LAT PROJECT DOCUMENT CHANGE NOTICE (DCN)

DCN No. LAT-XR-05650-01

SHEET 1 **OF** 1

ORIGINATOR: M Opie	**PHONE:** 650-926-2827	**DATE:** 1/21/05
CHANGE TITLE: DCN for LAT-PS-05648		**ORG.:**

DOCUMENT NUMBER	TITLE	NEW REV.
LAT-TD-05649	TEM/TPS Qualification/Acceptance Vibration Test Procedure	1

CHANGE DESCRIPTION (FROM/TO):
Initial release

REASON FOR CHANGE:

ACTION TAKEN: ☒ **Change(s) included in new release** ☐ **DCN attached to document(s), changes to be included in next revision**
☐ **Other (specify):**

DISPOSITION OF HARDWARE (IDENTIFY SERIAL NUMBERS):	**DCN DISTRIBUTION:**
☒ **No hardware affected (record change only)**	
☐ **List S/Ns which comply already:**	
☐ **List S/Ns to be reworked or scrapped:**	
☐ **List S/Ns to be built with this change:**	
☐ **List S/Ns to be retested per this change:**	
☐	

SAFETY, COST, SCHEDULE, REQUIREMENTS IMPACT? ☐ **YES** ☒ **NO**
If yes, CCB approval is required. Enter change request number:

APPROVALS	DATE	OTHER APPROVALS (specify):	DATE
ORIGINATOR: M Opie (signature on file)	1/21/05		
ORG. MANAGER: G Haller (signature on file)	1/24/05		
PSA- D. Marsh (signature on file)	1/24/05		
Lead- Dave Tarkington (signature on file)	1/21/05		
DCC RELEASE: Natalie Cramar (signature on file)	1/24/05	Doc. Control Level: ☒ Subsystem ☐ LAT IPO ☐ GLAST Project	

	Document #	Date Effective
	**LAT-TD-05649**	January 24, 2005
	Author(s) M. Opie J. Ku D. Tarkington	Supersedes
	Subsystem/Office	
Document Title **TEM/TPS – Qualification/Acceptance Vibration Test Procedure**		

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes

Gamma-Ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

TEM/TPS Qualification/Acceptance Vibration Test Procedure

TABLE OF CONTENTS

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1. PURPOSE

This document describes the test procedure for the vibration test of the TEM/TPS at Wyle Labs in Santa Clara.

2. SCOPE

The goal of the dynamic tests is to demonstrate that the hardware is acceptable for flight. This is accomplished by testing the TEM/TPS to qualification and acceptance levels. The fundamental frequency of the TEM/TPS will be verified by subjecting it to low level signature sweep test. The dynamic environments are simulated by sinusoidal vibration and random vibration. The response under dynamic excitation will be studied separately along the thrust and lateral directions.

A complete functional test will be performed before and after the vibration test sequence in order to verify the electrical integrity and optimum functionality after the dynamic loading.

3. ACRONYMS

AIT	Assembly Integration and Test
ASD	Acceleration Spectral Density
GLAST	Gamma-ray Large Area Space Telescope
LAT	Large Area Telescope
TBR	To be resolved
TBD	To be determined

4. APPLICABLE DOCUMENTS

Documents relevant to the development of this plan include:

[1] GEVS- General Environmental Verification Specification for STS & ELV, NASA GSFC

[2] GSFC 433-IRD-0001 Rev B, "GLAST Science Instrument – Spacecraft Interface Requirements Document" dated 4/24/02, Through change notice CH-11, issued 10/24/03

[3] 433-MAR-0001, Mission Assurance Requirements for the Large Area Telescope, Rev. A, 8 April 2003

[4] LAT-MD-00039-01, "Performance Assurance Implementation Plan".

[5] LAT-MD-00078-02, "Performance and Safety Assurance".

[6] LAT-MD-00091-01, "GLAST LAT Quality Manual".

[7] LAT-MD-00404-03, "LAT Contamination Control Plan".

[8] LAT-SS-00778-03, LAT Environmental Specifications by GLAST Design Engineering, System Engineering 7 Apr 2003

[9] LAT-DS-05651, "Vibration Fixture TEM/TPS".

5. TEST SUPPORT REQUIREMENTS

The vibration tests will be performed at Wyle Labs.

5.1. Environment

Unless otherwise specified, all tests required by this procedure shall be performed under the following conditions:

a) Temperature: 20 +/-5 C

b) Relative Humidity: 30 to 60 %

c) Atmospheric Pressure: 710 to 815mm Hg

5.2. Equipment

The test equipment that shall be used for vibration testing is listed in Section 7.3, Test Equipment. Equivalent equipment may be substituted if accuracy and effectiveness are not

decreased. The Quality Assurance and Test Engineering Representatives shall be informed of any such substitutions, and substitutions shall be recorded in the test log book.

5.3. Quality Assurance

Quality Assurance shall be in accordance with MAR [3] and PAIP [4]. Test Engineering shall notify QA a minimum of 24 hours prior to the planned start of testing. QA will maintain surveillance of the tests required by this procedure. After satisfactory completion of equipment inspection, test setup verification, and review of documentation, QA shall release the equipment to start testing by inspection stamping the shop order and the test data cover sheet. Major redlines/blacklines shall be documented on a NCR with MRB disposition. Prior to any test configuration breaks, interim MRB dispositions shall approve the redlines.

5.4. Safety

All testing shall be conducted so as to comply with the requirements of PSA [5].

5.4.1. Personnel Safety

People performing the test are not allowed to enter the vibration room while the shake table is operating. If necessary, only people authorized by the Facility Responsible can enter the vibration area wearing protective equipment following the Wyle internal safety procedures.

5.4.2. Hardware Safety

At the direction of the Responsible Engineer, testing may be halted at any time during the conduct of this procedure. Suspension of the test may result from failure or damage to the test specimen, failure of the test equipment, or insufficient resources in manpower and/or equipment to safely support the test. The circumstances of the suspension and further disposition of the test shall be documented.

5.5. Certifications

6. TEST PERFORMANCE REQUIREMENTS

6.1. Test Readiness Conditions

Prior to the performance of the tests the following conditions shall be verified.

a) readiness of the test article,

b) adequacy of the facility (contamination control, temperature and humidity, safety requirements)

c) calibration of the test equipment (fixture, controller, acquisition system, accelerometers)

d) procedures verification

6.2. Support Personnel Requirements

The tests will be attended by specialized personnel from SLAC. All the personnel involved in the execution of the test shall adequately follow the appropriate procedures listing the mounting stages of the TEM/TPS assembly on the shaker.

6.3. Test Personnel and Description

Test team member substitutions are permitted but should be noted in the test log.

The test team members are defined with the following responsibilities:

Role	Name	Institution/Company
Responsible Engineer	Dave Tarkington	SLAC
Test Engineer	Michael Opie	SLAC
Quality Assurance	Joe Cullinan	SLAC

Table 1 - Test Personnel

Responsible Engineer (RE): Responsible for planning, scheduling, and coordinating all resources and organizations to accomplish the test. He shall verify test set-up and execution conforms to all the applicable test plans and procedures. The RE is responsible for test procedure changes or revisions as a result of errors and omissions discovered during testing. The RE shall oversee completion of a final test report.

Test Engineer (TE): shall verify levels, review data, and declare load case completion and overall test success.

Quality Assurance (QA): is responsible for reviewing and approving test procedures, approving red line and black line changes to the procedures, verifying the test is being run according to approved procedures, and signing the data packages. QA shall witness vibration testing of each TTM/TPS at Wyle and review/approve EIDP for each test. Shall witness torque of TEM/TPS to the test fixture. Shall verify accelerometer locations on TEM/TPS and fixture per test procedure. Shall perform visual receiving inspection and acceptance of TEM/TPS when received from General Techonlogies (pre-vibe) and when received from Wyle (post-vibe).

7. TEST CONFIGURATION & SET-UP

7.1. Test Article

The test assembly will consist of the following hardware:

a) TEM/TPS Assembly (Drawing No. Multi). The TEM/TPS will be tested fixed base with spacers and no constraint on the outboard side.

b) Interface Spacers - Stiff spacers will be used between the TEM/TPS and Vibration fixture to ensure vibrational energy is introduced through the correct load path. The dimensions of the spacers are: ID=0.258 in, OD=0.500 in, Length=0.375 in. Material=304 SS. The bolt is a M6x30, class 12.9 steel socket head cap screw. With a material yield strength of 160 ksi (1100 MPa), the required installation torque for 65% of yield is 167 in-lbs.

c) Vibration Fixture - A vibration fixture will be used as an adapter between the vibration exciter and the TEM/TPS interface hole pattern. The vibration fixture is described in [9]. The vibration test fixture shall be bolted to the shaker head or slip plate by 3/8 in bolts torqued to 25 ft-lbs (300 in-lbs).

7.2. Coordinate system

The TEM/TPS shall be assigned a local coordinate system to orient the test axis and the measured responses. A right handed Cartesian coordinate system shall be established as shown in the Figure 1 below.

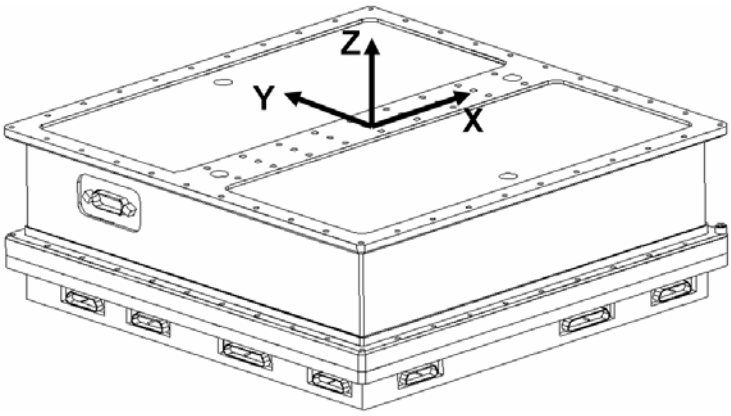

Figure 1 - TEM/TPS Test Coordinate System

7.3. Test equipment

Equivalent equipment may be substituted if accuracy and effectiveness are not decreased. The Quality Assurance and Test Engineering Representatives shall be informed of any such substitutions, and substitutions shall be recorded in the test log book.

The hardware and equipment that will be used for the dynamic test on the TEM/TPS are listed below:

- Exciter / Table: LDS V994 and LDS V984
- Control Acquisition system: LMS 64 channels
- Signal conditioners: ICP signal conditioner 584 (PCB)
- Measurement Accelerometers: uni-axial ICP 10 mV/g (PCB)
- Control accelerometers: uni-axial ICP 10 mV/g (PCB), 5 grams weight.

7.4. Accelerometer set-up

Accelerometer numbers, locations, and mounting axes are summarized in Table 2. The locations for these accelerometers are shown in Figures 2 through 5. Accelerometers are to be installed on mounting blocks or directly on a protective Kapton layer using L.D. Caulk (dental cement). In addition, accelerometers will be mounted on the vibration fixture to control the input.

7.4.1. Control Accelerometers

The fixture will be instrumented with one control accelerometer as shown in the figures 2, 4, and 5 below. When the acquisition system records a value exceeding the abort level, the test is automatically paused. The test conductor can allow only manually the continuation of the test or its termination.

7.4.2. Measurement Accelerometers

Uni-axial accelerometers (ICP 10mV/g) will be used to monitor the response to the input excitation. They will measure the amplitude and the relative angular phase with respect to the first channel of the control accelerometers.
The vibration level may be notched to a level determined by the output from the accelerometers to avoid exceeding the structural design loads of the test article.

Accel. #	Location	Axis
CZ1	Z Axis Control	+Z
AZ1	TPS Edge Center	+Z
AZ2	TPS Corner	+Z
AZ3	TPS Boss 1 (-X, -Y)	+Z
AZ4	TPS Boss 2 (+X, +Y)	+Z
AZ5	TEM Bottom Edge (at stand-off)	-Z
AZ6	TEM Bottom Center	-Z
CX1	X Axis Control	-X
AX1	TEM Edge Center	-X
AX2	TPS CG	-X
AX3	TPS Top Center	-X
AX4	TPS Top Edge	-X
CY1	Y Axis Control	-Y
AY1	TEM Edge Center	-Y
AY2	TPS CG	-Y
AY3	TPS Top Center	-Y
AY4	TPS Top Edge	-Y

Table 2 - Accelerometer Numbers and Locations on the TEM/TPS

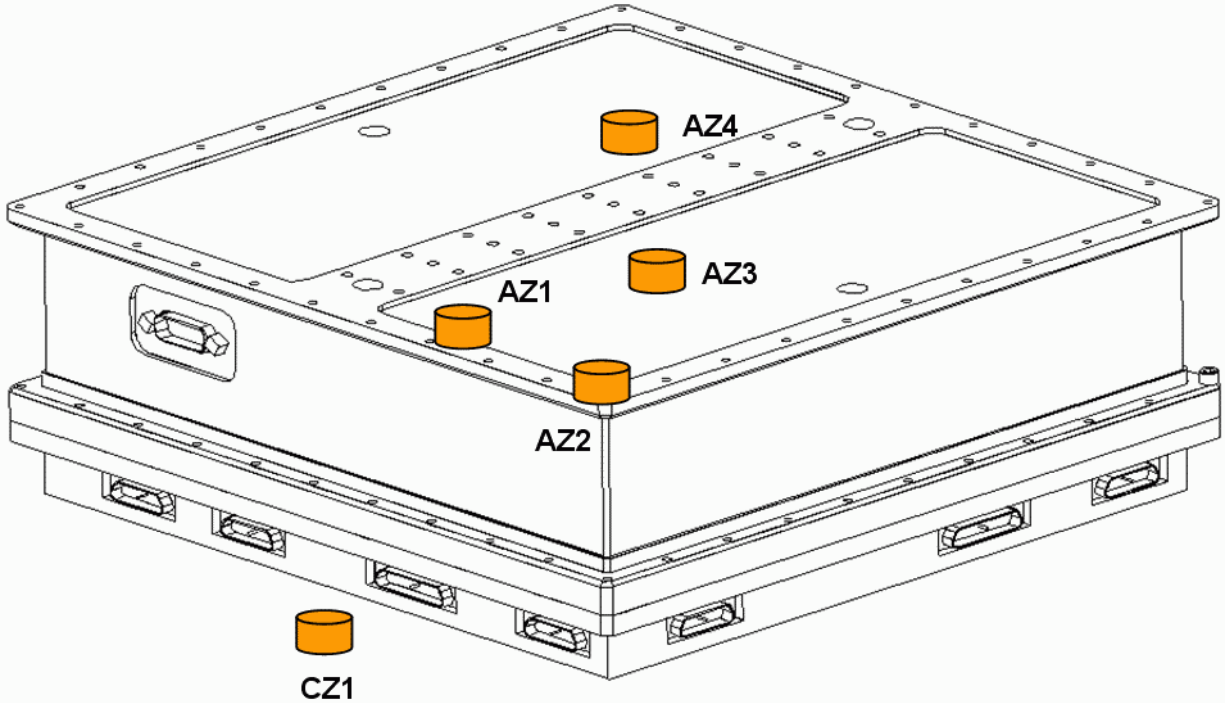

Figure 2 - Z-Axis Accelerometer Locations (Top)

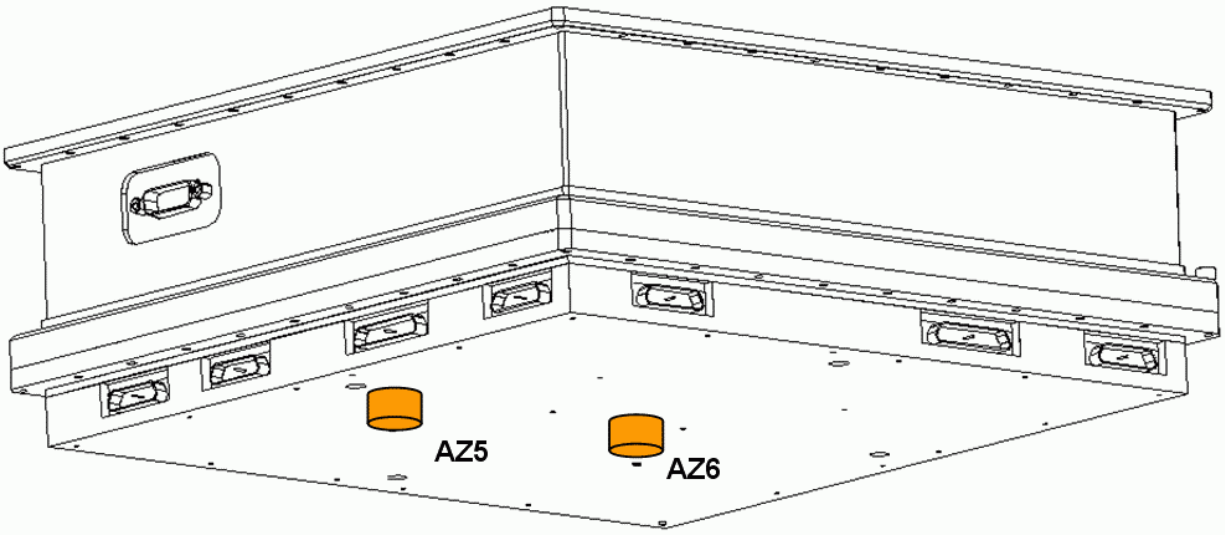

Figure 3 -Z-Axis Accelerometer Locations (Bottom)

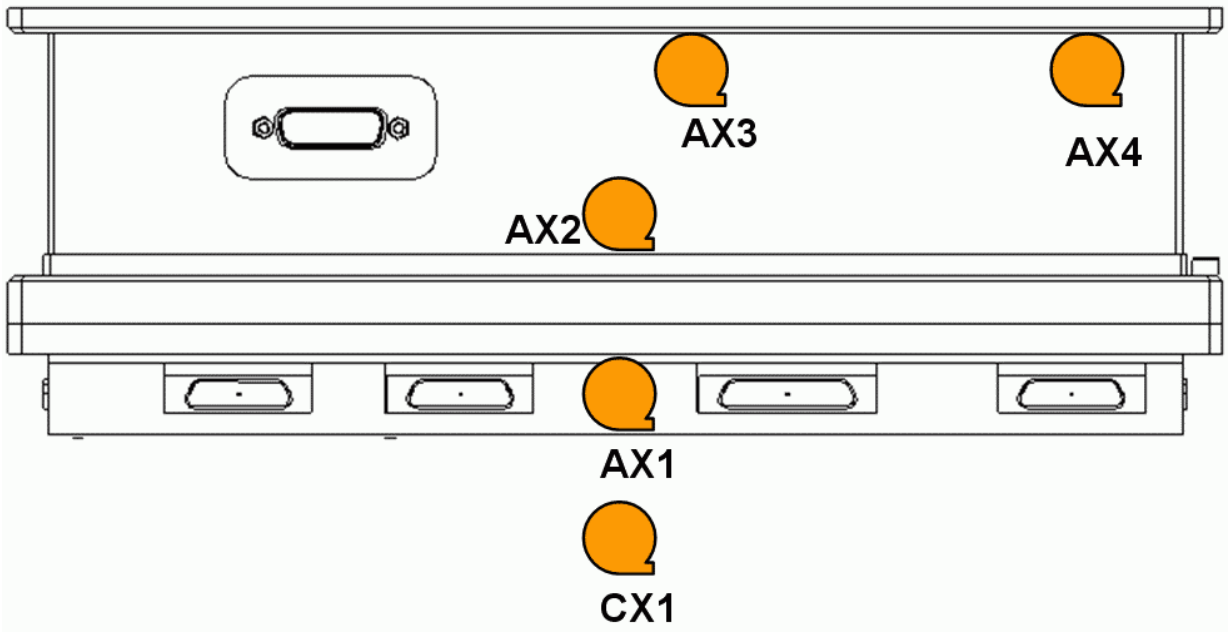

Figure 4 - X-Axis Accelerometer Locations

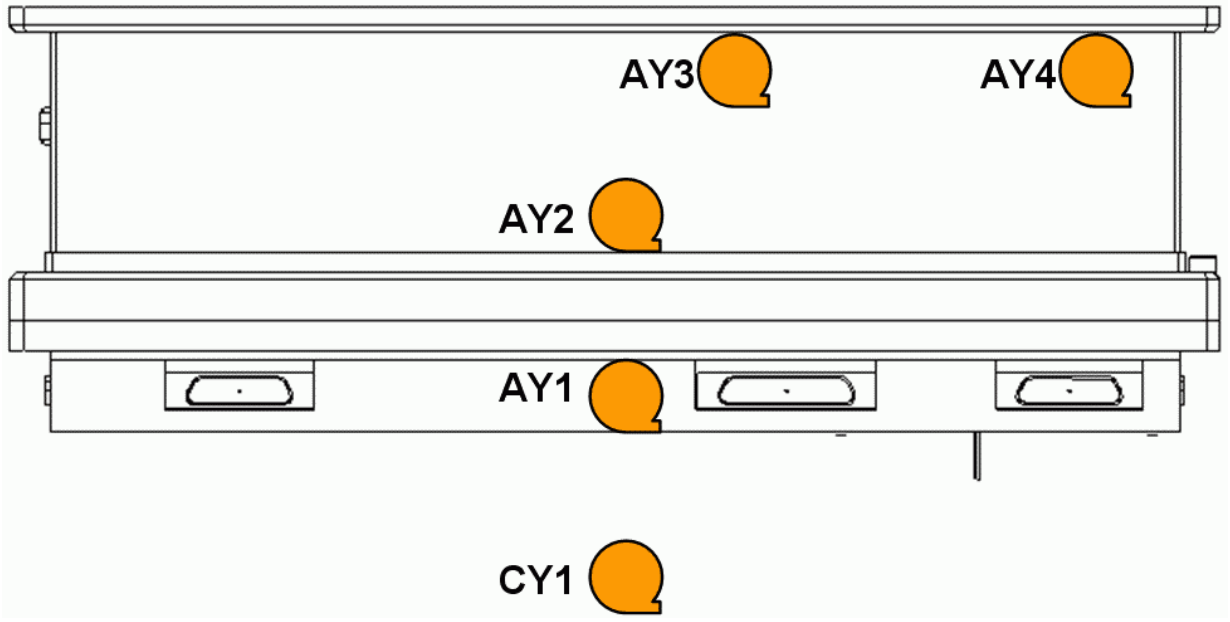

Figure 5 - Y-Axis Accelerometer Locations

7.4.2.1. Abort Levels

The abort limits for the Low Level Signature Sweep and the Random Test are shown in Table 3 below.

Accel. #	Location	Sine Abort Level [g]	Random Abort Level [g_{rms}]
CZ1	Z Axis Control	2.4	10.0
AZ1	TPS Edge Center	6.0	16.7
AZ2	TPS Corner	6.0	17.4
AZ3	TPS Boss 1 (-X, -Y)	20.0	35.8
AZ4	TPS Boss 2 (+X, +Y)	16.0	32.3
AZ5	TEM Bottom Edge (at spacer)	1.6	9.5
AZ6	TEM Bottom Center	16.0	56.6
CX1	X Axis Control	2.4	10.0
AX1	TEM Edge Center	1.8	11.2
AX2	TPS CG	4.2	17.7
AX3	TPS Top Center	5.4	19.4
AX4	TPS Top Edge	5.6	19.8
CY1	Y Axis Control	2.4	10.0
AY1	TEM Edge Center	6.0	14.6
AY2	TPS CG	7.2	18.8
AY3	TPS Top Center	10.2	20.4
AY4	TPS Top Edge	10.4	20.7

Table 3- Random Vibration: Abort Limits for Reference Accelerometers

7.5. Test Article Set-up

The TEM/TPS shall be mounted onto the vibration test fixture using the hardware and the bolt torque as described in section 7.1.

8. TEST LEVELS

8.1. Low Level Signature Sweep

A low amplitude sine sweep test is used to evaluate the transfer function of the TEM/TPS both along the thrust and lateral axis. It is mainly intended to measure the resonant frequencies and the *Q* factor of each mode.

A Low Level Signature Sweep will be performed before and after each random run. Changes in mode frequency and/or amplitude, as noted between sine sweep tests, will be used to identify possible structural damage that may have occurred during the dynamic test sequence.

The resonance search levels are summarized in **Error! Reference source not found.**. An input target amplitude of 0.15 $g_{0\text{-}pk}$ has been selected as the minimum acceleration level that can identify the transfer function and measure the response. The control accelerometers will monitor the input response: the alarm and abort levels are defined in **Error! Reference source not found.** as well. If the control signal is higher than the alarm a warning is displayed. When the acquisition system records a value exceeding the abort level, the test is automatically paused. The test conductor can allow only manually the continuation of the test or its termination

Frequency range	5 - 2000 Hz
Sweep Rate (Qualification)	2 oct/min
Sweep Rate (Acceptance)	4 oct/min
Target Amplitude	0.15 $g_{0\text{-}pk}$
Alarm Levels	± 1 dB
Upper Abort Level in Input	+12 dB
Lower Abort Level in Input	- 12 dB

Table 4 - Low Level Sine Control Abort Levels

8.2. Random Vibration

The random vibration is the test designed to study the structural response when an item is subjected to the launch environment. The TEM/TPS shall be subjected to the levels established in the LAT Environmental Specifications [8]. The test level is shown in Table 5 and will be controlled at the fixture base near the stand-off/spacer interface. The duration of the test is set according reference [8] and as shown in Table 5.

Each random run is automatically stepped up by the control system in the following order: -12dB, -9dB, -6dB, -3dB, and 0dB.

Each run will be preceded and followed by a Low Level Signature Sweep.

Electronics Module (TEM/TPS)
Random Vibration Spectra

Freq (Hz)	ASD Level (G^2/Hz) Accept	Qual
20	0.010	0.010
80	0.040	0.040
150	0.040	0.076
220	0.040	0.076
260	0.040	0.040
500	0.040	0.040
2000	0.010	0.010
Overall	6.8 Grms	7.1 Grms
Duration	60s/axis AT, PT 120s/axis QT	

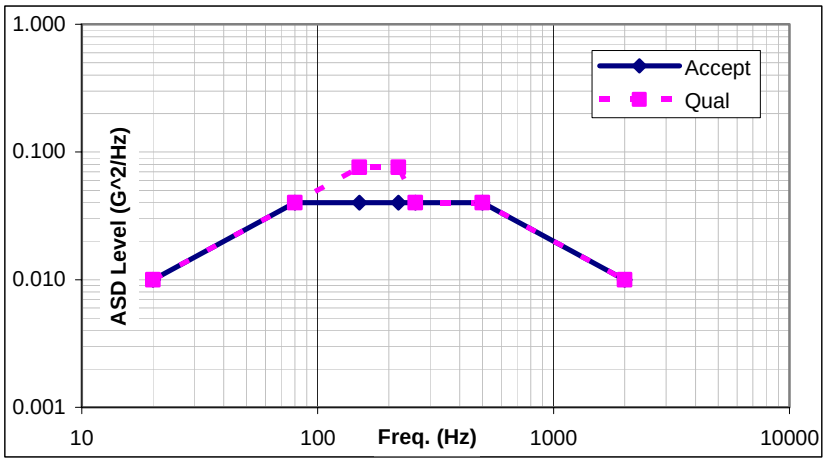

Table 5 - Random Vibration Test Spectra

9. TEST PERFORMANCE PROCEDURES

The TEM/TPS shall be subjected to dynamic tests in three directions: the vertical direction, coincident with the thrust axis (Z) and the two horizontal directions (Y and X) orthogonal to the thrust axis, as shown in the test sequence in Table 6. The Z axis test will be performed either with the shaker in the vertical position, while the lateral tests will be performed with the shaker in the horizontal position and connected to the slip plate.

The environmental dynamic tests include:

a) Pre- and post-test Low Level Signature Sweep.

b) Random vibration test

The test data will be monitored during the test runs, in order verify on-line the test sequence and to study in more detail the TEM/TPS response to the dynamic excitation.

A visual inspection of the item during and after the test will verify compliance with the test requirements.

Once the test has been terminated, the collected data will be analyzed in order to produce a test report containing the response plots of the amplitude and phase versus frequency for each accelerometer.

9.1. Test Success Criteria

The vibration test on the TEM/TPS will be considered successful if all the following criteria are met:

1. A test run will be considered to have passed when:
    a. All data channels appear to be reading accurately.
    b. Maximum responses are checked against predictions.
    c. No audible anomalies, no visual anomalies.
    d. The first fundamental frequency of a TEM/TPS will be greater than 400 Hz for the thrust axis (Z), and 300 Hz for the lateral axes (X and Y).
2. Progressive downward shifts in frequency and/or amplitude indicate a potential problem. All appreciable shifts must be justified before the test is allowed to proceed to a higher input level. Diagnostic runs should be performed to try to isolate the anomaly.
3. Difference in the resonance frequency of the 1^{st} mode between any pre-test signature run and post test signature run less than 2%; shifts greater than 2% must be investigated.
4. the post-test visual inspection shows no variation with respect to the pre-test visual inspection: all the screws are fastened to the established torque values, no mechanical damages or cracks are found.

During the test a run time data analysis will be done controlling the following items:

Damping will be investigated after low level signature sweeps to verify that the analysis assumptions are valid.

1. Fundamental modes will be identified and compared previous test results.
2. Pre and Post Signature sweep overlays will checked for frequency and amplitude shifts.

3. Response g_{rms} will be compared to predictions to verify that demonstrated static loads are not exceeded during random vibration runs.
4. Eventual discrepancies from former results must be investigated.

The test will be considered completed once the functional performance of the TEM/TPS has been verified. A comprehensive performance test (CPT) will be done after the vibration test sequence. The results of the functional test will be used as reference for the following TV test .

9.2. Non-conformance and Procedure Variation

Every time a significant procedure deviation is needed, a Procedure Variation Sheet must be generated according to the form shown in Appendix C and approved by the Responsible Engineer and Quality Assurance Support.

Every time a fail criteria occurs, a NCR will be opened and managed by Quality Control.

9.2.1. Test-case termination criteria

Test-case termination is required when:

– The first fundamental frequency does not meet the minimum required value;

– Loss of the shake system control;

– Shaker malfunctioning.

Ultimate decision will rest the Responsible Engineer on duty with input from the Test Engineer, Test Conductor, both of whom will consider the above criteria in the decision.

9.2.2. Emergency Procedures: contingency procedures

In the case a test termination criteria case is reached, a contingency procedure shall be followed in order to ensure safety of the test article:

- Immediate alert to the test engineer/Responsible Engineer
- Place the TEM/TPS in a safe condition.

An NCR shall be opened, followed by an MRB.

9.3. Axis change procedure

The dynamic tests will be performed on the three axis independently and successively. The vertical direction test will be performed with the shaker positioned along the Z axis, and then it will be rotated in the horizontal position and attached to the slip-table. During the change of axis activity, the TEM/TPS will be kept far from the shake table.

9.4. Handling

Personnel shall wear gloves and properly grounded wrist straps when handling the TEM/TPS.

9.5. TEM/TPS Test Sequence

This section outlines the test sequence to perform the dynamic test on the TEM/TPS on the thrust axis (Z) first and the two successive transverse axes (Y and X). The TEM/TPS shall be tested according to the steps shown in Table 6 below.

Run #	Test Description	Frequency	Comments
1	Z-Axis Low Level Signature Sweep	Input: 0.15 g 5 – 2000 Hz	
2	Z-Axis Random Vibration (Full level)	Input: 20 – 2000 Hz	Qualification = 120 sec duration Acceptance = 60 sec duration
3	Z-Axis Low Level Signature Sweep	Input: 0.15 g 5 – 2000 Hz	
4	X-Axis Low Level Signature Sweep	Input: 0.15 g 5 – 2000 Hz	
5	X-Axis Random Vibration (Full level)	Input: 20 – 2000 Hz	Qualification = 120 sec duration Acceptance = 60 sec duration
6	X-Axis Low Level Signature Sweep	Input: 0.15 g 5 – 2000 Hz	
7	Y-Axis Low Level Signature Sweep	Input: 0.15 g 5 – 2000 Hz	
8	Y-Axis Random Vibration (Full level)	Input: 20 – 2000 Hz	Qualification = 120 sec duration Acceptance = 60 sec duration
9	Y-Axis Low Level Signature Sweep	Input: 0.15 g 5 – 2000 Hz	

Table 6 - Dynamic Test Sequence

10. TEST DATA RECORDS AND DATA SHEETS

10.1. Test Log-book

A test record containing the performance detail information of each test and the step by step procedural execution log will be filled by the test conductor.

1. Test conductors and responsibilities;
2. Test item: specification and identification number (ID#);
3. Equipment Log (instrumentation list, description and calibration, as shown in appendix A);
4. Step by step test procedure indicating start and end times (par. **Error! Reference source not found.**):
    a. Incoming of the item;
    b. Equipment mounting stages;
    c. Item mounting Stages;
    d. Test performance;
5. Vibration test history to be filled by the test conductor (Appendix B)
6. Non-conformance Table;
7. Procedure Variation Sheet (Appendix C).

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10.2. Recorded Data

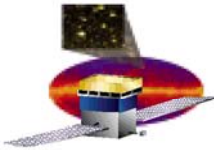
Wyle will release the test data both in electronic format (Universal file format) and in paper format (plots, photographs, etc…) for further analysis. Test data sheets will be used to record pass/fail data and to record performance metrics as required in this document.

10.3. Test Report

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

- a description of the test facility and test item;
- the filled-in test procedure
- a complete list of the non-conformances raised during the test and the corresponding procedure variation sheet;
- the test results (pictures and plots).

Appendix A – Accelerometer Sensitivities

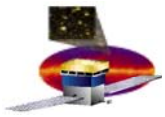


GLAST LAT ProjectTEM/TPS Delta-TRR for Vibration Testing

Accelerometer Sensitivities

Ch #	Accel. #	S/N	mV/g	Description / Location	Axis
	CZ1			Z Axis Control	+Z
	AZ1			TPS Edge Center	+Z
	AZ2			TPS Corner	+Z
	AZ3			TPS Boss 1 (-X, -Y)	+Z
	AZ4			TPS Boss 2 (+X, +Y)	+Z
	AZ5			TEM Bottom Edge (at stand-off)	-Z
	AZ6			TEM Bottom Center	-Z
	CX1			X Axis Control	-X
	AX1			TEM Edge Center	-X
	AX2			TPS CG	-X
	AX3			TPS Top Center	-X
	AX4			TPS Top Edge	-X
	CY1			Y Axis Control	-Y
	AY1			TEM Edge Center	-Y
	AY2			TPS CG	-Y
	AY3			TPS Top Center	-Y
	AY4			TPS Top Edge	-Y

Appendix B – Test Log

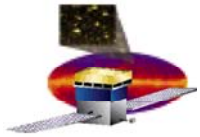


GLAST LAT ProjectTEM/TPS Delta-TRR for Vibration Testing

Test Log

Date	Time Start	Time Total	Axis	Level [g]	Frequency [Hz]	Remarks	Test	Run No.

Appendix C – Procedure Variation



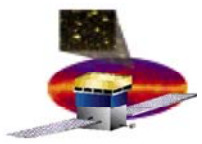
GLAST LAT ProjectTEM/TPS Delta-TRR for Vibration Testing

Installation Steps and Procedure Variations

Date	Axis	Test Setup	Installation Step Description	RE/QA Approval
	N/A		Incoming Visual inspection (e.g. ensure taped gaps are still sealed)	
	Z		Torque vibration fixture bolts to shaker to 25 ft-lbf (300 in-lbf)	
	Z		Torque TEM/TPS to vibration fixture to 167 in-lbf	
	Z		Confirm accelerometer installation	
	X		Torque vibration fixture bolts to shaker to 25 ft-lbf	
	X		Torque TEM/TPS to vibration fixture to 167 in-lbf	
	X		Confirm accelerometer installation	
	Y		Torque vibration fixture bolts to shaker to 25 ft-lbf	
	Y		Torque TEM/TPS to vibration fixture to 167 in-lbf	
	Y		Confirm accelerometer installation	

Date	Axis	Test Setup	Test Variation Description	RE/QA Approval

Appendix D –Test Data Package Checklist



GLAST LAT ProjectTEM/TPS Delta-TRR for Vibration Testing

Qualification/Acceptance Test Data Package Checklist
(Items supplied by Wyle Labs at end of test)

Item	✓	Description / Location
1		Calibrated Equipment List
2		Vibration Test plots (Pre- and Post test signature overlays and random vibration test data for Z, X, and Y axes
3		Electronic Data in UFF or equivalent format, if available
4		Photographs of test setup
5		Procedure data sheets (Appendices A, B, and C)
6		Visual Inspection Report
7		Test Control System Software Setup Sheets