GLAST LAT Specification	Document # LAT-SS-00778-0	Date Effective 22 Jun 2004
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Document Title **LAT Environmental Specification**		

1. Change History Log

Revision	Effective Date	Description of Changes
01	22 Mar 2003	Initial release
	7 Apr 2003	Updated Figure 8 and Section 11.3 paragraph 3
02	22 Jun 2004	Deleted and added reference documents & data sources ;Updated Tables 2-22, 24, 27;28(Deleted and Replaced): Revised Paragraph 12.4 Atomic Oxygen, deleted Figure 9; Numerous changes to Section 13 EMI Environments

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2. Contents

3. Purpose

This document defines the structural, thermal, and on-orbit exposure design and test environments for the LAT instrument and its subsystems.

4. Scope

This specification captures all requirements governing the environments to be used in the development, analysis, and test of the LAT and its subsystems. This includes launch structural loads, on-orbit thermal environments, and on-orbit debris, radiation, and other environments which may affect end-of-life reliability and performance. It also includes all ground handling and transportation environments.

5. Definitions

5.1. Acronyms

AT	Acceptance Test
ACD	Anticoincidence Detector
ASD	Acceleration Spectral Density
BOL	Beginning of Life
CAL	Calorimeter
CCAFS	Cape Canaveral Air Force Station
CCHP	Constant Conductance Heat Pipe
CCP	Contamination Control Plan (LAT-MD-00404)
CLA	Coupled-Loads Analysis
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
EMISM	EMI Safety Margin
EOL	End of Life
EPU	Event Processor Unit
GASU	Global trigger, Acd, and Systems routing Unit
GEVS	"General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components"
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
ICD	Interface Control Documents between the LAT and LAT subsystems.
IR	InfraRed
IRD	"GLAST LAT—Spacecraft Interface Requirements Document" (433-IRD-0001)
LAT	Large Area Telescope
LV	Launch Vehicle
GLAST	Gamma-ray Large Area Space Telescope
MECO	Main Engine Cut-Off
MSS	"Mission System Specification" (433-SPEC-0001)
MUF	Modeling Uncertainty Factor
PDU	Power Distribution Unit
PFQ	Proto-Flight Qualification
PPG	"Delta II Payload Planners Guide" (MDC 00H0016)
RF	Radio Frequency
RMS	Root Mean Square
RSS	square Root Sum of the Squares
SC	Spacecraft
SIU	Spacecraft Interface Unit
SLAC	Stanford Linear Accelerator Center
SRS	Shock Response Spectrum
TBD	To Be Determined
TBR	To Be Resolved
TEM	Tower Electronics Module

TID	Total Ionizing Dose
TKR	Tracker
TPS	TEM Power Supply
TSA	Tile Shell Assembly
VCHP	Variable Conductance Heat Pipe

5.2. Definitions

A: Ampere
Arcmin: An arcmin is a measure of arc length. One arcmin is 1/60 degree.
Arcsec: An arcsec is a measure of lengths of arc. One arcsec is 1/60 arcmin
cm: centimeter
dB: decibel
deg: degree
degC: degree celsius
E-Box: electronic box
G, g: unit of gravitational acceleration, g = 9.81 m/s^2
GHz: gigahertz
Hz: Hertz, cycles/second
I: current
in.: inch
kg: Kilogram
km: kilometer
krad: kilorad
LAT Coordinate System: Defined in LAT-TD-00035
m: meter
Max, max: Maximum
Mech: Mechanical Systems
MHz: megahertz
Min, min: Minimum
min: minute
Mm: millimeters
mV: millivolt
μA: microampere
μV, uV: microvolt
N: Newton
Pa: Pascal
psi: pounds per square inch
pT: picoTesla
rad: Radian
Req: Requirement
s, sec: seconds
T: Tesla
V: Volt

W: Watts

6. Applicable Documents

LAT-MD-00404, "LAT Contamination Control Plan"

LAT-SS-00010, "GLAST LAT Performance Specification", August 2000.

LAT-MD-00408-01, "LAT Program Instrument Performance Verification Plan," March, 2003.

433-IRD-0001, "Large Area Telescope (LAT) Instrument—Spacecraft Interface Requirements Document", May, 2002. Referred to as the "IRD."

433-SPEC-0001, "GLAST Mission System Specification", May, 2002. Referred to as the "MSS."

433-SPEC-0003, "Spacecraft Performance Specification," May, 2002. Referred to as the "SPS."

433-MAR-0001, "Mission Assurance Requirements (MAR) for the Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)", June 9, 2000

433-RQMT-0005, "Electromagnetic Interference (EMI) Requirements Document." Referred to as the "GLAST EMI Spec."

GEVS-SE Rev A, "General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components", June 1996. http://arioch.gsfc.nasa.gov/302/gevs-se/toc.htm

MDC 00H0016, "Delta II Payload Planners Guide (PPG)", October 2000. http://www.boeing.com/defense-space/space/delta/docs/DELTA_II_PPG_2000.PDF

NPD 8010.2B, "NASA Policy Directive, Use of Metric System of Measurement in NASA Programs."

LAT-TD-00035-03, "LAT Coordinate and Numbering System," February, 2003.

LAT-TD-00234-3, "LAT Preliminary Structural Design Report," 26 July 2002.

SLAC-I-720-0A24E-002, "Specification for Seismic Design of Buildings, Structures, Equipment, and Systems at the Stanford Linear Accelerator Center," 4 December 2000.

GLAST Early-CLA Results – LAT-Related, Farhad Tahmasebi & Carlton Miller, dated 19 Dec 2003

E-mail from Farhad Tahmasebi to Martin Nordby, received 27 January 2003, 11:51 am PST.

GLAST Early-CLA Results – LAT-Related; Farhad Tahmasebi & Carlton Miller, dated 19 Dec 2003

LAT-TD-00234-3, "LAT Preliminary Structural Design Report," 26 July 2002. Loads result from static analysis using MECO and Lift-off/Air-Loads static-equivalent accelerations for LAT.

"Interface Displacements," John Hodgson, 18 November 2002. Memo reporting displacements of from lat9 model.

GLAST Early CLA Partial Results – Observatory and S/C-LAT Interface Forces; Farhad Tahmasebi, dated 5 Feb 2004

LATv10.08 Static Analysis with Nov01 MECO loads; Subcases 201 through 204

LAT Sine Vibration Test Specifications: Farhad Tahmasebi, dated 3/15/04

SAI-TM-487, "Updated GLAST LAT-Subsystem Vibration Test Levels", Mar 04

"ACD Design Limit Load Factors (g)," Farhad Tahmasebi, undated document e-mailed to Martin Nordby 25 Nov 2002. Obsolete; superceded by (9)

LAT ACD Sine Vibration Specifications: Farhad Tahmasebi, dated 2/24/04

CAL Tab Limit Load Tables, Martin Nordby, 20 November 2002.

LAT Calorimeter Sine Vibration Specifications; Farhad Tahmasebi & Carlton Miller, dated 16 Jan 2004

"LAT Calorimeter Random Vibration Test Levels," Farhad Tahmasebi, 25 Feb 2002.

LAT TKR Sine Vibration and Static Test Specifications; Farhad Tahmasebi, dated 9 Jan 2004

SAI-TM-2443, "GLAST Tracker Random Vibration Analysis", Jan, 2004

"LAT Tracker Random Vibration Test Levels," Farhad Tahmasebi, 27 Feb 2002.

"LAT TEM Random Vibration Test Levels," Farhad Tahmasebi, 21 Aug 2002.

SAI-TM-2499 "GLAST LAT Radiator Vibroacoustic Analysis", Apr 04

7. Ground Environments

7.1. Structural Load Environments

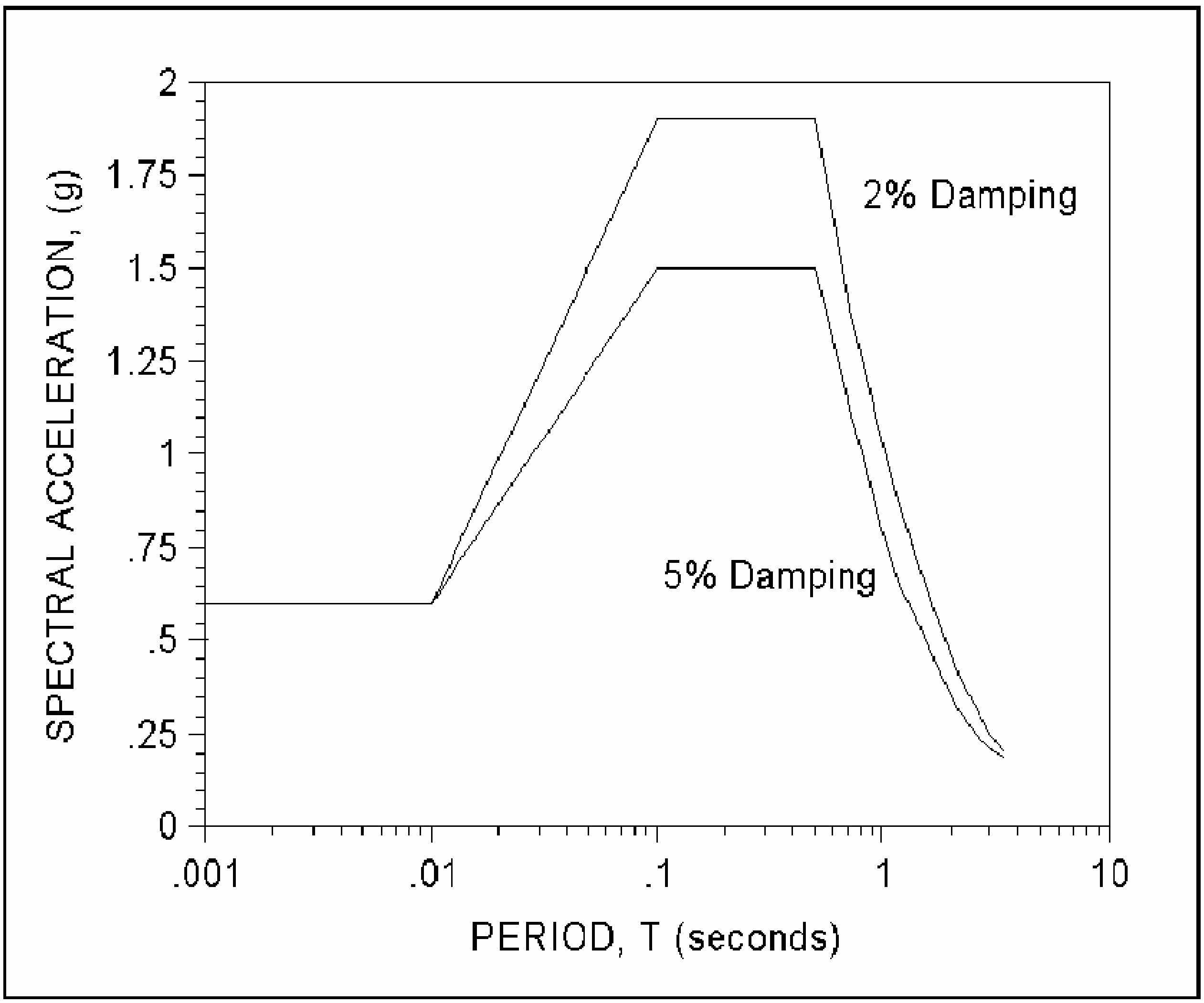
Seismic Environment

All Large Area Telescope (LAT) systems, sub-system flight hardware, and transport and handling ground support equipment (GSE) that will be used or stored at the Stanford Linear Accelerator Center (SLAC) shall be designed to withstand the static-equivalent accelerations shown in Figure 1 and Figure 2, below, for horizontal and vertical ground accelerations, respectively. GSE shall also be designed to protect any flight hardware with which it interfaces, while being subjected to these seismic loads. Note that the amplitude of acceleration is a function of the period of the device and the expected damping of the structure.

Source of requirement: SLAC Seismic Design Spec

Data sources:

SLAC-I-720-0A24E-002, "Specification for Seismic Design of Buildings, Structures, Equipment, and Systems at the Stanford Linear Accelerator Center," 4 December 2000.



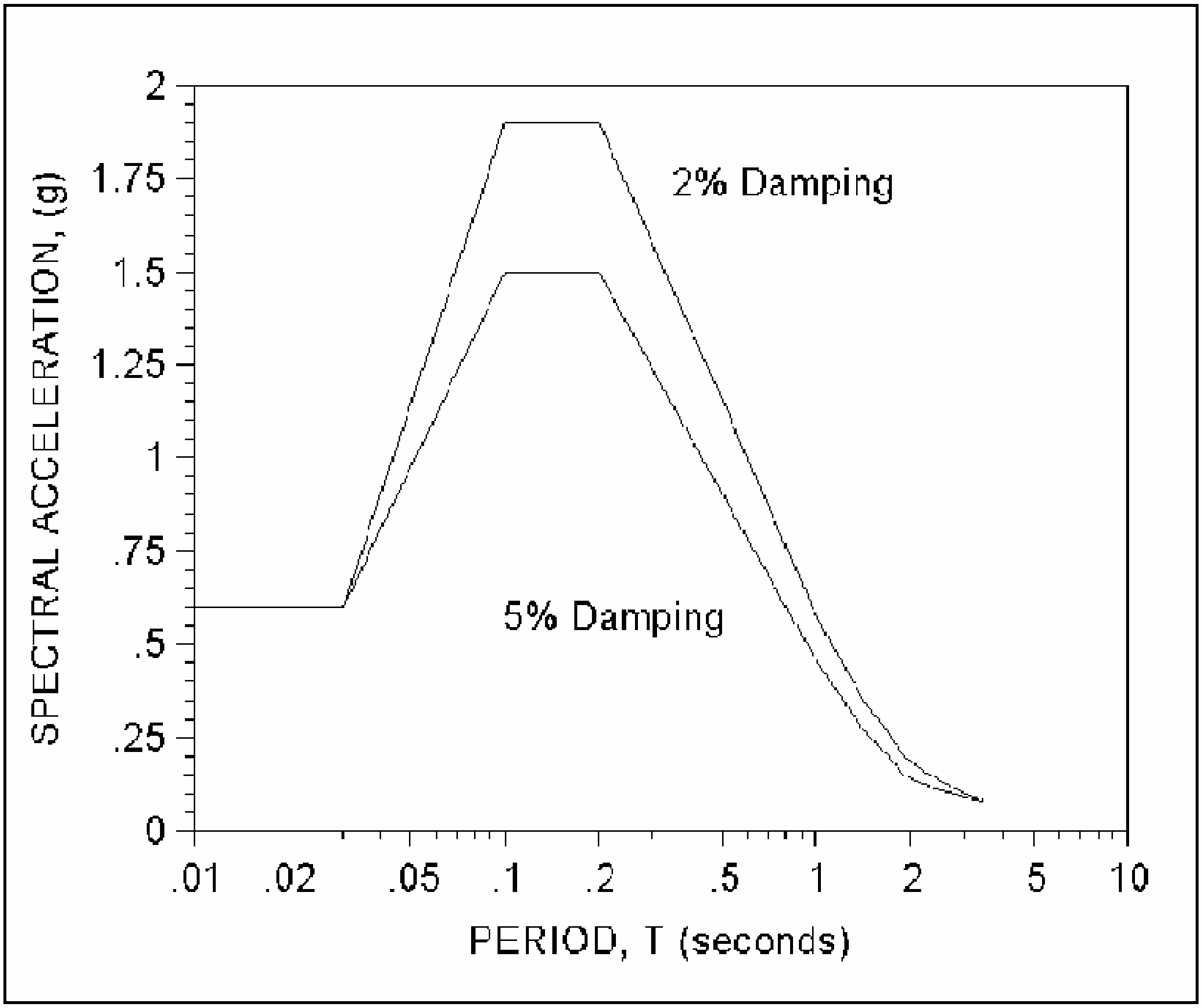


Figure 1: Response Spectra for LAT Components—Horizontal Motions

Figure 2: Response Spectra for LAT Components—Vertical Motions

Ground Transportation Static-Equivalent Accelerations

TBD: From Eric Gawehn

TBD: Get req's for CCAFS ground handling

Airplane Static-Equivalent Accelerations

TBD: From Eric Gawehn

7.2. Dynamic Environments

Ground Transport Dynamic Environment

TBD: From Eric Gawehn

TBD: Get req's for CCAFS ground handling

Airplane Transport Dynamic Environment

TBD: From Eric Gawehn

7.3. Thermal and Humidity Environments

LAT components and assemblies shall be capable of fully functioning and being stored in the range of ground ambient environments described in Table 1, below.

Environment	Low	High	Driving Req
Bench test operating temperature	15 C	30 C	IRD 3.2.1.5.1
Ground storage/transport temperature	0 C	40 C	TBD
Operating/storage relative humidity	30%	45%	IRD 3.2.1.5.2

Table 1: Ground Ambient Environments

8. Structural Load Environment

8.1. Static-Equivalent Accelerations

LAT components and assemblies shall be designed to perform after exposure to the static-equivalent accelerations at their center-of-mass as shown in Table 2 through, below. For design purposes, all accelerations for a given launch case must be applied in all directions simultaneously, including any rotational acceleration. Launch events have been grouped into two launch cases. “Lift-off/Airloads” includes maximum acceleration predictions for lift-off, transonic, and Max Q launch events. The “MECO” case includes maximum accelerations for the main engine cut-off event. For axial loads, (+) indicates an acceleration which compresses the payload on the launch vehicle (LV), while (-) indicates tension.

Furthermore, for all subsystems but the Calorimeter (CAL) the accelerations must be scaled until they produce in at least one interface the limit loads described in Section 8.2. These scaled accelerations must be used in the structural design of the subsystem. For the CAL, acceleration values are used as-is.

For testing purposes, peak accelerations need only be applied one axis at a time. Acceptance test accelerations shown have been calculated from the design predictions to ensure that the test event produce interface limit loads comparable to those generate by the simultaneous combination of design accelerations. Qualification test levels are a direct scaling of the acceptance levels by 1.25. Note that for the axial accelerations indicated, if strength qualification testing is performed on a shaker table the test object will experience equal accelerations in tension and compression. Test planning must factor in this symmetry, even though the tables below show asymmetric accelerations.

Data sources:

(1) Obsolete; superceded by (9)

(2) Obsolete; superceded by (9)

(3) 433-IRD-0001, “Large Area Telescope (LAT) Instrument—Spacecraft Interface Requirements Document”, May, 2002.

(4) “LAT Tracker Random Vibration Test Levels,” Farhad Tahmasebi, 27 Feb 2002.

(5) “LAT Calorimeter Random Vibration Test Levels,” Farhad Tahmasebi, 25 Feb 2002.

(6) “LAT TEM Random Vibration Test Levels,” Farhad Tahmasebi, 21 Aug 2002.

(7) Obsolete; superceded by (9)

(8) E-mail from Farhad Tahmasebi to Martin Nordby, received 27 January 2003, 11:51 am PST.

(9) GLAST Early-CLA Results – LAT-Related; Farhad Tahmasebi & Carlton Miller, dated 19 Dec 2003

(10) LAT TKR Sine Vibration and Static Test Specifications; Farhad Tahmasebi, dated 9 Jan 2004

(11) LAT Calorimeter Sine Vibration Specifications; Farhad Tahmasebi & Carlton Miller, dated 16 Jan 2004

(12) GLAST Early CLA Partial Results – Observatory and S/C-LAT Interface Forces; Farhad Tahmasebi, dated 5 Feb 2004

(13) LAT ACD Sine Vibration Specifications; Farhad Tahmasebi, dated 24 Feb 2004

(14) LAT ACD Static Test Loads; John Ku, dated Feb 2004

LAT	Design		Accept (+)		PFQ (+)		Unit
Launch Event	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	
Lateral (X)	+/-1.36	+/-0.2	+/-1.36	+/-0.2	+/-1.7	+/-0.25	g
Lateral (Y)	+/-1.82	+/-0.2	+/-1.82	+/-0.2	+/-2.28	+/-0.25	g
Axial (Z)	+2.9/-0.28	+6.8	+2.9/-0.28	+6.8	+3.63/-0.35	+8.5	g
Rot X	+/-44.26	0	+/-44.26	0	+/-55.33	0	rad/sec^2
Rot Y	+/-11.12	0	+/-11.12	0	+/-13.9	0	rad/sec^2
Rot Z	+/-9.04	0	+/-9.04	0	+/-11.3	0	rad/sec^2
Source	(9)	(3)	(9)	(3)	(9)	(3)	

Table 2: LAT Static-Equivalent Accelerations

TKR	Design (*)		Accept (+)	Qual (+)	Unit
Launch Event	Lift-Off/ Airloads	MECO			
Lateral (X)	+/-1.71		+/-4.4	+/-5.5	g
Lateral (Y)	+/-2.49		+/-4.4	+/-5.5	g
Lateral (%)		+/-0.2			g
Axial (Z)	+4.74/-1.91	+6.8	+6.8/-1.9	+8.5/-2.4	g
Rot X	+/-54.17	0	0	0	rad/sec^2
Rot Y	+/-15.27	0	0	0	rad/sec^2
Rot Z	+/-9.06	0	0	0	rad/sec^2
Source	(9)	(3)	(9)	(10)	

Comments: (*) For analysis, apply design accel's simultaneously
(+) For test, apply test accel's along one axis at a time
(%) Apply load along +/- X and Y axes and each 45 degree vector

Table 3: Tracker Static-Equivalent Accelerations

CAL	Design (*)		Accept (+)	Qual (+)	Unit
Launch Event	Lift-Off/ Airloads	MECO			
Lateral (X)	+/-1.46		+/-6.0	+/-7.5	g
Lateral (Y)	+/-2.14		+/-6.0	+/-7.5	g
Lateral (%)		+/-0.2			g
Axial (Z)	+4.74/-1.91	+6.8	+6.8/-1.9	+8.5/-2.4	g
Rot X	+/-47.53	0	0	0	rad/sec^2
Rot Y	+/-13.74	0	0	0	rad/sec^2
Rot Z	+/-9.06	0	0	0	rad/sec^2
Source	(9)	(3)	(9)	(11)	

Comments: (*) For analysis, apply design accel's simultaneously
(+) For test, apply test accel's along one axis at a time
(%) Apply load along +/- X and Y axes and each 45 degree vector

Table 4: Calorimeter Static-Equivalent Accelerations

ACD	Design (*)		Accept (+)		PFQ (+)		Unit
Launch Event	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	
Lateral X	+/-1.7	+/-0.2	+/-5.8	+/-0.2	+/-7.25	+/-0.25	g
Lateral Y	+/-3.24	+/-0.2	+/-4.2	+/-0.2	+/-5.25	+/-0.25	g
Axial (Z)	+2.89/-0.2	+6.8	+2.89/-0.2	+6.8	+/-3.61/-0.25	+8.5	g
Rot X	+/-49.12	0	0	0	0	0	rad/sec^2
Rot Y	+/-11.46	0	0	0	0	0	rad/sec^2
Rot Z	+/-9.11	0	0	0	0	0	rad/sec^2
Source	(9)	(3)	(14)	(3)	(14)	(3)	

Table 5: Anticoincidence Detector Static-Equivalent Accelerations

Elec	Design (*)		Accept (+)	PFQ (+)	Unit
Launch Event	Lift-Off/ Airloads	MECO			
Lateral (X)	+/-1.41		+/-6.25	+/-7.8	g
Lateral (Y)	+/-2.76		+/-6.25	+/-7.8	g
Lateral (%)		+/-0.2			g
Axial (Z)	+4.76/-1.93	+6.8	+6.8/-1.9	+8.5/-2.4	g
Rot X	+/-48.79	0	0	0	rad/sec^2
Rot Y	+/-13.56	0	0	0	rad/sec^2
Rot Z	+/-9.22	0	0	0	rad/sec^2
Source	(9)	(3)	(9)	(9)	

Comments: (*) For analysis, apply design accel's simultaneously
(+) For test, apply test accel's along one axis at a time
(%) Apply load along +/- X and Y axes and each 45 degree vector

Table 6: Electronics Box Static-Equivalent Accelerations

Grid Box	Design		Accept (+)		PFQ (+)		Unit
Launch Event	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	
Lateral (X)	+/-1.36	+/-0.2	+/-1.36	+/-0.2	+/-1.7	+/-0.25	g
Lateral (Y)	+/-1.82	+/-0.2	+/-1.82	+/-0.2	+/-2.28	+/-0.25	g
Axial (Z)	+2.9/-0.28	+6.8	+2.9/-0.28	+6.8	+3.63/-0.35	+8.5	g
Rot X	+/-44.26	0	+/-44.26	0	+/-55.33	0	rad/sec^2
Rot Y	+/-11.12	0	+/-11.12	0	+/-13.9	0	rad/sec^2
Rot Z	+/-9.04	0	+/-9.04	0	+/-11.3	0	rad/sec^2
Source	(9)	(3)	(9)	(3)	(9)	(3)	

Table 7: Grid Box Static-Equivalent Accelerations

Radiator	Design (*)		Accept (%)		PFQ (%)		Unit
Launch Event	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	Lift-Off/ Airloads	MECO	
Lateral (X)	+/-1.85		+/-1.85		+/-2.31		g
Normal (Y)	+/- 11.68		+/- 11.68		+/-14.6		g
Lateral ($)		+/-0.2		+/-0.2		+/-0.25	g
Axial	+7.02/-3.85	+6.8	+7.02/-3.85	+6.8	+8.78/-4.81	+8.50	g
Rot (X)	+/- 43.48	0	+/- 43.48	0	+/-54.35	0	rad/sec^2
Rot (Y)	+/- 12.75	0	+/- 12.75	0	+/-15.94	0	rad/sec^2
Rot (Z)	+/- 8.26	0	+/- 8.26	0	+/-10.325	0	rad/sec^2
Source	(9)	(3)	(9)	(3)	(9)	(3)	

Comments: (*) For analysis, apply design accel's simultaneously
(%) Single-axis test levels to be derived with pre-test analysis
($) Apply load along +/-X and Y axes and each 45 degree vector
Normal (Y) load includes an acoustic factor of 8.5g.

Table 8: Radiator Static-Equivalent Accelerations

8.2. Interface Limit Loads

Structural interface features, and the components and assemblies to which they attach, shall be designed to carry the maximum predicted interface loads, as described in the tables, below. Note that these design limit loads may be predicted to occur at only one of a number of the structural interfaces, but all identical interfaces must be designed using the maximum limit loads.

Data sources:

(1) Obsolete, superceded by (7)

(2) Obsolete, superceded by (7)

(3) MDC 00H0016, “Delta II Payload Planners Guide (PPG)”, October 2000, Section 4.2.3.1 Figure 4-18 and Table 4-5

(4) LAT-TD-00234-3, “LAT Preliminary Structural Design Report,” 26 July 2002. Loads result from static analysis using MECO and Lift-off/Air-Loads static-equivalent accelerations for LAT.

(5) “Interface Displacements,” John Hodgson, 18 November 2002. Memo reporting displacements of from lat9 model.

(6) CAL Tab Limit Load Tables, Martin Nordby, 20 November 2002.

(7) GLAST Early CLA Partial Results – Observatory and S/C-LAT Interface Forces; Farhad Tahmasebi, dated 5 Feb 2004

(8) LATv10.08 Static Analysis with Nov01 MECO loads; Subcases 201 through 204

(9) SAI-TM-2499 “GLAST LAT Radiator Vibroacoustic Analysis”, Apr 04

Note that for data sources (4) and (5) the Spacecraft (SC) interface was modeled as a rigid connection, with no interface compliance. Joint compliance may affect load predictions.

Tracker—Grid Interface Loads on Flexures

Tracker (TKR) module interfaces to the LAT Grid shall use the limit loads shown in Table 9. Flexures should be designed and tested using the worst combination of shear and either tension or compression, whichever produces the highest stresses. Each load case must be evaluated to assure that the peak stress environment for the flexure is modeled.

TKR-Grid Flexures	Design		Accept	Qual	Unit
Launch Event	Lift-Off/ Transonic	MECO			
Mid-Side Flexures					
Shear	1454	2061	1454	1818	N
Tension/Compress.	582	291	582	728	N
Corner Flexures					
Shear	691	80	691	864	N
Tension/Compress.	945	1,193	945	1,181	N
Source	(7)	(4)			

Table 9: TKR Interface Design Limit Loads on Flexures

In addition to the limit loads shown above, the TKR-Grid interface shall be designed to accommodate the out-of-plane distortion of the interface as shown in Table 10. The maximum interface displacements and flexure forces occur in the MECO thrust load case, in the corner bay.

Note that interface loads resulting from these distortions should not be added to the limit loads discussed above. These loadings are separate, and occur at different times during launch. Further, distortion analysis and testing should not be superimposed with any vibration analysis or testing, as these also occur at different times during launch. However, analysis of the MECO static-equivalent accelerations and interface distortions should be superimposed.

Flexure Position	Location		MECO Distortion; Source: (8)		
	X	Y	Ux [mm]	Uy [mm]	Uz [mm]
Right Midside	-374.501	-561.752	0.012	0.070	-0.225
Upper Right	-382.303	-397.908	0.053	0.053	-0.295
Upper Right	-397.908	-382.303	0.053	0.052	-0.295
Top Midside	-561.752	-374.501	0.069	0.010	-0.225
Upper Left	-725.596	-382.303	0.074	-0.015	-0.141
Upper Left	-741.201	-397.908	0.069	-0.011	-0.134
Left Midside	-749.003	-561.752	0.026	-0.005	-0.132
Lower Left	-741.201	-725.596	-0.001	-0.001	-0.130
Lower Left	-725.596	-741.201	-0.001	-0.001	-0.130
Bottom Midside	-561.752	-749.003	-0.004	0.028	-0.132
Lower Right	-397.908	-741.201	-0.011	0.070	-0.134
Lower Right	-382.303	-725.596	-0.015	0.074	-0.141

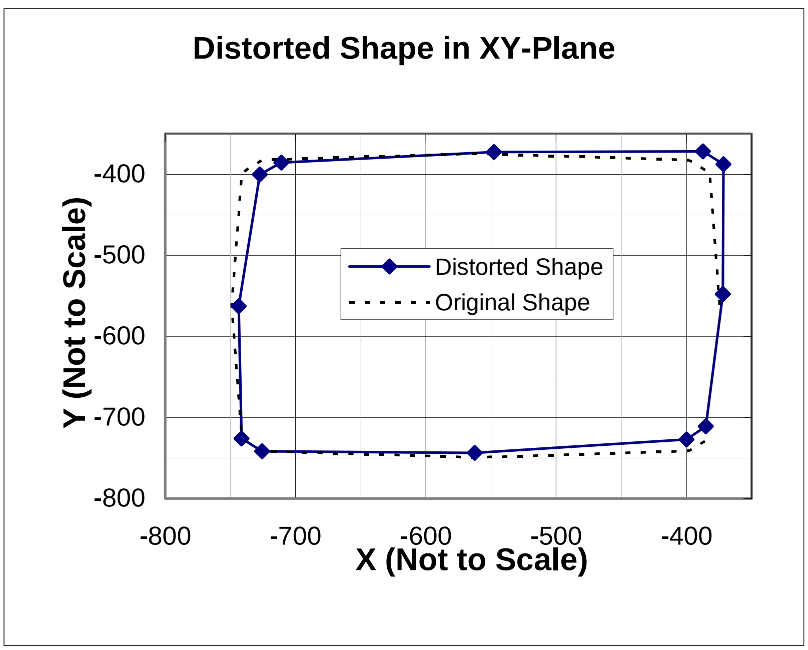


Table 10: TKR-Grid Interface Maximum Distortion [Source: (8)]

<u>CAL—Grid Interface Loads on CAL Tabs</u>

Calorimeter (CAL) module interfaces to the LAT Grid shall use the limit loads shown in Table 11. All tabs should be designed and tested using whichever of the load cases shown in the table produces the highest stresses. Each load case must be evaluated to assure that the peak stress environment for the tab is modeled.

Note that a MUF of at least 15% must be added to all loads shown, for both design and testing.

CAL Tabs	Design Load Cases				Acceptance Test				Qualification Test					
	LC1	LC2	LC3	ECLA	LC1	LC2	LC3	ECLA	LC1	LC2	LC3	ECLA	Unit	Comments
F(x)*	4373	1140	-3302	1717	4373	1140	-3302	1717	5467	1424	-4128	2146	N	Across tab in plane of plate
F(y)*	206	2994	1414	1825	206	2994	1414	1825	258	3742	1767	2281	N	Along tab
F(z)*	-195	-11	654	248	-195	-11	654	248	-244	-14	817	310	N	Out of plane of plate
M(x)*	1.39	-0.05	-6.09	4.90	1.39	-0.05	-6.09	4.90	1.74	-0.06	-7.61	6.13	N-m	Tab Bending/Prying
M(y)*	0.45	-1.28	0.22	2.80	0.45	-1.28	0.22	2.80	0.56	-1.60	0.27	3.50	N-m	Torque/Twist
M(z)*	20.98	4.58	-14.86	9.70	20.98	4.58	-14.86	9.70	26.22	5.73	-18.57	12.13	N-m	Yaw
Source	(6)	(6)	(6)	(7)										

Notes: Interface loads are for CAL tab thickness of 7 mm

* Forces act in tab local coordinate system shown below, and apply irrespective of global tab orientation

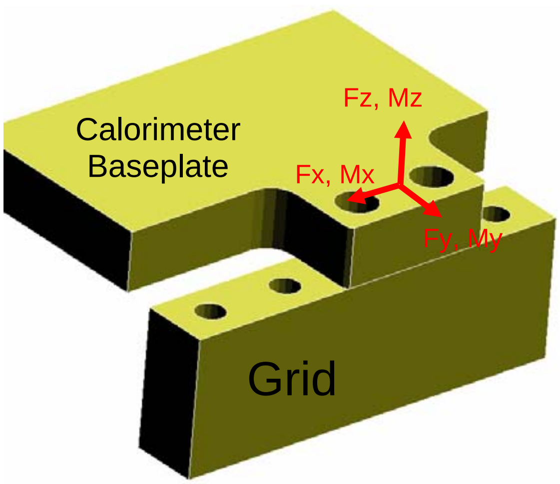


Table 11: CAL-Grid Tab Limit Loads

In addition to the limit loads shown above, the CAL-Grid interface shall be designed to accommodate the out-of-plane distortion of the interface as shown in Table 12. This distortion occurs as a result of Grid deflection during the MECO event. Interface loads resulting from these distortions should not be added to the limit loads discussed above. These loadings are separate, and occur at different times during launch. Further, distortion analysis and testing should not be superimposed with any vibration analysis or testing, as these also occur at different times during launch. However, analysis of the MECO static-equivalent accelerations and interface distortions should be superimposed.

	Tab Location [mm]		Tab Motion [mm]		
#	X	Y	Ux	Uy	Uz
1	-136.68	-187.25	0.00	0.00	-0.13
2	-87.75	-187.25	0.00	0.00	-0.13
3	-48.75	-187.25	0.00	0.00	-0.13
4	-9.75	-187.25	0.00	0.00	-0.13
5	29.25	-187.25	0.00	-0.01	-0.13
6	68.25	-187.25	0.00	-0.01	-0.13
7	117.68	-187.25	0.00	-0.01	-0.13
8	187.25	-136.68	0.00	-0.02	-0.15
9	187.25	-87.75	0.00	-0.02	-0.18
10	187.25	-48.75	0.00	-0.02	-0.20
11	187.25	-9.75	0.00	-0.01	-0.22
12	187.25	29.25	0.00	-0.01	-0.24
13	187.25	68.25	0.00	-0.01	-0.26
14	187.25	117.65	-0.01	-0.01	-0.28
15	136.68	187.25	-0.01	-0.01	-0.29
16	87.75	187.25	-0.01	-0.01	-0.27
17	48.75	187.25	-0.01	0.00	-0.25
18	9.75	187.25	-0.01	0.00	-0.23
19	-29.25	187.25	-0.01	0.00	-0.21
20	-68.25	187.25	-0.02	0.00	-0.19
21	-117.68	187.25	-0.02	0.00	-0.17
22	-187.25	136.65	-0.01	0.00	-0.13
23	-187.25	87.75	-0.01	0.00	-0.13
24	-187.25	48.75	-0.01	0.00	-0.13
25	-187.25	9.75	0.00	0.00	-0.13
26	-187.25	-29.25	0.00	0.00	-0.13
27	-187.25	-68.25	0.00	0.00	-0.13
28	-187.25	-117.68	0.00	0.00	-0.13

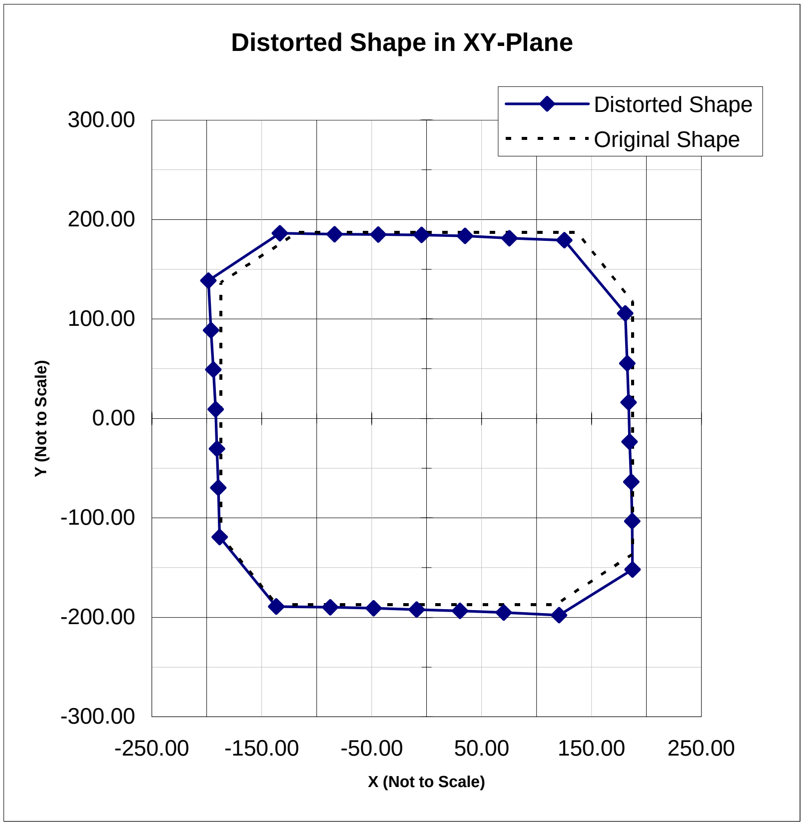


Table 12: CAL-Grid Interface Distortion for Worst-Case Grid Bay [Source: (8)]

The distortions shown are for a Grid corner bay, where the maximum distortions occur. The "Tab Location" columns show the original x and y coordinates of the center points of the tabs' interfaces with the Grid in the local coordinate system. The fourth, fifth, and sixth columns show the displacements due to the MECO thrust.

ACD—Grid Mount

Anticoincidence Detector (ACD) interface designs shall use the limit loads as shown in

Table 13. Until such time as an updated CLA is complete, ACD stress analysis should use the loads shown. For analysis, the shear and tension/compression loads should be combined in the worst-case load configuration.

ACD-Grid Mount	Design	Accept.	PFQ	Unit	Comment
Corner Mounts					
Shear	0	0	0	N	RSS of X, Y max shear
Tens/Compression	1042	1042	1303	N	Parallel to LAT Z-axis
Mid-Side Mounts					
Shear	4170	4170	5213	N	RSS of X, Z shears in plane of Grid wall
Tens/Compression	4039	4039	5049	N	Normal to Grid wall
Source					

Table 13: ACD-Grid Limit Loads

In addition to the limit loads shown, the ACD-Grid interface shall be designed to accommodate the out-of-plane distortion of the interface as shown in Table 14. This distortion occurs as a result of Grid deflection during the MECO event. The interface displacements for the MECO event are nearly cylindrically symmetric, and there are only three unique connection points: two mid-side and one corner, so three sets of displacements fully describe the interface distortion. The vertical displacements shown have been normalized so that the lower mid-side connection is the zero point. Displacements are in cylindrical coordinates. Alternatively, the ACD may be analyzed using the integrated LAT FEA model to ensure the Grid distortions are adequately captured in the analysis.

Interface loads resulting form these distortions should not be added to the limit loads discussed above, which occur at different times during launch. Further, distortion analysis should not be superimposed with any vibration analysis or testing, as these also occur at different times during launch. However, analysis of the MECO static-equivalent accelerations and interface distortions should be superimposed.

ACD	Displacements	
Mount Point	Radial	Vertical
Lower Midside	-39	0
Upper Midside	-97	-5
Corner	6	-140

Dimensions in microns

Data Source: (5)

Table 14: ACD-Grid Interface Distortion

Electronic Box—CAL Interface Loads

The limit loads for the stand-off post mount to the CAL bottom plate is shown in Table 15. These loads should be used for the design of the neighboring components, as well as the stand-offs themselves. The loads are approximate, based on hand analysis of using the electronics box (E-Box) accelerations from above, but should bound the interface loads. Complete analysis of this will be completed for CDR and more precise limit load predicts will be added then. Note that these loads apply at the plane of the interface, which is the connection of the stand-off to the CAL base plate back side.

E-Box Stand-Off	Design	Accept.	Qual	Unit
Tension	3,750	3,750	4,688	N
Compression	2,625	2,625	3,281	N
Shear	1,288	1,288	1,609	N
Bending Moment	19.3	19.3	24.1	N-m

Table 15: E-Box--CAL Flex Post Limit Loads (Source [7])

LAT—SC at LAT Mount Boss

The LAT interface to the SC bus flexures shall use the limit loads shown in Table 16. The lift-off/transonic loads shown in this table are the maxima of loads for all four mount points for all of the flight events during this launch time frame. Loads for a given load case shall be applied simultaneously for design analyses and testing.

LAT-SC Mount	Design		Acceptance		Protoflight Qual		Unit	Comment
Launch Event	Lift-Off/ Transonic	MECO	Lift-Off/ Transonic	MECO	Lift-Off/ Transonic	MECO		
Radial								Along radial line through mount point
Force	+/-969	0	+/-969	0	+/-1211	0	N	
Moment	+/-303	0	+/-303	0	+/-379	0	N-m	
Tangential								Parallel to Grid wall
Force	+/-25243	0	+/-25243	0	+/-31554	0	N	
Moment	+/-503	0	+/-503	0	+/-629	0	N-m	
Z-Axis					21,991			Parallel to LAT Z-axis
Force	+38774 / -17593	45,218	+38774 / -17593	45,218	+48468 / -21991	56,523	N	
Moment	+/-473	0	+/-473	0	+/-591	0	N-m	
Source	(12)	(4)	(12)	(4)	(12)	(4)		

Table 16: LAT-SC Mount Limit Loads [Source: (7)]

Radiator Interface Loads

The Radiator interface to the Grid Radiator Mount Brackets and Variable Conductance Heat Pipe (VCHP) interface to the Heat Pipe Patch Panel shall use the limit loads shown in Table 17. The Radiator interface to the SC bus struts shall use the limit loads shown in Table 18. Loads are derived from the LAT static-equivalent analysis, using LAT center-of-gravity accelerations. The preliminary CLA of the LAT/Radiators on a generic spacecraft predicted a maximum strut load of only 365 N, so the CLA does not produce the limit load for this interface. Acoustic analysis predictions could alter these limit loads for the interface to the SC mount struts. Until such analysis is completed and validated, these loads are expected to bound the design.

CLA-Based Analysis*

Rad-Rad Mnt Bkt	Design	Accept	PFQ	Unit
In-Plane Lateral	795	795	994	N
Normal to Plane	1,440	1,440	1,800	N
Z-Axis	1,336	1,336	1,670	N
Source	(4), (9)			

VCHP-Patch Plate	Design	Accept	PFQ	Unit
In-Plane Lateral	8	8	10	N
Normal to Plane	88	88	110	N
Z-Axis	27	27	34	N
Source	(4), (9)			

Acoustic-Based Analysis

Rad-Rad Mnt Bkt	Design	Accept	PFQ	Unit
In-Plane Lateral	66	66	83	N
Normal to Plane	3,174	3,174	3,968	N
Z-Axis	397	397	496	N
Source	(9)			

VCHP-Patch Plate	Design	Accept	PFQ	Unit
In-Plane Lateral	6	6	8	N
Normal to Plane	109	109	136	N
Z-Axis	134	134	167	N
Source	(9)			

Table 17: Radiator-Grid Interface Limit Loads (Source [9])

Radiator-SC Strut	Design	Accept	PFQ	Unit
In-Plane Lateral	0	0	0	N
Normal to Plane	2,997	2,997	3,746	N
Z-Axis	0	0	0	N
Source	(9)			

Table 18: Radiator-SC Strut Limit Loads (Source [9])

8.3. Pressure and Pressure Changes

LAT components and assemblies shall be capable of withstanding the time rate of change of pressure in the launch vehicle fairing, as shown in Figure 3, below. In accordance with Goddard Environmental Verification Specification (GEVS) section 2.4.6, qualification by analysis must demonstrate a positive margin with respect to the maximum profile shown of 100%. Acceptance verification is not required.

Source of requirement: MSS 3.2.5.2

Data sources:

MDC 00H0016, "Delta II Payload Planners Guide (PPG)", October 2000, Section 4.2.1, Figure 4-6

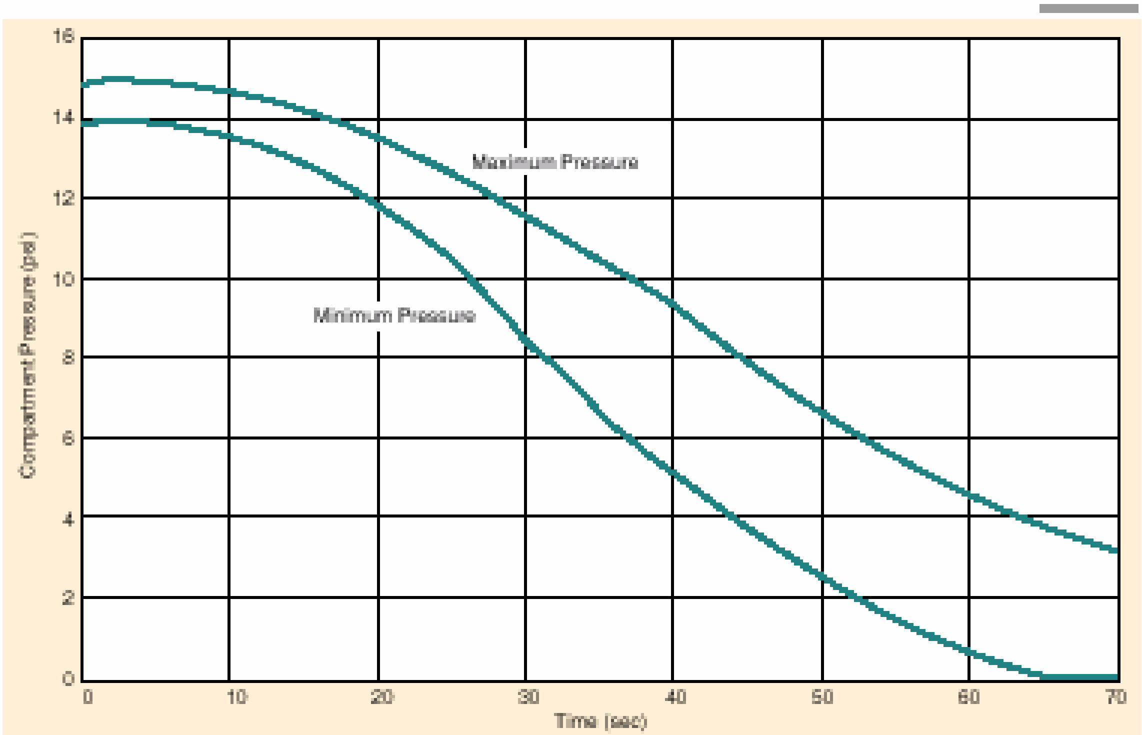


Figure 4-6. Delta II Payload Fairing Compartment Absolute Pressure Envelope

Figure 3: Pressure Rate-of-Change During Launch (note pressure is in psi: 1 psi = 6895 Pa)

9. Vibration and Acoustic Environments

High frequency sinusoidal vibration, random vibration, and acoustic environments must be examined separately in determining margins of safety. Qualification and verification tests—if any—for any or all of these environments can be performed separately.

9.1. Sinusoidal Vibration

The LAT and all subsystems shall be capable of full operational performance after exposure to the sinusoidal vibration loads due to the launch environment shown in, below. The spectra shown in the table is clipped at 50 Hz with respect to the PPG spectra. This is specified in the IRD requirement, which reiterates Goddard Space Flight Center (GSFC) policy that sine vibration testing is performed only up to 50 Hz. Notching of the test levels shown is allowed to avoid over-testing of the structures. However, justification for this should be addressed in the particular test plans.

Data sources:

(1) MDC 00H0016, "Delta II Payload Planners Guide (PPG)", October 2000, Sections 4.2.3.4 and 4.2.4.3, Tables 4-7 and 4-12, as modified by IRD instructions

(2) GEVS-SE Rev A, "General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components", June 1996, Table 2.4-4, Section 2.4.2.5

(3) LAT Sine Vibration Test Specifications: Farhad Tahmasebi, dated 3/15/04

(4) LAT ACD Sine Vibration Specifications: Farhad Tahmasebi, dated 2/24/04

(5) LAT Calorimeter Sine Vibration Specifications: Farhad Tahmasebi, dated 1/16/04

(6) LAT TKR Sine Vibration and Static Test Specifications: Farhad Tahmasebi, dated 1/9/04

LAT Acceptance Test Levels			
Axis	Freq. (Hz)	Test levels [g]	Sweep Rate [oct./min]
Thrust	5 - 15	0.3	4
	15 - 25	0.9	4
	25 - 35	2.2	1.5
	35 - 50	0.5	4
	5 - 15	1.7	4
	15 - 25	0.4	4
	25 - 35	0.4	1.5
Lateral	35 - 50	0.4	4

LAT Protoflight Test Levels			
Axis	Freq. (Hz)	Test levels [g]	Sweep Rate [oct./min]
Thrust	5 - 15	0.4	4
	15 - 25	1.2	4
	25 - 35	2.8	1.5
	35 - 50	0.7	4
	5 - 15	2.2	4
	15 - 25	0.5	4
	25 - 35	0.5	1.5
Lateral	35 - 50	0.5	4

Notes:
1) The test levels represent LAT Net CG responses
2) Input levels may be notched so that the interface forces or response accelerations do not exceed flight loads predictions

Table 19: LAT Sinusoidal Vibration Levels (Source [3])

In addition to the Observatory level sine vibration environment, subsystems shall be capable of full operational performance after exposure to the sinusoidal vibration loads associated with observatory resonances in the launch environment. Table 20 through Table 22 show the appropriate subsystem sine vibration loads when coupled to the observatory.

LAT TKR Acceptance Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	1.92 g	4
	25 - 35	4.72 g	1.5
	40 - 50	1.6 g	4
Lateral (X&Y)	5 - 15	2.56 g	4
	15 - 25	1.12 g	4
	25 - 35	1.12 g	1.5
	35 - 40	1.12 g	4
	40 - 50	1.84 g	4
LAT TKR Protoflight Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	2.4 g	4
	25 - 35	5.9 g	1.5
	40 - 50	2 g	4
Lateral (X&Y)	5 - 15	3.2 g	4
	15 - 25	1.4 g	4
	25 - 35	1.4 g	1.5
	35 - 40	1.4 g	4
	40 - 50	2.3 g	4
LAT TKR Prototype/Qual Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	2.4 g	2
	25 - 35	5.9 g	0.75
	40 - 50	2 g	2
Lateral (X&Y)	5 - 15	3.2 g	2
	15 - 25	1.4 g	2
	25 - 35	1.4 g	0.75
	35 - 40	1.4 g	2
	40 - 50	2.3 g	2

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 2.4g'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.

Table 20: TKR Subsystem Sinusoidal Vibration Levels (Source [6])

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	1.5
	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	1.5
	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	1.5
	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	1.5
	35 - 43	1.5 g	4
	43 - 50	1.9 g	4
LAT CAL Prototype/Qual Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	2.5 g	2
	25 - 35	5.9 g	0.75
	40 - 50	2.1 g	2
Lateral (X&Y)	5 - 15	2.7 g	2
	15 - 25	1.2 g	2
	25 - 35	1.2 g	0.75
	35 - 43	1.5 g	2
	43 - 50	1.9 g	2

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.

Table 21: CAL Subsystem Sinusoidal Vibration Levels (Source [5])

LAT ACD Acceptance Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 15	0.3 g	4
	15-25	0.9 g	4
	25 - 35	2.1 g	1.5
	35 - 50	0.5 g	4
Lateral (X&Y)	5 - 15	2.0 g	4
	15 - 25	0.7 g	4
	25 - 35	0.7 g	1.5
	35 - 40	0.7 g	4
	40 - 50	1.5 g	4
LAT ACD Protoflight Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 15	0.4 g	4
	15-25	1.2 g	4
	25 - 35	2.7 g	1.5
	35 - 50	0.7 g	4
Lateral (X&Y)	5 - 15	2.5 g	4
	15 - 25	0.9 g	4
	25 - 35	0.9 g	1.5
	35 - 40	0.9 g	4
	40 - 50	1.9 g	4
LAT ACD Prototype/Qual Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 15	0.4 g	2
	15-25	1.2 g	2
	25 - 35	2.7 g	0.75
	35 - 50	0.7 g	2
Lateral (X&Y)	5 - 15	2.5 g	2
	15 - 25	0.9 g	2
	25 - 35	0.9 g	0.75
	35 - 40	0.9 g	2
	40 - 50	1.9 g	2

Notes: (1) The test levels represent ACD Net CD Responses
(2) Input levels should be notched to that interface forces or response accelerations do not exceed flight loads predictions

Table 22: ACD Subsystem Sinusoidal Vibration Levels (Source [4])

9.2. Random Vibration

LAT subsystem modules (a.k.a: "components," as defined in GEVS) shall be capable of full operational performance after exposure to the random vibration acceleration spectral density (ASD) levels due to the launch environment described in Table 23, below. The values to be used are defined as the "generalized random vibration power spectral density" in GEVS. Thus, the vibration spectrum shown for the Delta II in Appendix D, Table D-6 may NOT be used for subsystem random vibration design or testing. The rationale for using the higher generalized spectrum is that the Delta II Heavy has never been used before, so random vibration spectra are not fully understood. Thus, using the generalized spectrum from GEVS is most likely to bound the actual spectrum we should see.

	ASD Level (G^2/Hz)	
Freq (Hz)	**Accept**	**Qual**
20	0.013	0.026
20-50	+6 dB/oct	+6 dB/oct
50-800	0.080	0.160
800-2000	-6 dB/oct	-6 dB/oct
2000	0.013	0.026
Overall	10 G_{rms}	14.1 G_{rms}

Table 23: Random Vibration Levels per GEVS-SE Section 2.4.2.5 for Components Weighing Less than 22.7 kg

The GEVS generalized table allows the amplitude of the vibration spectrum to be scaled by the mass of the component. The scaling methodology is described in GEVS Section 2.4.2.5. Table 24 through Table 28 show the subsystem vibration spectra scaled appropriately according to the GEVS algorithm and using the subsystem mass indicated in the table. Note that the scaling allows for a reduction in acceleration amplitude with increased mass. Thus, to be conservative in the scaling, the base mass of each subsystem is used, with no added reserve.

These spectra shall be used to design and test each subsystem. However, they should not be used to evaluate deflections or relative motions of subsystems. CLA and acoustic analysis will determine the correct random vibration spectra to be used for this evaluation.

Note that LAT-MD-00408-01, the LAT Performance Verification Plan, specifically omits the assembled LAT and the Radiator sub-assemblies from a random vibration test. Thus, design and test environments for these structures is not included. For both structures, the appropriate random vibration environments results from the acoustic loads impinging on the structures. This analysis will be used to generate the appropriate test spectra.

Data sources:

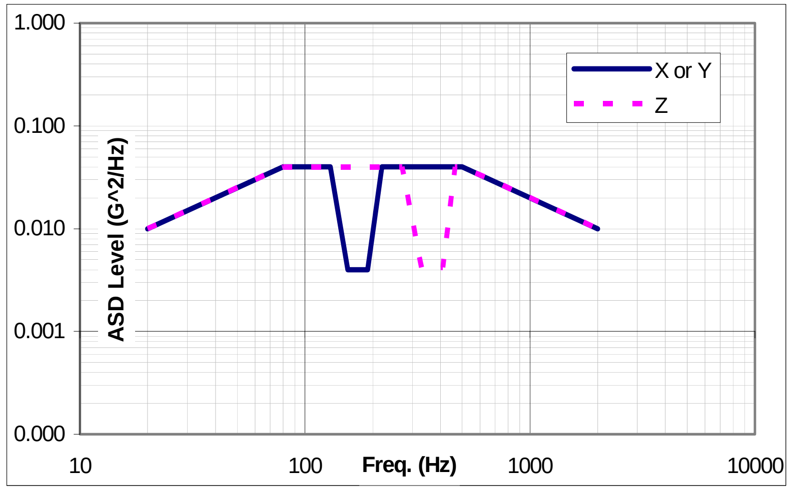
(1) GEVS-SE Rev A, “General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components”, June 1996, Table 2.4-4, Section 2.4.2.5

(2) SAI-TM-2443, “GLAST Tracker Random Vibration Analysis”, Jan, 2004

(3) SAI-TM-487, “Updated GLAST LAT-Subsystem Vibration Test Levels”, Mar 04

TKR Module
Random Vibration Spectra

Freq (Hz)	Accept and Qual ASD	
	X or Y	Z
20	0.010	0.010
80	0.040	0.040
130	*0.040*	*0.040*
155	*0.004*	*0.040*
190	*0.004*	*0.040*
220	*0.040*	*0.040*
270	*0.040*	*0.040*
330	*0.040*	*0.004*
410	*0.040*	*0.004*
465	*0.040*	*0.040*
500	0.040	0.040
2000	0.010	0.010
Overall	6.59 Grms	6.35 Grms
Duration	60s/axis AT, PT 120s/axis QT	



NOTE: These levels are based upon fundamental frequencies of 175 Hz in X or Y, 370 Hz in Z, and Q=10. The notch portion (italics) will require adjustment if freqeuncy or Q varies by more than 10%.

Table 24: TKR Module Random Vibration Acceleration Spectral Density (Source: [2])

CAL Module
Random Vibration Spectra

Freq (Hz)	ASD Level (G^2/Hz)	
	Accept	Qual
20	0.010	0.010
40	0.020	0.020
990	0.020	0.020
2000	0.010	0.010
Overall	5.8 Grms	5.8 Grms
Duration	60s/axis AT, PT 120s/axis QT	

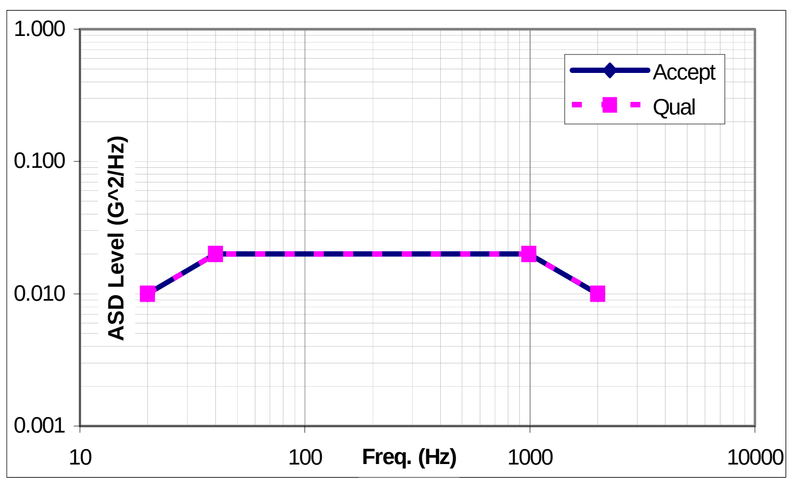
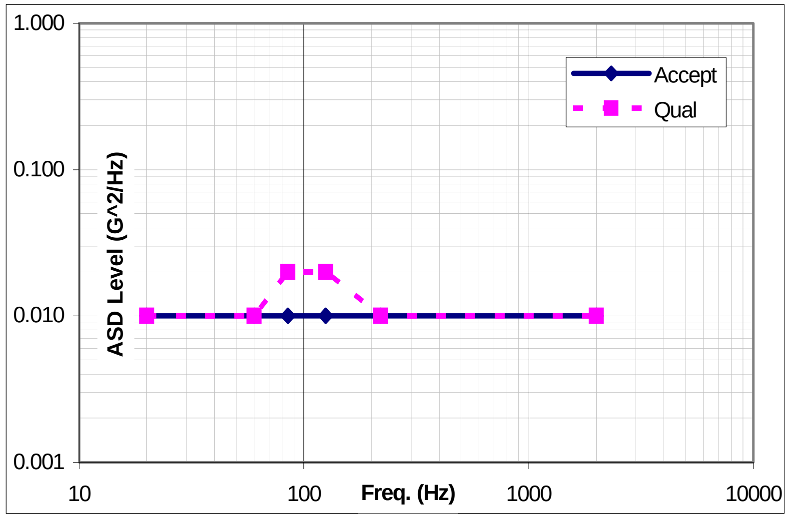


Table 25: CAL Module Random Vibration Acceleration Spectral Density (Source: [3])

ACD
Random Vibration Spectra

Freq (Hz)	ASD Level (G^2/Hz) Accept	Qual
20	0.010	0.010
60	0.010	0.010
85	0.010	0.020
125	0.010	0.020
220	0.010	0.010
2000	0.010	0.010
Overall	4.4 Grms	4.55 Grms
Duration	60s/axis AT, PT 120s/axis QT	



Notes: ACD random vibe testing may be replaced with acoustic testing, if analysis shows this more accurately represents flight dynamic loading.

Table 26: ACD Random Vibration Acceleration Spectral Density (Source: [3])

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	

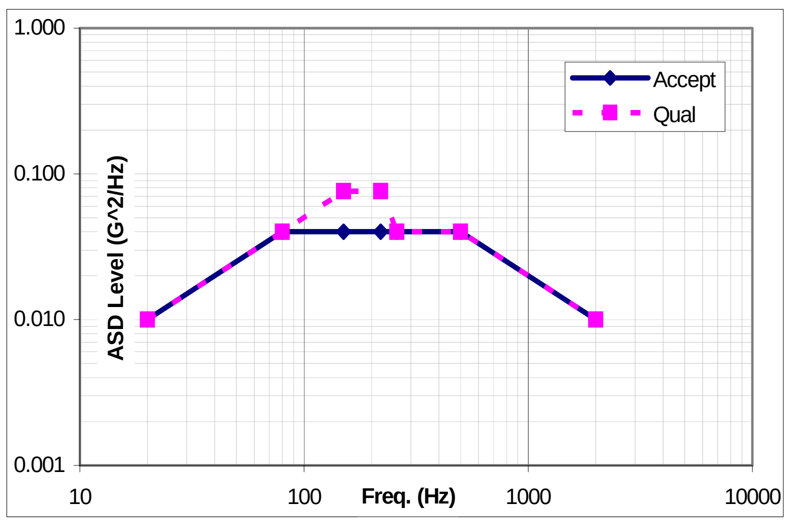


Table 27: Electronics Box (TEM/TPS) Random Vibration Acceleration Spectral Density (Source [3])

Electronics Module (Special Boxes)
Random Vibration Spectra

Freq (Hz)	ASD Level (G^2/Hz) Accept	Qual
20	0.010	0.010
75	0.037	0.038
80	0.040	0.055
115	0.180	0.360
160	0.180	0.360
325	0.040	0.060
350	0.040	0.050
500	0.040	0.050
2000	0.025	0.050
Overall	8.91 Grms	11.51 Grms
Duration	60s/axis AT, PT 120s/axis QT	

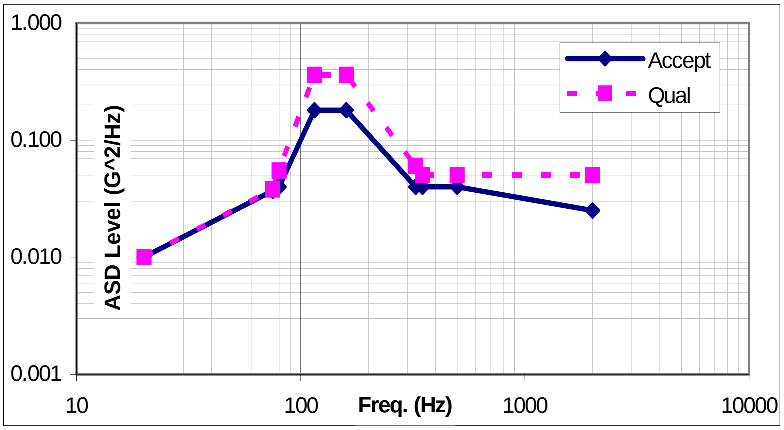


Table 28: Electronics Box (EPU, SIU, PDU, GASU) Random Vibration Acceleration Spectral Density (Source [3])

9.3. Acoustic

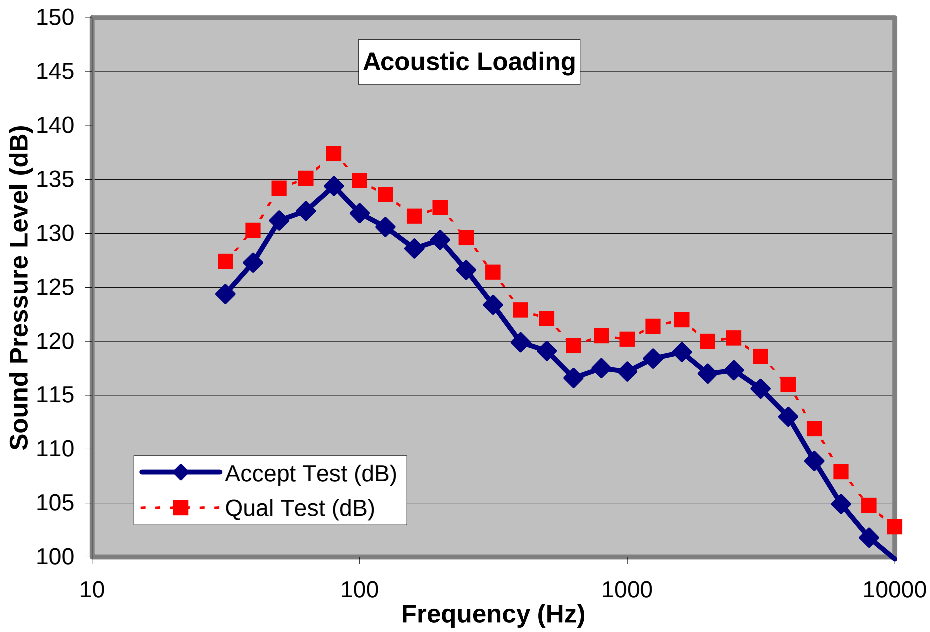
The LAT and all subsystem components and assemblies shall be capable of full operational performance after exposure to the acoustic loads due to the launch environment shown in Figure 4, below. No attenuation should be claimed for interior subsystems. All subsystems must be designed to accommodate the full acoustic loading. This preliminary acoustic spectrum for the Delta II 2920-10H launch vehicle shall be used for design. The spectrum includes adjustments to the 2920-10 acoustic spectrum for the heavier solids of the 2920-10H configuration, the payload fill factor in the fairing based on the GLAST Observatory design as of October 2002, and reductions for launch pad B acoustic improvements at Cape Canaveral Air Force Station (CCAFS).

Source of requirement: same as IRD 3.2.2.8.5

Data sources:

Draft Change Request to 433-SPEC-0003, "Spacecraft Performance Specification," May, 2002, Section 3.2.5.2, provided by Bernie Graf on 3 December 2002.

Freq (Hz)*	Accept Test (dB)	Qual Test (dB)
31.5	124.4	127.4
40	127.3	130.3
50	131.2	134.2
63	132.1	135.1
80	134.4	137.4
100	131.9	134.9
125	130.6	133.6
160	128.6	131.6
200	129.4	132.4
250	126.6	129.6
315	123.4	126.4
400	119.9	122.9
500	119.1	122.1
630	116.6	119.6
800	117.5	120.5
1000	117.2	120.2
1250	118.4	121.4
1600	119	122
2000	117	120
2500	117.3	120.3
3150	115.6	118.6
4000	113	116
5000	108.9	111.9
6300	104.9	107.9
8000	101.8	104.8
10000	99.8	102.8
OASPL	140.8	143.8



(*) One-third octave center frequency
Protoflight Levels = Qualification Levels
Test Duration = 60 seconds for acceptance and protoflight tests
Test Duration = 120 seconds for qualification (prototype) tests

Figure 4: Acoustic Load Environment

10. Shock Environment

The LAT and all subsystem components and assemblies shall be capable of full operational performance after exposure to the shock response spectrum (SRS) due to the launch environment described in Figure 5, below. These are proto-flight test levels. No attenuation of the shock levels internal to the LAT should be used in the design of subsystems for shock loading.

Source of requirement: same as IRD 3.2.2.8.6

Data sources:

Draft change to 433-IRD-0001, submitted by S. Seipel to GLAST project office 31 October 2002. Based on data provided by Spectrum Astro accommodation manager, Tim Morse, dated 22 October 2002.

LAT-SC Mount		LAT Radiator	
Freq (Hz)	**SRS** (g's)	**Freq** (Hz)	**SRS** (g's)
100	24	100	85
242	24	350	85
1201	606	1269	1127
2095	606	1724	1127
3342	932	2228	1427
5000	932	5000	1427
6715	606	5879	1127
10000	606	10000	1127

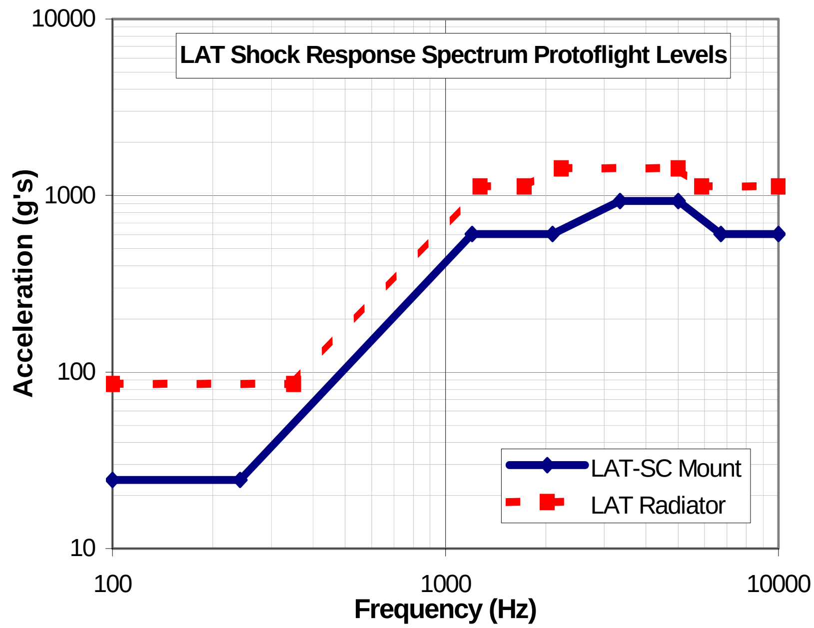


Figure 5: Shock Response Spectrum at the LAT Interface to the SC

11. Thermal Environment

11.1. Orbital Parameters

The LAT shall be in an initial orbit of 550 km, with a range of 450 km, min to 575 km, max, a maximum inclination of 28.5 degrees and a maximum eccentricity of 0.01. LAT components and assemblies shall be capable of operation within the full phase-space allowed by these orbital parameters and the fluxes defined in the table below.

Source of requirement: MSS 3.1.1.4

Data sources:

433-SPEC-0001, "GLAST Mission System Specification", May, 2002, Section 3.1.1.4

11.2. Environmental Thermal Loads

The LAT shall be able to be pointed anywhere, at any time, for any duration, during any normal LAT operating mode.

The environmental parameters and absorbed fluxes delineated in Table 29 shall be used in the design and thermal analysis of the LAT and its subsystems. The design absorbed environmental heat loads shall be applied during LAT thermal-vacuum tests.

The LAT shall be designed to maintain thermal self-control, and to control all LAT subsystems and components within the operating temperature limits shown in Table 30.

Parameter	Surv.	Cold-Case	Nom	Hot-Case	Units	Source
Earth IR on any exposed surface	208	208	265	265	W/m^2	IRD 3.2.3.5, Table 3-3
Earth Albedo on any exposed surfaces	0.25	0.25	0.4	0.4		IRD 3.2.3.5, Table 3-3
Solar Flux on surfaces exposed to +X direction	1286	1286	1419	1419	W/m^2	IRD 3.2.3.5, Table 3-3
Solar flux due to 1 deg glancing view of the sun on +/- Y surfaces	0	0	0	6	W/m^2	SPS 3.4.5.1
Orbit-average absorbed solar flux on one Radiator due to re-pointing	0	0	27	0	W	SPS 3.4.5.1

Table 29: Environmental Heat Loads on the LAT

11.3. Temperature Limits

The LAT and its subsystems shall be designed and tested to operate/survive the temperature extremes shown in Table 30. For all subsystems but Electronics, the temperatures shown are for the hottest/coldest part of the subsystem, and indicate the extremes to which the subsystem must be tested. For the electronics boxes, the temperatures shown are for the box interface to the heat sink.

The survival temperature limits shown are test temperatures for subsystems with units off.

Qualification temperature (QT) limits indicate the range over which the unit will operate within specifications at beginning of life (BOL). Other qualification testing or analysis should demonstrate that the unit also functions within specification at end of life (EOL) at QT. See Section 14 for a definition and description of the test temperatures. Qualification limits shall be used for all prototype qualification units and protoflight qualification (PFQ) units. During LAT thermal-vacuum testing, sink temperatures will be adjusted until at least one subsystem temperature 10 degrees C beyond its operating limit, with the goal of most subsystems reaching this limit.

Acceptance Test (AT) temperature limits specify the range over which the unit will operate within specifications at both BOL and EOL. Operating within specifications at EOL will be shown by having sufficient margin over BOL conditions. All flight hardware shall be tested to AT limits.

Operating limits are the on-orbit operational temperature extremes for the component. This bounds the temperature predictions of the LAT thermal models, with a minimum margin of 5 degC.

Component	Low Temp Limits			High Temp Limits			Survival	
	Qual	AT	Oper.	Oper.	AT	Qual	Low	High
Tracker Module	-30	-20	-15	30	35	50	-30	50
Calorimeter Module	-30	-20	-15	25	35	50	-30	50
TEM, TPS Box (1)	-40	-35	-30	45	50	55	-40	60
EPU Box (1)	-40	-35	-30	45	50	55	-40	60
SIU Box (1, +)	-40	-35	-30	45	50	55	-40	60
PDU Box (1, +)	-40	-35	-30	45	50	55	-40	60
GASU Box (1, +)	-40	-35	-30	45	50	55	-40	60
ACD, BEA Sub-Ass'y (2, +)	-25	-20	-15	30	35	40	-40	45
TSA Sub-Ass'y (+)	-40*	-35	-30	35	40	45	-40	45
Grid Box Sub-Ass'y (+)	-40*	-15	-10	30	35	40	-40	40
CCHP Components	-40*	-15	-10	30	35	40	-67	60
VCHP Components	-40*	-15	-10	30	35	40	-67	60
Radiator Sub-Ass'y (+)	-40	-35	-30	20	25	30	-67	60

Notes:

All temperatures are in degrees C; see acronym list for an explanation of acronyms used

Temperatures shown are for the hottest/coldest extremity of the subsytem, except as indicated

(+) Protoflight units only. Qual temps shown are for proto-flight qual testing

(*) Not all performance requirements will be met at EOL for this test. See Appendix A for a full explanation

(1) Temperatures shown are for the box interface to its heat sink

(2) BEA temperature limits apply to the full ACD assembly as well

Table 30: LAT Design and Test Temperature Limits

12. On-Orbit Environment

12.1. Micrometeoroid Environment

LAT material, components, and assemblies shall be capable of normal operation in the micrometeoroid environment for the life of the mission, as defined in MSS 3.3.6.1.1, with no loss of performance.

The micrometeoroid environment is derived from the latest NASA update to the Orbit Debris Environment Model (ORDEM2000) which is the NASA standard accepted debris model.

The micrometeoroid environment for the GLAST mission is shown in Figure 3. The actual output from the Debris Assessment Software is shown in Table 3. Micrometeoroid impacts are assumed to come from any random direction. An orbital altitude of 575km was used to generate this environment as it is the worst case.

Object size [m]	Max MM Flux [hits/m^2/yr]
1.00E-05	3.88E+02
1.00E-04	7.78E+00
1.00E-03	7.09E-03
1.00E-02	2.21E-06
1.00E-01	1.00E-12
1.00E+00	1.00E-12

Table 31: Micrometeoroid Assessment Software Results

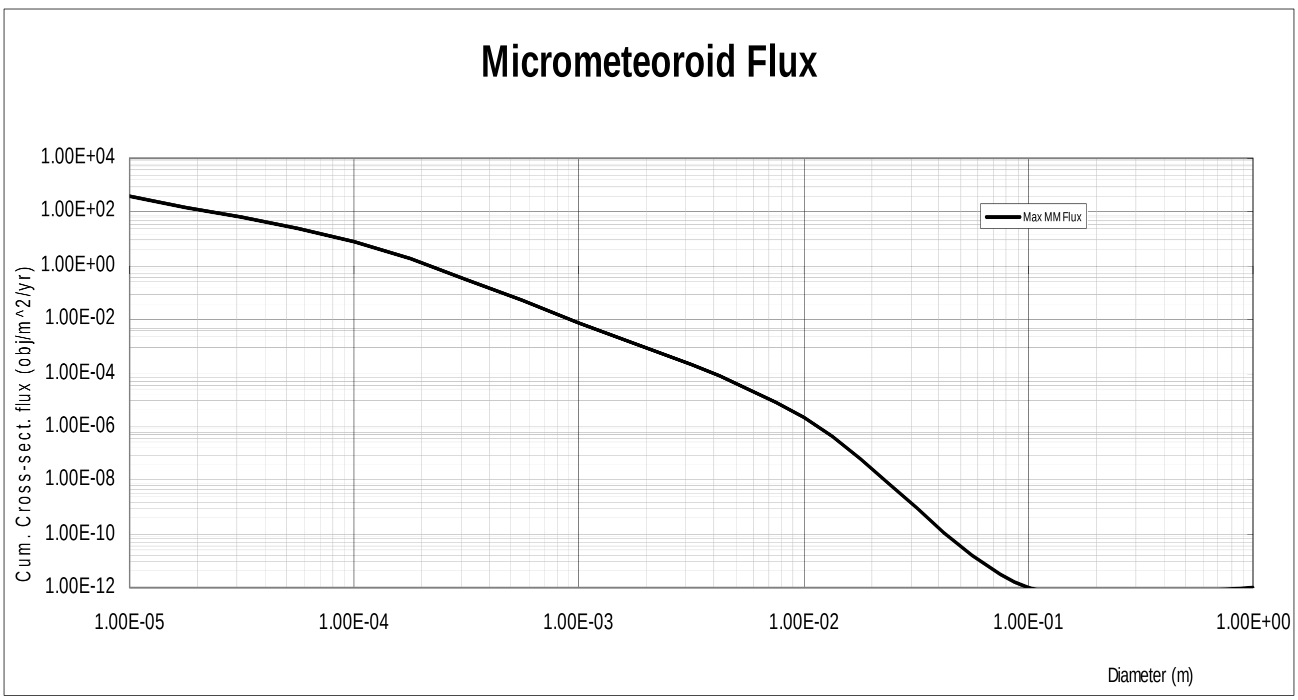


Figure 6: GLAST Mission Micrometeoroid Flux

12.2. Debris Environment

LAT material, components, and assemblies shall be capable of normal operation in the debris environment for the life of the mission, as defined in MSS 3.3.6.1.2, with no loss of performance. The debris flux field for the GLAST mission is shown in Table 32 and Figure 7.

The debris environment is derived from the latest NASA update to the Orbit Debris Environment Model (ORDEM2000) which is the NASA standard accepted debris model.

Particle Velocity [km/sec]: Object size [m]	0.5 kps [obj/m^2/yr]	7.5kps [obj/m^2/yr]	16.5 kps [obj/m^2/yr]	Total Flux [obj/m^2/yr]
1.00E-05	7.72E+00	3.27E+02	7.06E-04	1.40E+03
1.00E-04	3.69E-01	1.20E+01	7.01E-05	4.94E+01
1.00E-03	8.53E-04	2.66E-02	1.43E-07	1.06E-01
1.00E-02	5.34E-08	7.58E-07	1.17E-09	9.72E-06
1.00E-01	6.10E-09	1.29E-07	1.17E-09	1.17E-06
1.00E+00	3.03E-09	6.49E-08	6.59E-10	5.33E-07

Table 32: Output Results For ORDEM2000 Display Average Flux Vs Size. Butterfly Module Was Used For Velocities

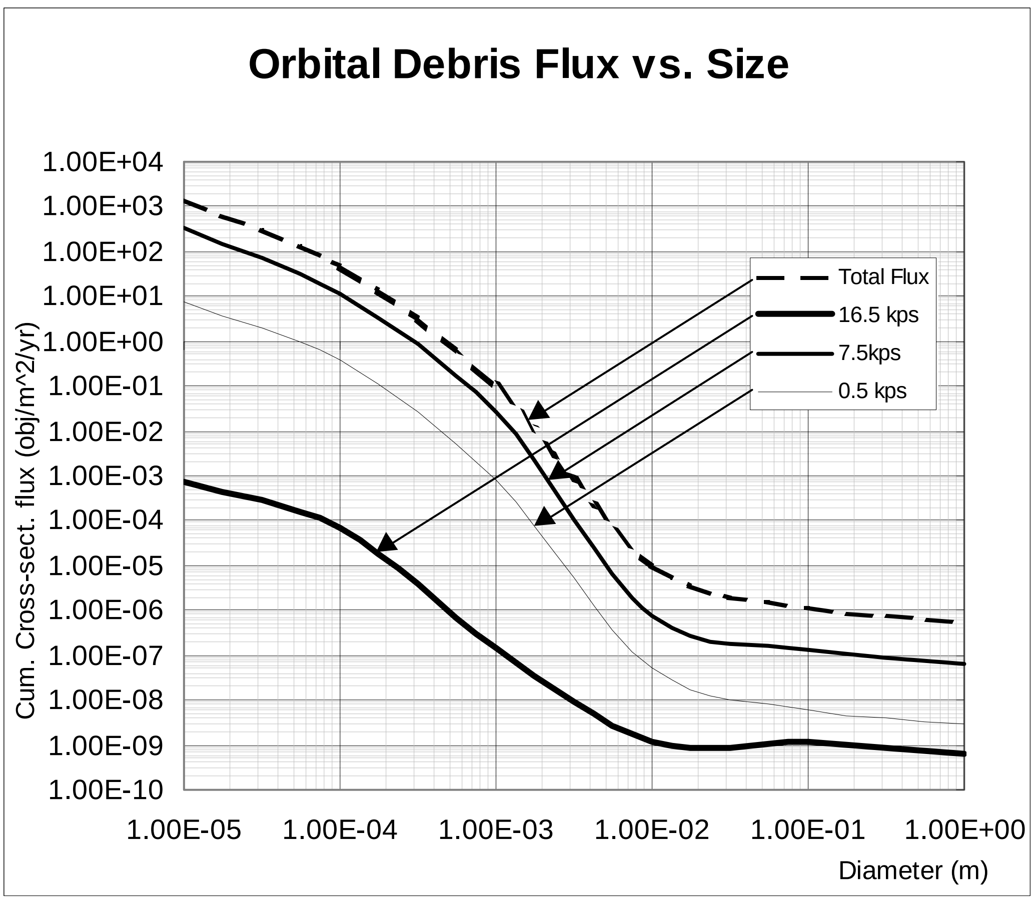


Figure 7: GLAST Program Derived Orbital Debris Flux

12.3. Radiation

LAT materials, components, and assemblies shall be capable of normal operation in the space radiation environment for the life of the mission, as defined in Figure 8, below, with no loss of performance. The Total Ionizing Dose (TID) shown is the top level dose requirement, including a standard factor of safety of 2 used at NASA. For un-shielded components, the TID is 4.5 krad (Si) for the 5 year GLAST mission. Note that the curve shown does not include any built-in design margin. This should be applied as appropriate at the component design level.

See MSS 3.3.6.2 for details of using this in part design and qualification

Data sources:

433-SPEC-0001, “GLAST Mission System Specification”, May, 2002, Section 3.3.6.2.

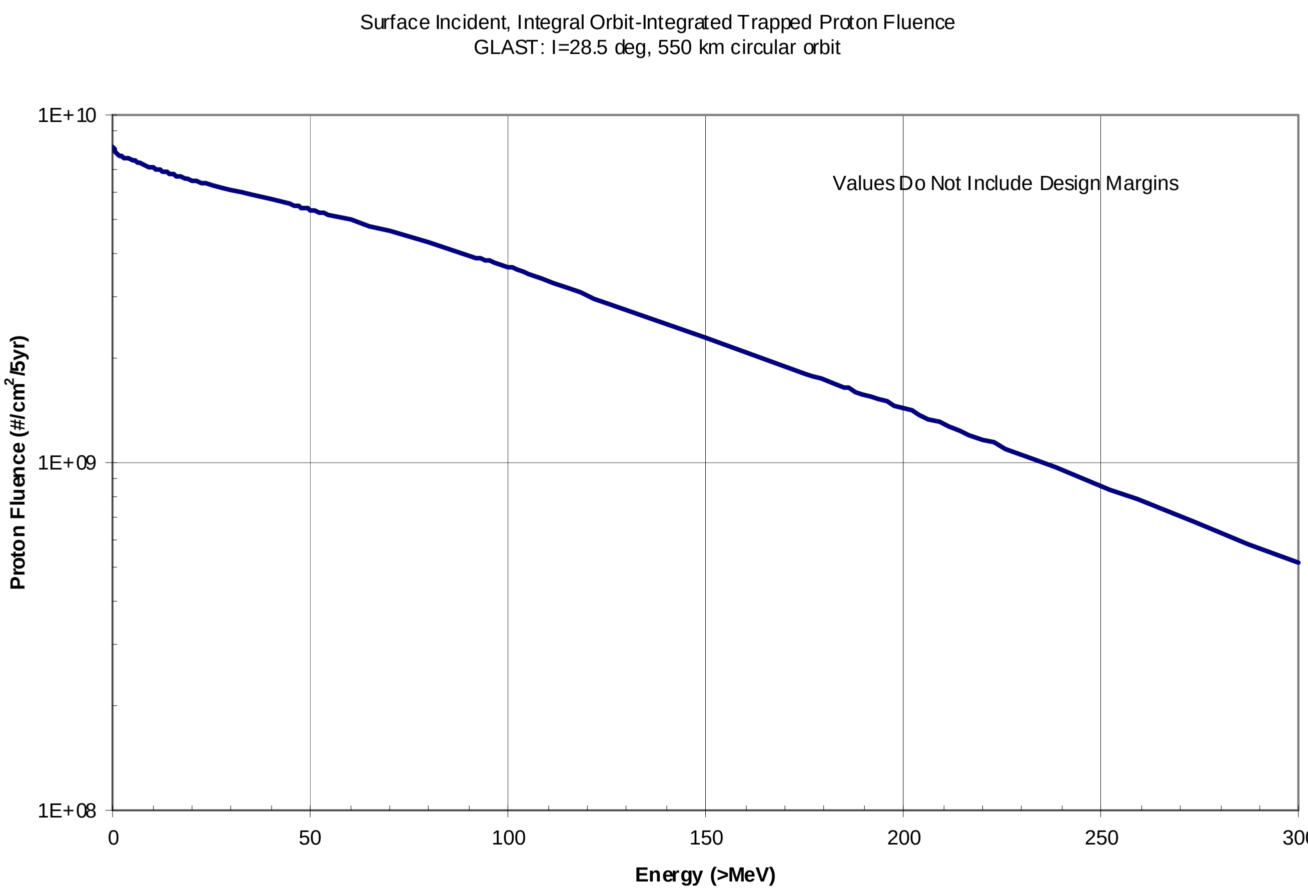


Figure 8: Total Ionizing Dose Environment for the LAT

12.4. Atomic Oxygen

The atomic oxygen envirornment, which shall be used for analysis, 3.67 E+21 atoms/cm2

for all components except the solar arrays. The atomic oxygen environment, which shall be used for analysis of the

solar arrays, is 1.17E+21 atoms/cm2

13. EMI Environments

The LAT EMI requirements are delineated in section 5 of the GLAST EMI requirements document, 433-RQMT-0005. This section of the Environmental Specification covers the EMI/EMC requirements for the LAT equipment.

13.1. Emissions

Radiated Emissions (RE102, RE101)

All LAT equipment shall limit unintentional electric field emissions (RE102) to levels less than the limits specified in Figure 9. Measurement bandwidths above 1 GHz may be modified, if necessary, to achieve sufficient EMI receiver sensitivity.

All LAT components shall limit unintentional magnetic field emissions (RE101) to levels less than the limits specified in Figure 10 when measured at a distance of 1 meter from the instrument enclosure.

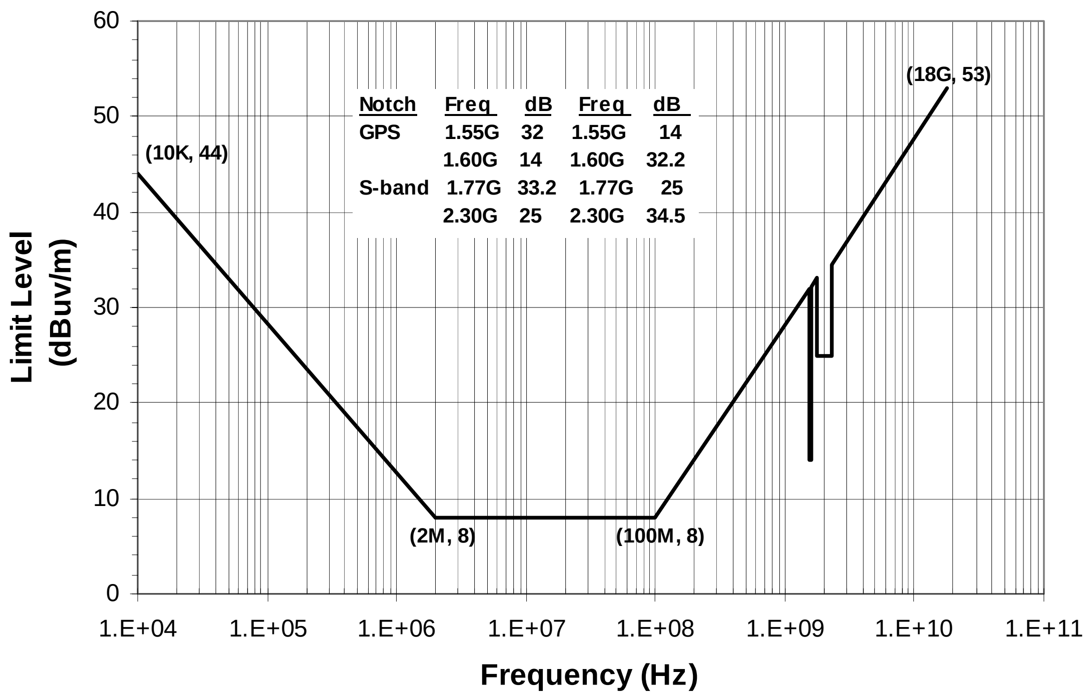


Figure 9: RE102 – All LAT Equipment

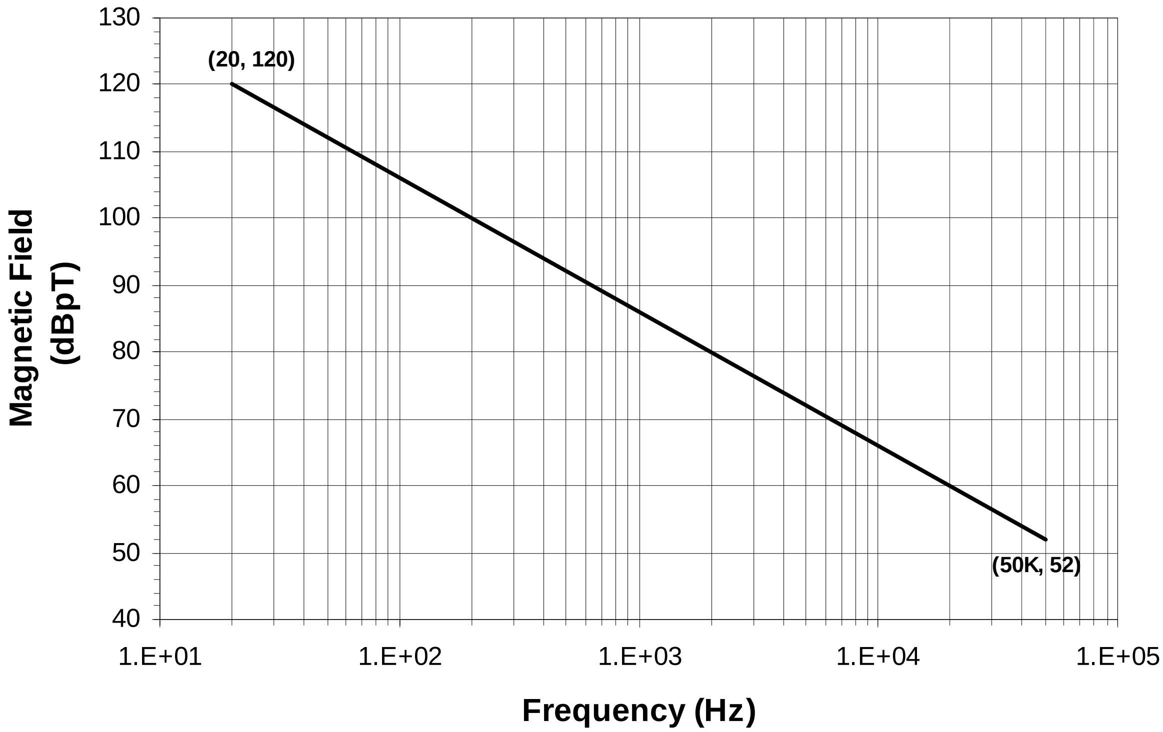


Figure 10 RE101 – All LAT Equipment

Conducted Emissions (CE102, CECM)

LAT equipment shall limit prime power conducted emissions to levels less than the limits specified in Figures 11, 12, 13, and 14. (IL – internal load)

Refer to Figure 15 for the applicability of these requirements.

LAT equipment shall limit prime power common mode conducted emissions to levels less than or equal to the limits specified in Figure 16.

LAT equipment shall limit repetitive spikes to less than the limits specified in Figures 11, 12, 13, 14, and 16.

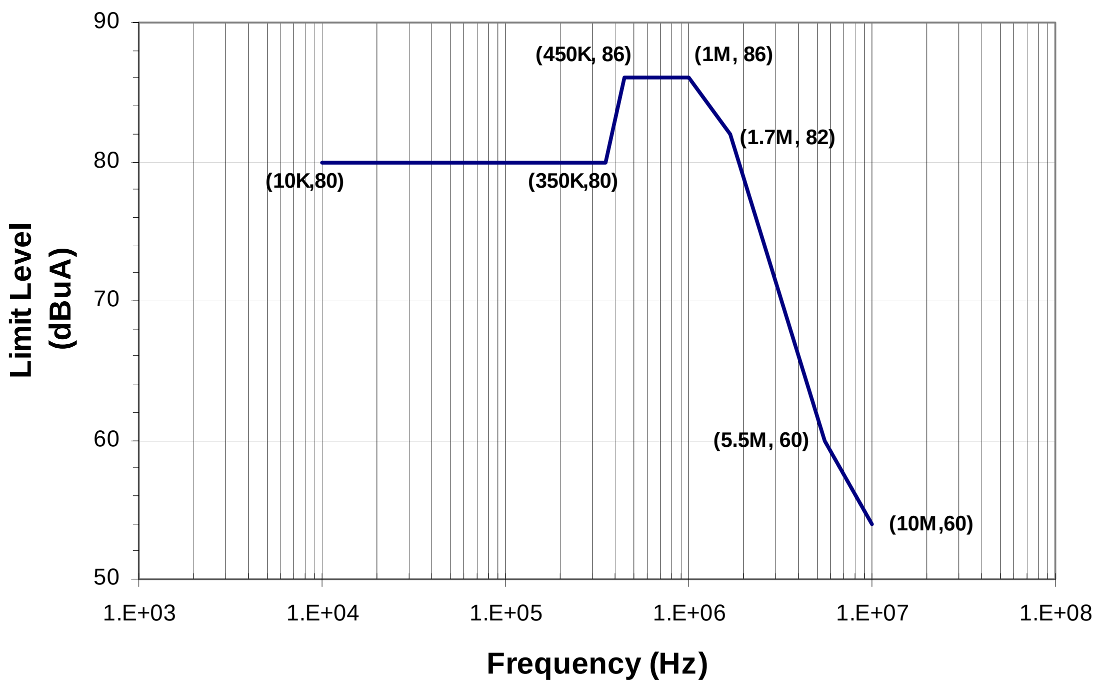


Figure 11. CE102 Spacecraft PRU – LAT DAQ

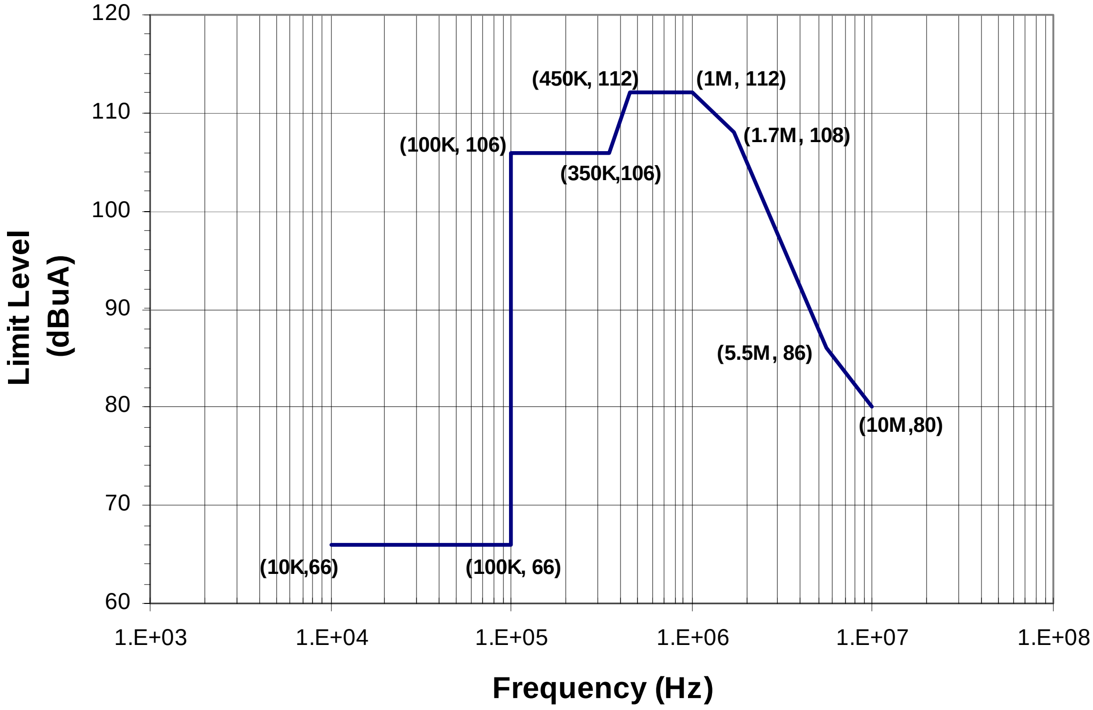


Figure 12. CE 102 LAT PDU – TPS (TEM, CAL, TRKR), EPU (IL), GASU (ACD BEA, IL), PDU (IL)

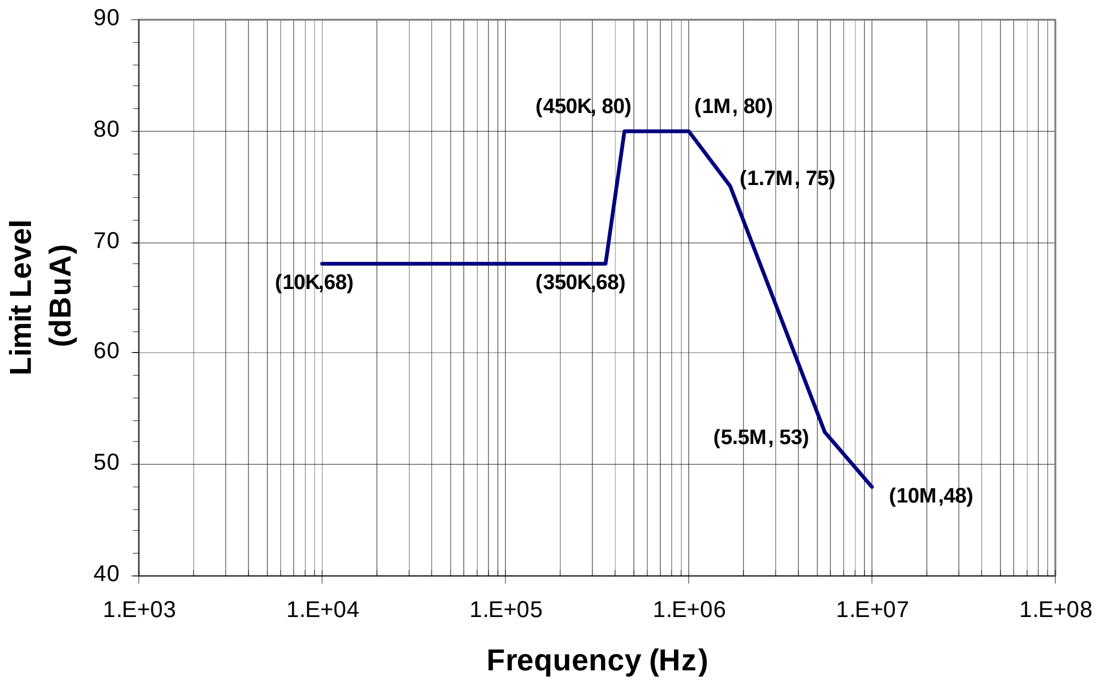


Figure 13. CE102 Spacecraft PRU – LAT SIU (IL), VCHP Heaters

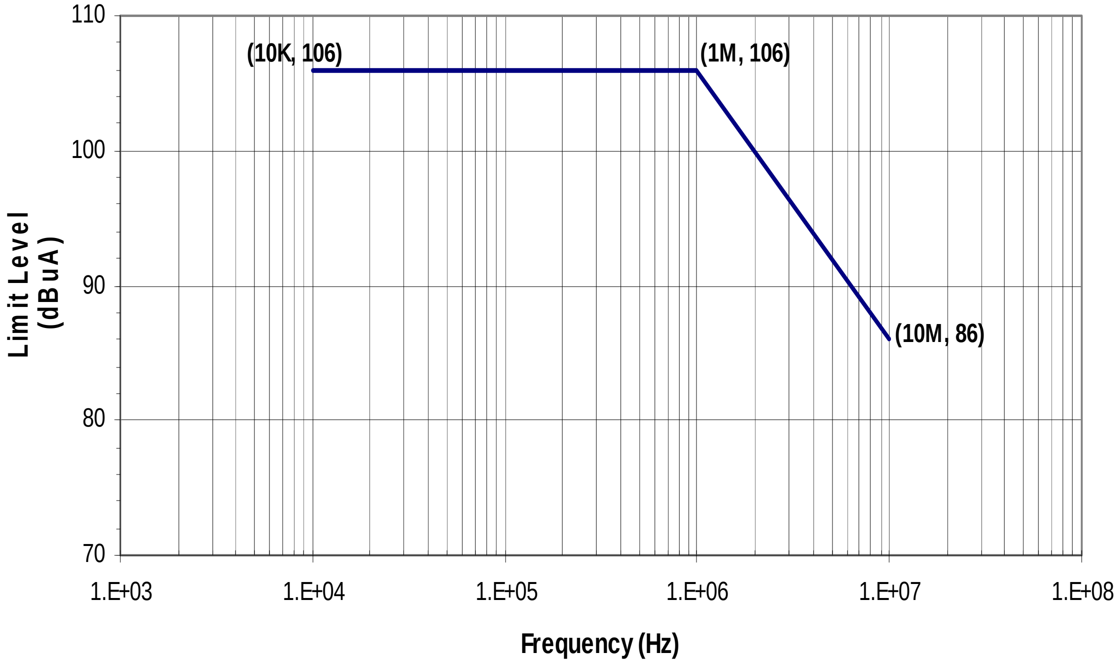


Figure 14. CE102 Spacecraft PDU – LAT Anti-freeze and Make-up Heaters

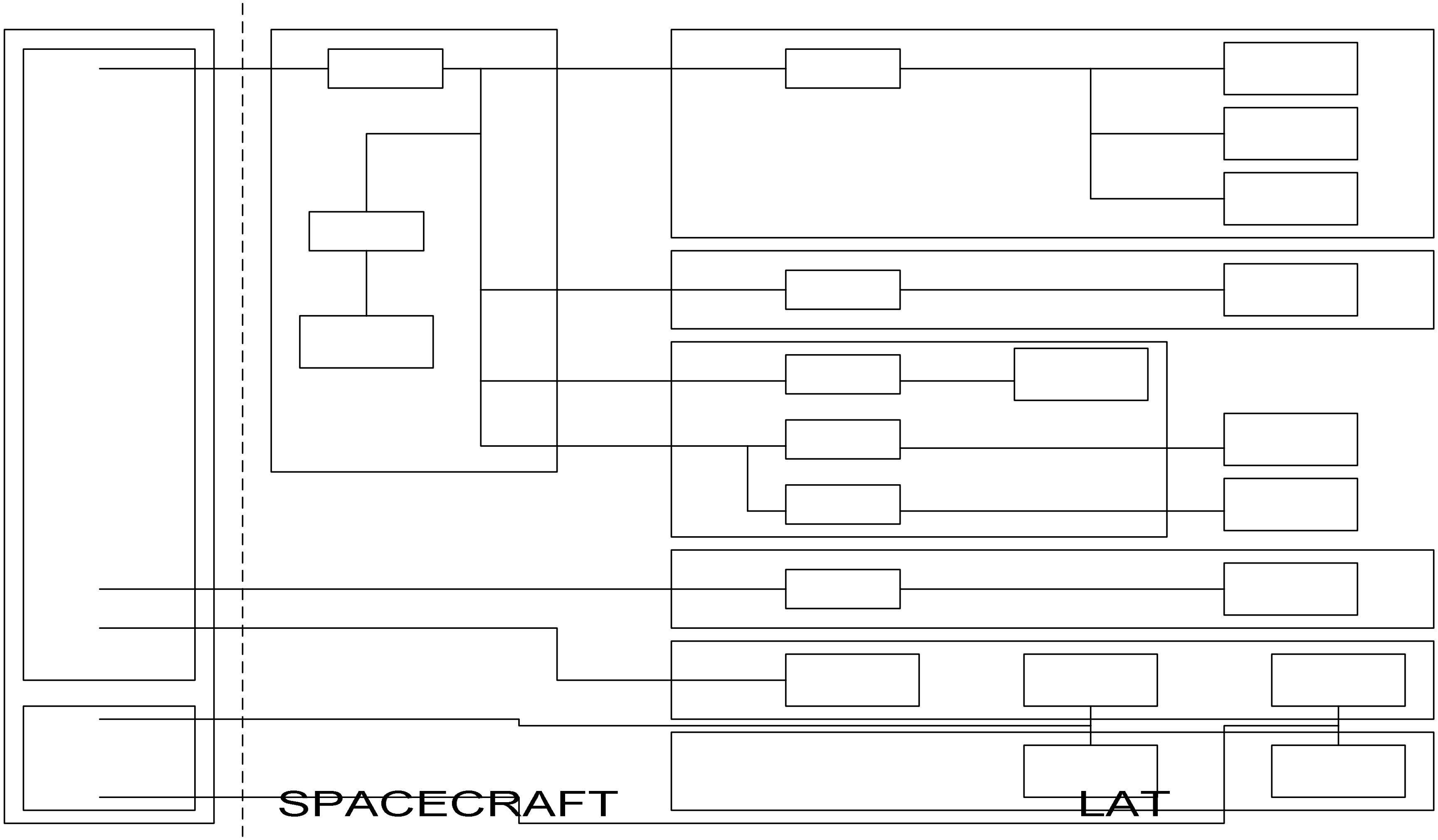


Figure 15. Applicability of Requirements in Figures 11, 12, 13, 14, 23, 24, 25, 26

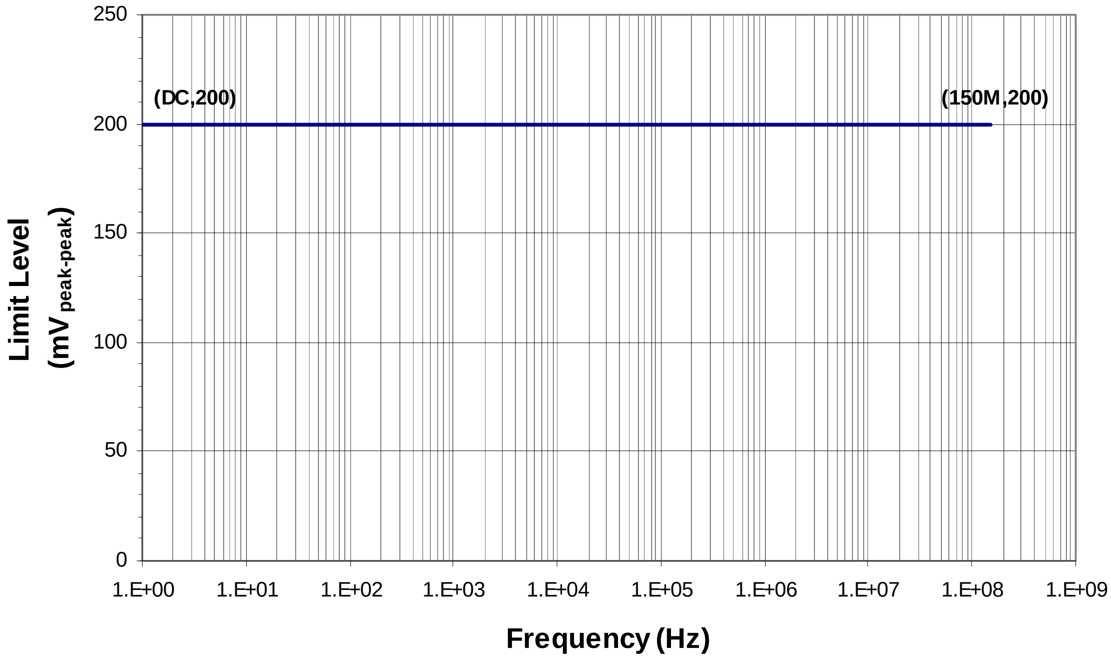


Figure 16. Conducted Emissions Common Mode – All LAT Equipment

13.2. Radiated Susceptibility and Definition of Susceptibility Criteria

The susceptibility criteria for instruments are divided into three categories. These categories are survive, operate and perform and are defined as follows:

a. Survive is defined as the ability to withstand the applied environment without any permanent loss of performance capability. Survival is required for both powered and unpowered states.

b. Operate is defined as the ability to withstand the applied environment without malfunction, loss of capability, change of operation state/mode, memory changes or need for outside intervention. Operate is the ability of an instrument/equipment to execute all ancillary and housekeeping tasks including self test but does not include the ability to take scientific data.

c. Perform is defined as the ability to execute its science mission or to meet its specified performance. Perform requires that the Operate criteria be met.

The applicability of the above susceptibility criteria verses the applied environmental levels for the instrument/equipment is detailed in Table XI.

Table XI. Instrument/Equipment Susceptibility Requirements

Test	Instruments		
	Survive	**Operate**	**Perform**[5]
CS101/102	-	-	Y
CS06	Y	Y	Y
RS101	-	-	Y
RS103[1]	Y[4]	N[4]	N
RS103[3]	Y	Y	Y
Magnetic Properties[6][7]	Y	Y	Y

Y = Applicable; N = Not Applicable; D = Degraded Sensitivity, Test Plan specifies limits

(1) Composite of normal checkout, launch vehicle, and launch susceptibility levels (Figure 18)
(3) On-orbit Spacecraft generated susceptibility levels (Figure 19)
(4) By analysis or test
(5) Definition of susceptibility (i.e., criteria for performance) defined in test plan.
(6) Immunity to Spacecraft and Earth generated magnetic fields
(7) Box level test

Radiated Susceptibility, Electric Fields (RS103)

All LAT equipment shall survive exposure to the radiated susceptibility environments specified in Figure 17.

All LAT equipment, except the BEA and Tracker Towers, shall survive and perform when subjected to the radiated susceptibility environment specified in Figure 18.

The BEA and Tracker Towers shall survive and perform when subjected to the radiated susceptibility environment specified in Figure 19.

The peak transmitter levels in Figure 19 for S-and Ku-bands are the worst case applied maximum level of Spacecraft sources listed in Table XII.

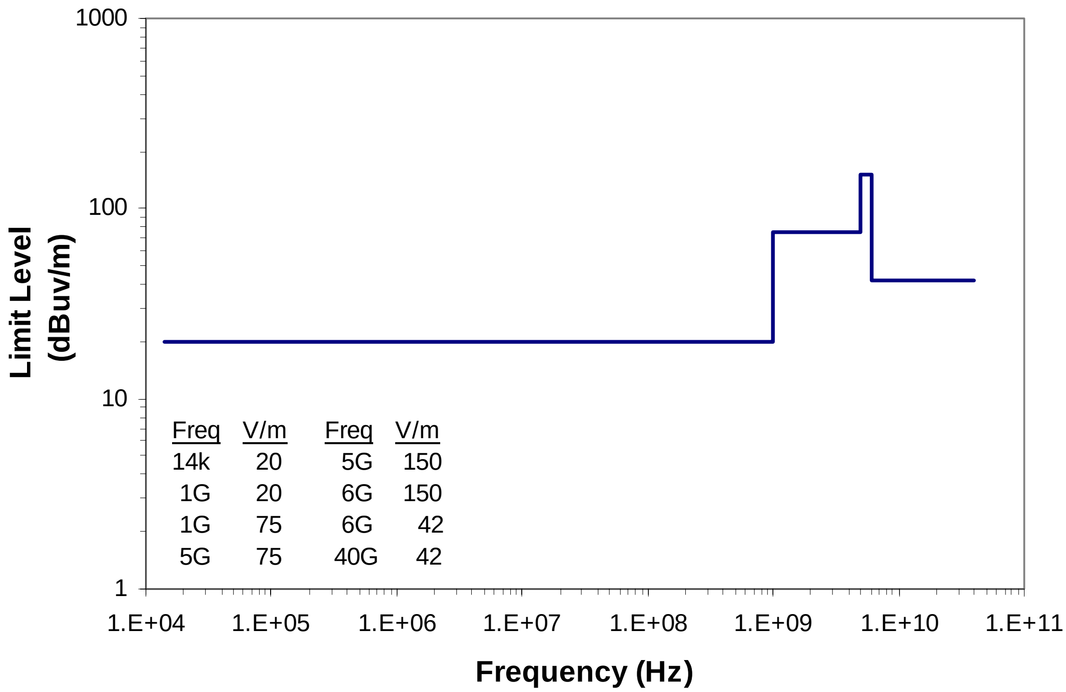


Figure 17. RS103 Launch – All LAT Equipment

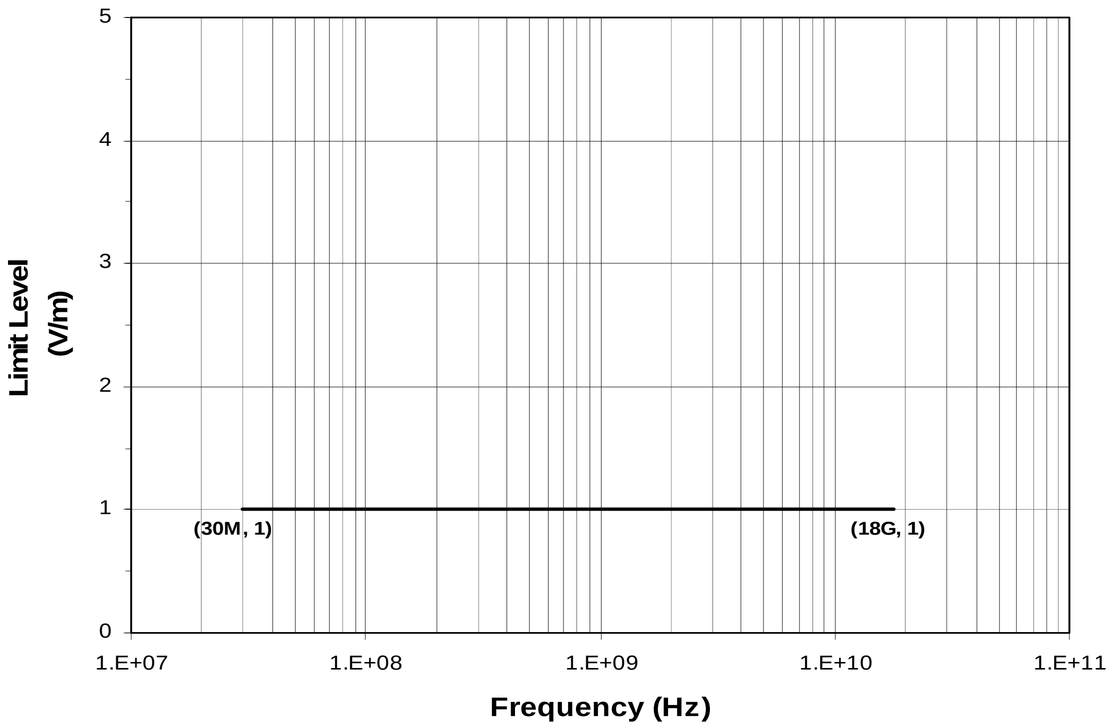


Figure 18. RS103 Perform – All LAT Equipment except BEA and Tracker Tower

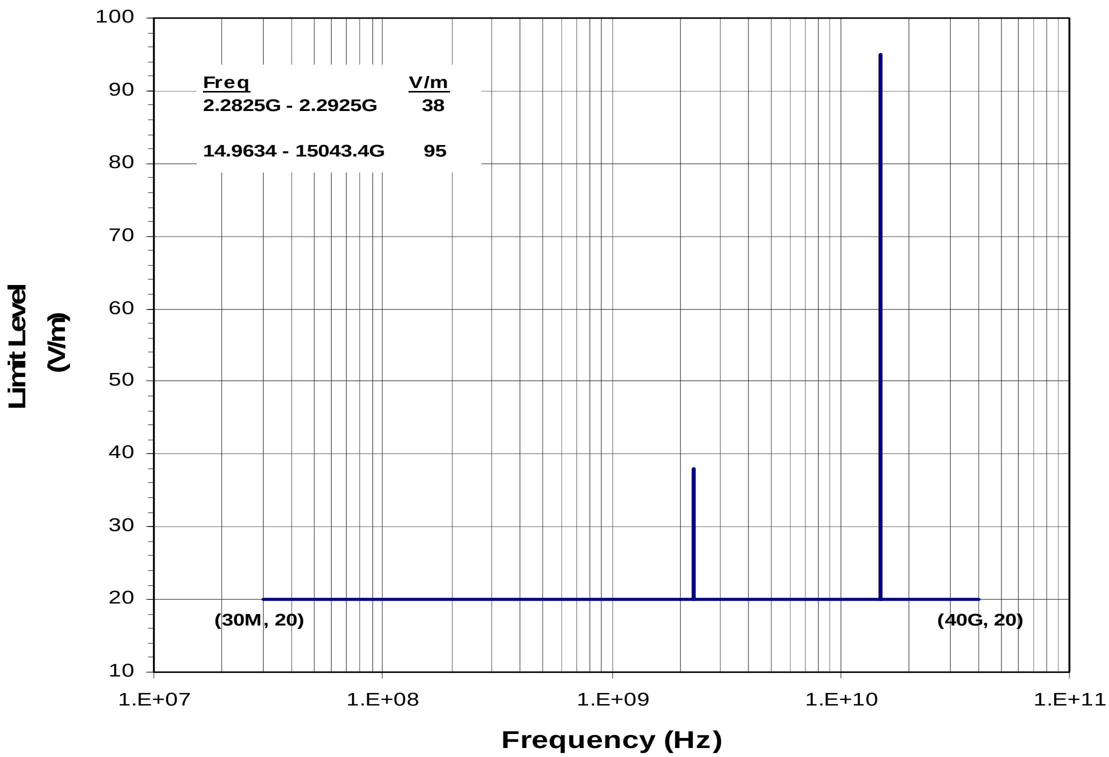


Figure 19. RS103 Perform – BEA and Tracker Tower

Table XII. Spacecraft-Generated GLAST RF Sources					
Transmitter	**Band**	**Center Frequency (GHz)**	**Modulation Type**	**Bandwidth (MHz)**	**Volts/m @ Inst (E_{peak})**
STDN	S	2.2875	QPSK	<5 (1)	38V/m
Science D/L	Ku	15.0034	~QPSK	<80 (1)	95V/m
(1) Width of main lobe of the transmitter spectrum (null to null).					

Radiated Susceptibility, Magnetic Fields (RS101)

All LAT equipment, except the BEA and Tracker Towers, shall perform when subjected to the radiated magnetic field requirement of Figure 20.

The BEA and Tracker Towers shall perform when subjected to the radiated magnetic field requirement of Figure 21.

All LAT equipment shall meet the magnetic field requirement of Para. 3.2.4.3 in 433-IRD-0001.

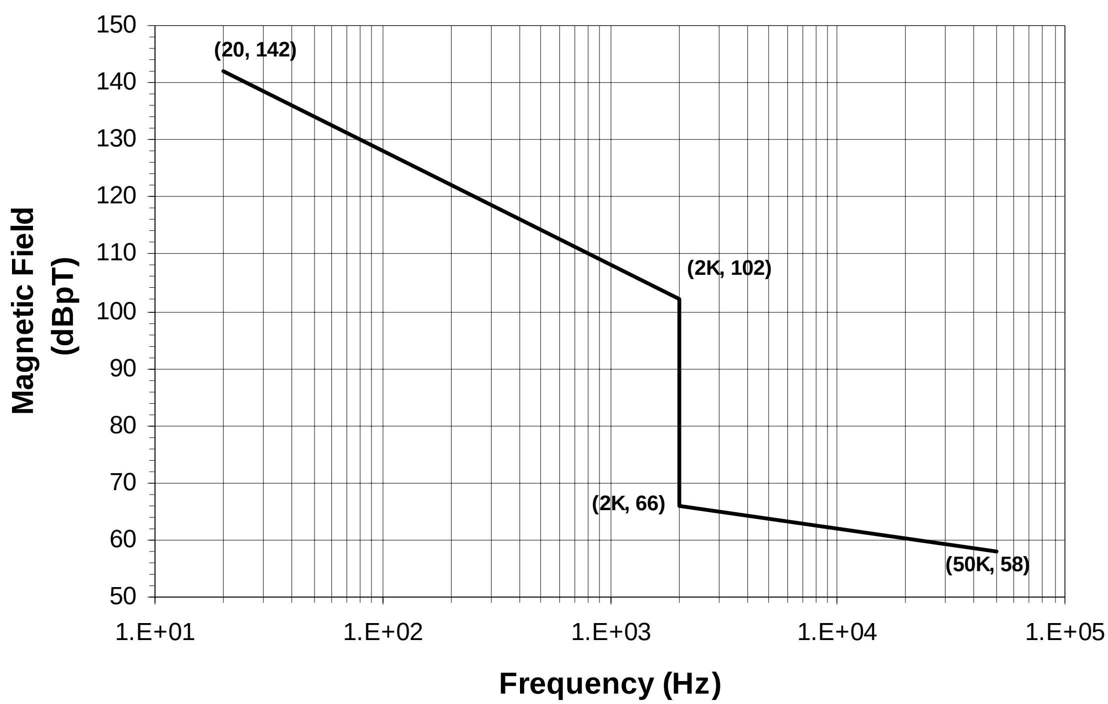


Figure 20. RS101 Perform – All LAT Equipment except BEA and Tracker Tower

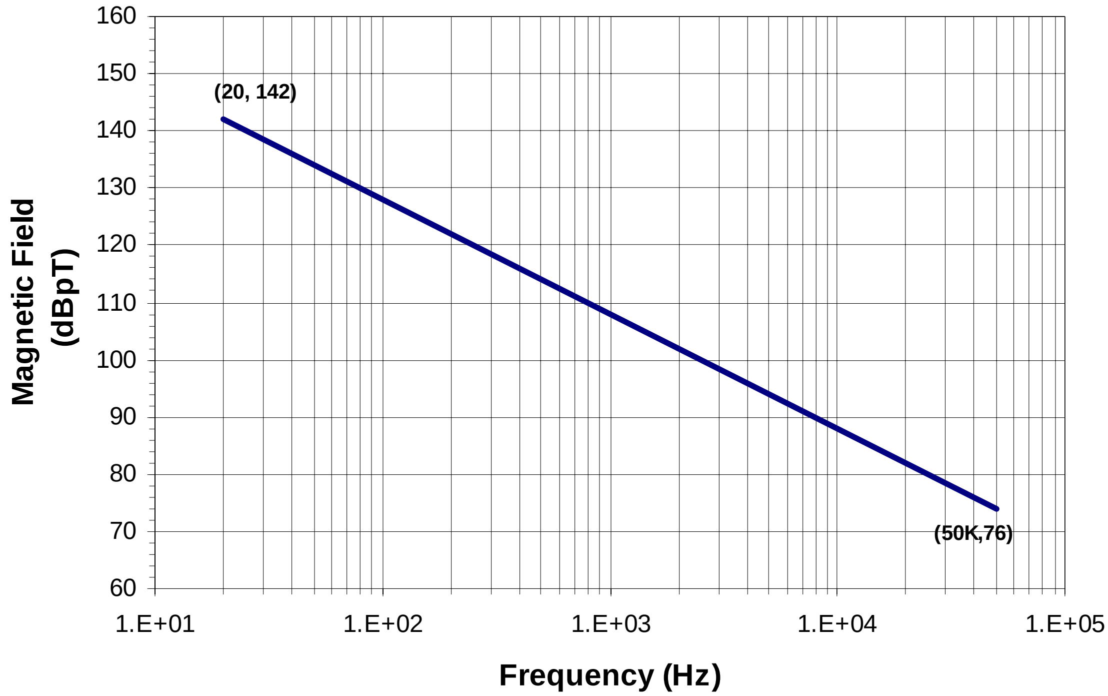


Figure 21. RS101 Perform – BEA and Tracker Tower

Figure 22. Not Used

13.3. Conducted Susceptibility (CS102, CS06, CSCM)

LAT equipment shall perform when subjected to conducted sinewave (CS102) noise injected on the primary power input per Figures 23, 24, 25, and 26.

Refer to Figure 15 for the applicability of these requirements.

LAT equipment shall perform when subjected to common mode noise injected on the primary power input leads (line-to-chassis and return-to-chassis) as shown in Figure 27.

LAT equipment shall operate when subjected in the powered state to both positive and negative polarity transients (CS06-Operate) injected on the primary power input (line-to-line) with the wave shape as shown in Figure 28. Instruments shall operate after being subjected in the unpowered state to both positive and negative polarity transients (CS06-Operate) injected on the primary power input (line-to-line) with the wave shape as shown in Figure 28.

LAT equipment shall survive when subjected to both positive and negative polarity fuse blow/fault transients injected on the primary power input leads (line-to-chassis and return-to-chassis) as shown in Figure 29 (CS06-Survive). This requirement applies with the unit operating (powered) and nonoperating (unpowered). Testing, to verify compliance, shall be restricted to nonflight hardware.

LAT equipment shall perform when subjected to transient noise (CS06-Perform) injected on the primary power input with the wave shape as shown in Figure 30.

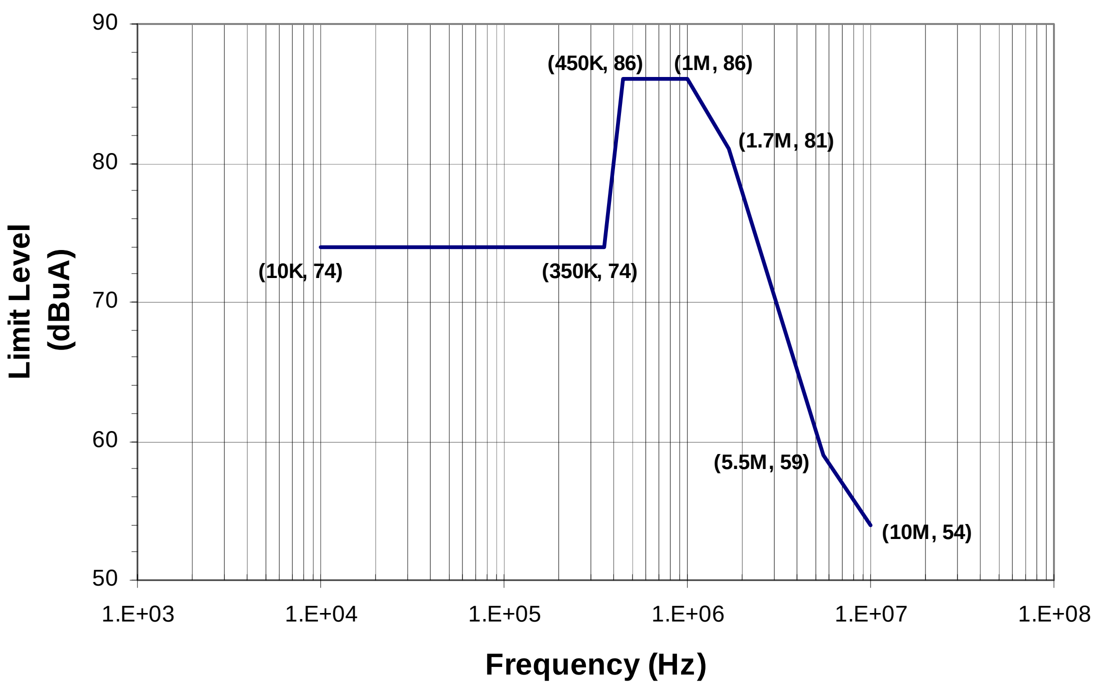


Figure 23. CS102 Spacecraft PRU – LAT DAQ

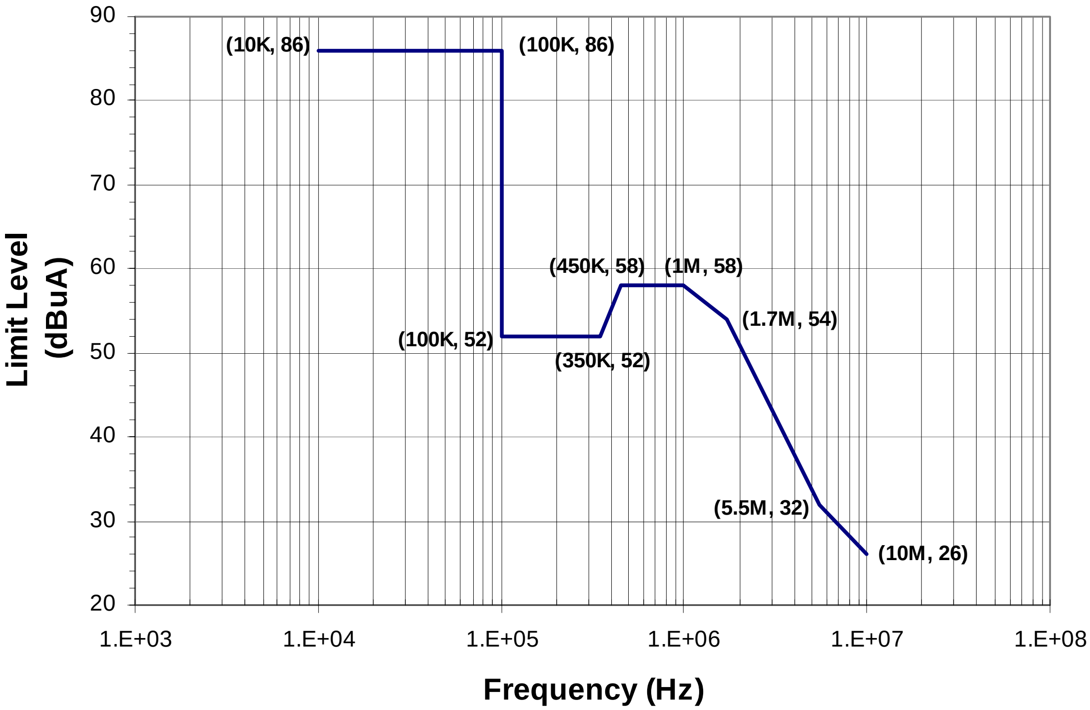


Figure 24. CS102 LAT PDU – TPS (TEM, CAL, TRKR), EPU (IL), GASU (ACD BEA, IL), PDU (IL)

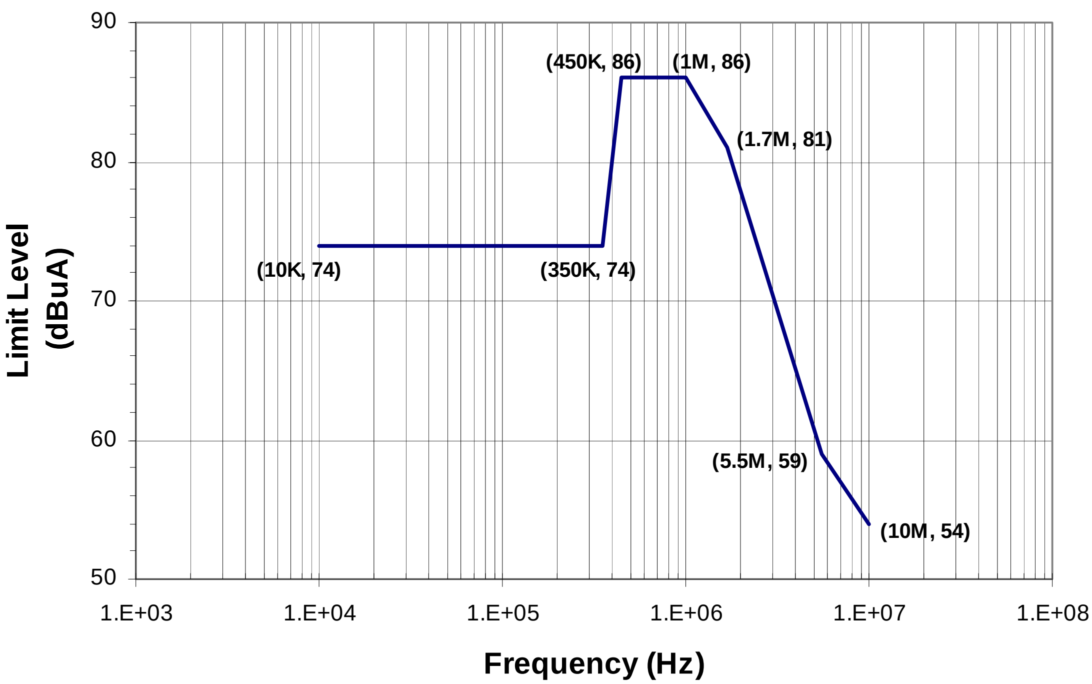


Figure 25. CS102 Spacecraft PRU – LAT SIU (IL), VCHP Heaters

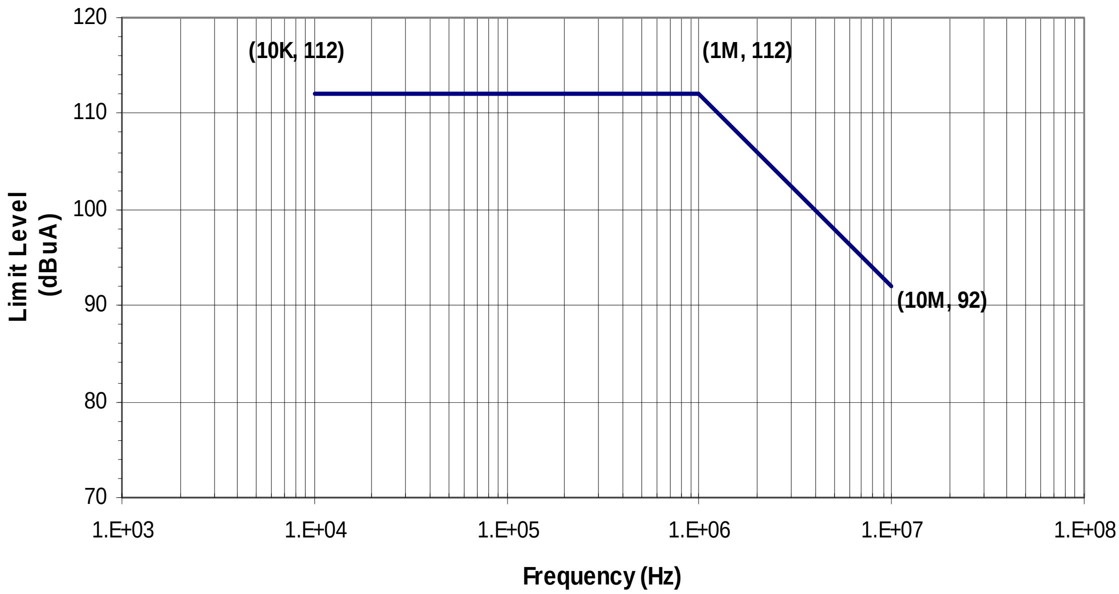


Figure 26. CS102 Spacecraft PDU – LAT Anti-freeze and Make-up Heaters

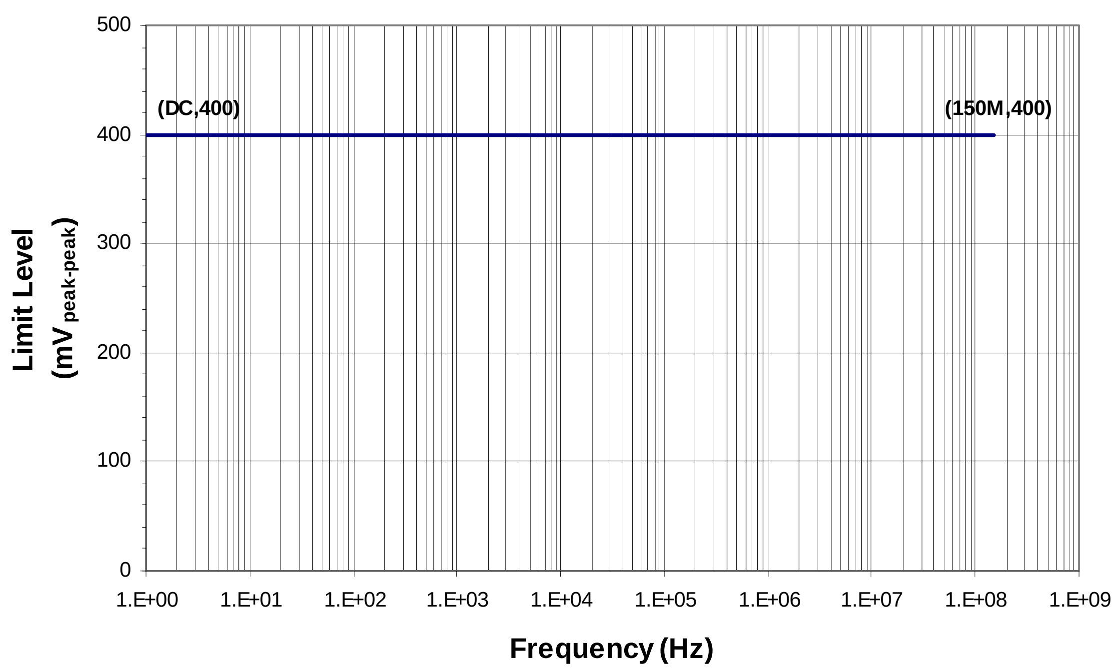


Figure 27. Conducted Susceptibility Common Mode – All LAT Equipment

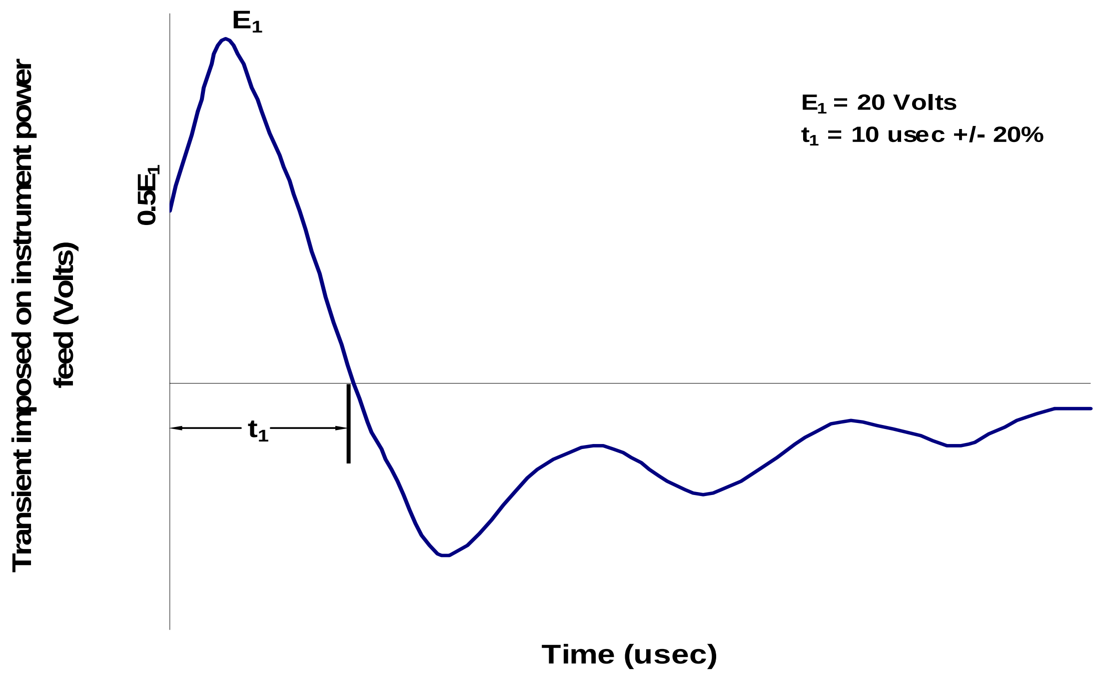


Figure 28. CS06 Operate – All LAT Equipment

Figure 29. CS06 Survive – All LAT Equipment (TBS)

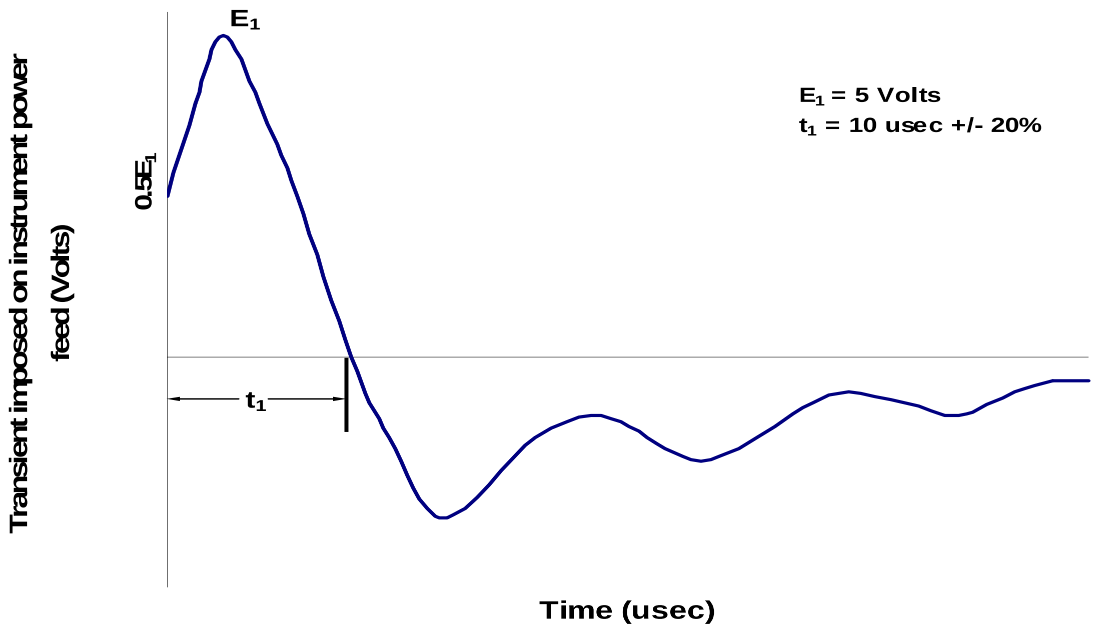


Figure 30. CS06 Perform – All LAT Equipment

13.4. Instrument Magnetic Properties

Each instrument stand-alone component static dipole moment shall not exceed 5.0 Am^2 initially and shall not exceed 5.0 Am^2 after torque rod activity.

13.5. Electromagnetic Interference Safety Margin

The Electromagnetic Interference Safety Margin (EMISM) for safety critical circuits (such as EEDs) shall be 20 dB, verified by analysis or test. EMISM for other EMC elements shall be 6 dB, verified by comparison of emissions and susceptibility test data.

13.6. Superposition

The radiated and conducted susceptibility requirements will be superimposed on the system critical circuit under investigation to establish the EMISM. This requirement shall be verified by analysis of equipment EMI test data.

14. Appendix A: Subsystem Test Temperature Explanations

14.1. Anticoincidence Detector

At the cold qualification temperature for the Tile Shell Assembly (TSA) of -40 degC, the ACD can not guarantee to meet its science efficiency requirement.. At these low temperatures the gaps between tiles open up enough to cause the net efficiency to drop below the required minimum. This is not something that can be measured, so we have to depend on calculations and simulations.

CDR analysis indicates that the ACD will meet its minimum efficiency requirement at an average temperature of -20 degC. When at this average temperature, the minimum ACD temperature is approximately 5 degC colder, or –25 degC. This corresponds to the qualification temperature for the ACD. However, the TSA will be qualified at lower temperatures, since the survival requirements are independent of our performance requirements. At this temperature, the ACD will not meet its efficiency requirement, but all aspects of the thermal and structural design will be fully qualified. This will demonstrate significant design robustness of the TSA, due to the large thermal margin compared to the ACD operating temperature.

14.2. Mechanical Systems

Thermal transport performance of heat pipes is a function of temperature. Thus, as temperatures exceed the operating range of the heat pipe, the heat pipe performance will slowly degrade until they will eventually no longer meet their performance requirements. This is especially an issue on the cold end of the operating range.

For the Grid Box, the qualification temperature range is –40 to +40 degC. This range has been established to assure that the design and workmanship of this protoflight unit is robust, with large margins in its thermal design. However, the Grid Box heat pipes will not meet all transport requirements over this range and a demonstration of full transport performance of the heat pipes will not be required.

For the Radiators, the temperature ranges listed are for the hottest/coldest extremities of the Radiator. On the cold end, the VCHP and its reservoir will not be as cold, due to the active heating to maintain Radiator thermal control. Also, the VCHP’s will not meet all transport requirements at qualification temperature, but this test is to verify the design and workmanship, and a demonstration of transport performance will not be required.