT-DS-04138) over the test article and lower into place.
4. Attach the Lifting Fixture Assembly to the top frame of the CAL Module per LAT-PS-04237. Tighten the MJ4 socket-head cap screws to 34-35 in-lb
5. Remove the ¼-20 socket-head cap screws from the Vibration Test Fixture Interface Plates.
6. Lift the CAL test article from the test fixture per LAT-PS-04237.

7.2.3 Re-Orientation of the Test Article on the Test Fixture

1. Verify that certified grounding strap is connected to the CAL Tower Module
2. Attach personal wrist strap to the CAL Tower Module
3. Reorient the test article so that its test axis is pointing in the test direction according to the particular test flow (Section 7.3) and lower into the Vibration Test Fixture
4. Secure the Interface Plates onto the Vibration Test Fixture using ¼-20 socket-head cap screws. Tighten fasteners to 112-124 in-lb.
5. Remove MJ4 socket-head cap screws securing the CAL Lifting Fixture Hoist Plate (LAT-DS-02795) to the top frame of the CAL Module.
6. Using the overhead crane, lift the CAL Lifting Fixture Assembly (LAT-DS-04138) from the test article.

7.3 STRUCTURAL ENVIRONMENT TEST FLOW

Each axis of the test article will be characterized using the structural environments, described in Section 6, according to the test flow shown in Section 7.3.1 through Section 7.3.3.

At the conclusion of the environmental test flow for each axis, the functionality of the CAL Tower Module is verified in accordance with Section 7.4 of this procedure.

7.3.1 X-Axis Structural Environment Test Flow

Run #	Test Description	Frequency (Hz)	Test Level	Duration	Comments
1	Low-Level Random Vibration (Pre-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Identify modal frequency
2	Random Vibration (-12 dB, -6 dB)	Input: 20 Hz –2000 Hz	See Section 6.2	As Required for Data	Verify Notching Criteria
3	Random Vibration (Full Level)	Input: 20 Hz –2000 Hz	See Section 6.2	1 Minute (minimum)	Notch if Required
4	Sinusoidal Vibration (-12 dB, -6 dB)	Input: 5 Hz – 15 Hz, 15 Hz – 25 Hz, 25 Hz – 35 Hz, 35 Hz – 43 Hz, 43 Hz – 50 Hz	See Section 6.3		Verify Notching Criteria
5	Sinusoidal Vibration (Full Level)	Input: 5 Hz – 15 Hz, 15 Hz – 25 Hz, 25 Hz – 35 Hz, 35 Hz – 43 Hz, 43 Hz – 50 Hz	See Section 6.3		Notch if Required
6	Sine-Burst (-12 dB, -6 dB)	Input:, 25 Hz	See Section 6.4	5 Cycles	N/A
7	Sine-Burst (Full Level)	Input: ±7.5 gpk, 25 Hz	See Section 6.4	5 Cycles	N/A

Run #	Test Description	Frequency (Hz)	Test Level	Duration	Comments
8	Low-Level Random Vibration (Post-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Compare Pre and Post FRFs
9	CAL Functional Testing LAT-MD-01370	N/A	N/A	N/A	In Accordance with Section 7.4

NOTE: Run 1 and 8: Maximum allowable frequency shift between the pre- and post-test measurement of the fundamental frequency must be within 10%.

Run 6 and 7: Sine-Burst Test Required for QM test article only

7.3.2 Y-Axis Structural Environment Test Flow

Run #	Test Description	Frequency (Hz)	Test Level	Duration	Comments
1	Low-Level Random Vibration (Pre-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Identify modal frequency
2	Random Vibration (-12 dB, -6 dB)	Input: 20 Hz –2000 Hz	See Section 6.2	As Required for Data	Verify Notching Criteria
3	Random Vibration (Full Level)	Input: 20 Hz –2000 Hz	See Section 6.2	1 Minute (minimum)	Notch if Required
4	Sinusoidal Vibration (-12 dB, -6 dB)	Input: 5 Hz – 15 Hz, 15 Hz – 25 Hz, 25 Hz – 35 Hz, 35 Hz – 43 Hz, 45 Hz – 50 Hz	See Section 6.3		Verify Notching Criteria
5	Sinusoidal Vibration (Full Level)	Input: 5 Hz – 15 Hz, 15 Hz – 25 Hz, 25 Hz – 35 Hz, 35 Hz – 43 Hz, 45 Hz – 50 Hz	See Section 6.3		Notch if Required
6	Sine-Burst (-12 dB, -6 dB)	Input:, 25 Hz	See Section 6.4	5 Cycles	N/A
7	Sine-Burst (Full Level)	Input: $\pm$7.5 gpk, 25 Hz	See Section 6.4	5 Cycles	N/A
8	Low-Level Random Vibration (Post-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Compare Pre and Post FRFs
9	CAL Functional Testing LAT-MD-01370	N/A	N/A	N/A	In Accordance with Section 7.4

<u>NOTE</u>: Run 1 and 8: Maximum allowable frequency shift between the pre- and post-test measurement of the fundamental frequency must be within 10%.

Run 6 and 7: Sine-Burst Test Required for QM test article only

7.3.3 Z-Axis Structural Environment Test Flow

Run #	Test Description	Frequency (Hz)	Test Level	Duration	Comments
1	Low-Level Random Vibration (Pre-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Identify modal frequency
2	Random Vibration (-12 dB, -6 dB)	Input: 20 Hz –2000 Hz	See Section 6.2	As Required for Data	Verify Notching Criteria
3	Random Vibration (Full Level)	Input: 20 Hz –2000 Hz	See Section 6.2	1 Minute (minimum)	Notch if Required
4	Sinusoidal Vibration (-12 dB, -6 dB)	Input: 5 Hz – 20 Hz, 25 Hz – 35 Hz, 40 Hz – 50	See Section 6.3		Verify Notching Criteria
5	Sinusoidal Vibration (Full Level)	Input: 5 Hz – 20 Hz, 25 Hz – 35 Hz, 40 Hz – 50	See Section 6.3		Notch if Required
6	Sine-Burst (-12 dB, -6 dB)	Input:, 25 Hz	See Section 6.4	5 Cycles	N/A
7	Sine-Burst (Full Level)	Input: ±8.5 gpk, 25 Hz	See Section 6.4	5 Cycles	N/A
8	Low-Level Random Vibration (Post-Test Signature)	Input: 0.5, gRMS 20 Hz -2000 Hz	See Section 6.1	As Required for Data	Compare Pre and Post FRFs
9	CAL Functional Testing LAT-MD-01370	N/A	N/A	N/A	In Accordance with Section 7.4

<u>NOTE</u>: Run 1 and 8: Maximum allowable frequency shift between the pre- and post-test measurement of the fundamental frequency must be within 10%.

Run 6 and 7: Sine-Burst Test Required for QM test article only

7.4 FUNCTIONAL PERFORMANCE TESTING

At the conclusion of the environmental test flow for each axis, the following procedure will be performed to verify that the AFEE and CDEs of the CAL Module are still functional.

1. Verify that certified grounding strap is connected to the CAL Tower Module
2. Attach personal wrist strap to the CAL Tower Module
3. Remove the test article from the vibration test fixture using the procedure outlined in Section 7.3.2
4. Using the overhead crane, lift and suspend the test article above the Vibration Test Fixture.
5. Install the test article into the Shipping Container per LAT-PS-04237.
6. Disconnect the certified grounding strap from the CAL Tower Module
7. Start performance testing and muon collection in accordance with LAT-MD-01370, *CAL Comprehensive and Limited Performance Test Definition.* The Limited Performance Test (LPT) shall be performed, with the muon collection included in the LPT extended to one hour of accumulation time. This LPT establishes that proper communication between TEM and CAL exist, that all registers of the CAL function properly, that pedestal amplitude and noise in all four energy ranges remain stable, and that the optical performance of each CDE remains stable.

8 PASS/FAIL CRITERIA

The GLAST CAL Module will have passed this series of testing if the following criteria are met:

- The proper test levels are applied in accordance with this procedure.
- The GLAST CAL Module incurs no detrimental damage.
  - Pre and Post FRFs indicate no significant changes in dynamic response (less than 10% frequency shift).
  - Visual inspections show no physical damage.
- Acquisition of data is recorded and suitable for correlation with the FEA models
- Successful LPT functional testing of the AFEE and TEM electronics in accordance with LAT-MD-01370, *CAL Comprehensive and Limited Performance Test Definition,* following the structural environmental test flow for each axis. “Successful” is defined to be “no change in pass/fail status.”
- Successful CPT functional testing of the AFEE and TEM electronics in accordance with LAT-MD-01370 at the conclusion of the vibration test program. “Successful” is defined to be “no change in pass/fail status.”