Environmental Test Requirements: Structural

- LAT Structural Tests: There are three environmental tests that relate to the integrated LAT structure:
  1. Sine Vibration Test: test to flight accelerations and measurement of response accelerations (transmissibility), and natural frequencies
  2. Modal Survey Test (contingency): measurement of natural frequencies and mode shapes, and correlation to analytical model (FEM)
  3. Acoustic Test: test to flight sound pressure levels (SPL) and measurement of response accelerations
- These three environmental tests will be described in more detail in the following slides

Specific Test Requirements: Sinusoidal Vibration Test

- Test Configuration (TBD)
  - Radiators not attached
    - Mass simulators added to represent load path from Radiators
    - Configuration of mass simulators is TBD
  - Mounted to Spectrum Astro-provided test flexures
    - Test flexures will be proof tested at SLAC prior to GRID static test
    - Adapter plate (TBD) to interface flexure base to slip table/expander head

- 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 the Table at upper right. 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.

- In order to address any vulnerability to the MECO high frequency (110 Hz – 120 Hz) event, the LAT and all subsystems will conduct a low-level sine sweep test to identify all resonant frequencies up to 150 Hz. This low-level sine sweep spectrum for the LAT and all subsystems is shown in Table at lower right. It should be noted that low-level input can result in high-level responses equal to or greater than design. Therefore, this test should have response limiting enabled with acceptance limits.

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

LAT and Subsystem Low-level Sine Test Levels

Axis	Freq. (Hz)	Test levels	Sweep Rate [Oct/min]
All (X, Y, & Z)	5 - 150	0.15 g	2

Specific Test Requirements: Sinusoidal Vibration Test

- Objectives: The sinusoidal vibration test for the LAT instrument is intended to verify that the LAT can sustain launch and deployment into orbit. Specifically, the objectives of the testing program are to:
  1. Verify the strength of the LAT and subsystem interfaces under proto-flight qualification (PFQ) level loading and duration in their flight configuration.
  2. Measure primary natural frequencies and identify primary modes of the LAT in launch configuration.
  3. Determine the transmissibility and response level for sinusoidal vibration input.
  4. Validate the accuracy of the LAT finite element model (FEM) and correlate model predictions with sinusoidal vibration test results. A modal survey may also be performed if mode identification indicates LAT fundamental frequencies below 50Hz.
  5. Verify the workmanship and processes used in the manufacture and assembly of the LAT.
- Test Flow: Order of vibration direction is somewhat arbitrary, but baseline is to test in X-axis first, Y-axis second, and Z-axis last. The typical test flow for each axis:
  – Low-Level Sine Sweep to 150 Hz (establish pre-test signature, review data)
  – Half-Level Sine Sweep to 50 Hz (check notching, review data, make adjustments)
  – Full-Level Sine Sweep to 50 Hz (impart launch loads, review data)
  – Low-Level Sine Sweep to 150 Hz (check post-test signature to pre-test signature, complete axis)
- Test Flow Philosophy: The LAT will be subjected to sine sweep vibration of varying levels with the following results:
  – High-level sine sweep will verify the LAT’s ability to survive the low frequency launch environment (Obj. 1)
  – Low-level signature sweeps pre- and post-test will be used to verify there is no structural degradation (Obj. 1)
  – Low-level signature sweep will serve to identify fundamental mode frequencies and confirm approximate mode shapes (Obj. 2, 4)
  – Low-level signature sweep data will be used to derive transfer functions by normalizing response to base input (Obj. 3, 4)
  – High-level sine sweep will provide a workmanship test for hardware such as wiring harness, MLI, and cable support and strain-relief, which will not have been fully verified at the subsystem level (Obj. 5)

Specific Test Requirements: Sinusoidal Vibration Test

- Success Critera: The outcome of the tests will be measured by the following criteria:
  - No failure or damage to the LAT assembly as determined by physical inspection.
  - No significant changes to the dynamic signature as determined by the pre and post low-level sine vibration inputs.
  - No permanent deformations in the LAT structure or of any subsystem or component.
  - No significant degradation of instrument or system performance.
- Test Instrumentation by subsystem, total of 57 Channels, installed by I&T, IFCT (LW), checkout by I&T, ET (ML)

– ACD	→	10 Accel Channels,	10 Uniax (9 FA),	0 Triax
– TKR	→	7 Accel Channels,	7 Uniax (7 FA),	0 Triax
– CAL	→	6 Accel Channels,	0 Uniax,	2 Triax (2 FA)
– E-Box	→	9 Accel Channels,	5 Uniax (3 FA),	2 Triax (2 FA)
– Mech	→	25 Accel Channels,	1 Uniax (1 FA),	8 Triax

- Data Out:
  - XY Frequency response datafiles and hardcopies (phase and magnitude) for all channels → I&T, ET (ML)
  - Pre- and Post-test signature overlays for all channels → I&T, ET (ML)
  - Data review and mode identification (real time) →DI&A, SA (JK)
    - Ensure levels properly induced into LAT, i.e. no undertest or significant overtest (Obj. 1)
    - Identify modes compared with analysis (there should only be flexure modes under 50 Hz; Obj.2, 4)
    - Calculate Transmissibility (Obj. 3)
    - Ensure no frequency shifts or other structural problems (Obj. 5)
    - Ensure LAT fundamental frequencies are above 50 Hz (does not include flexure mode)
      - If >50 Hz, no modal test is required, per the MAR
      - If <50 Hz, a modal test with mode shape correlation is required
- Other Deliverables or Work:
  - Physical Inspection of LAT between Axes → I&T, IFCT (LW)
  - Reorientation of LAT between Axes (Swing or night shift?) → I&T, IFCT (LW)
  - At end of test, all data from low-level, half-level, and full-level, and all photos and set-up sheets should be concatenated into binders → I&T, ET (ML)
  - All electronic data should be burned to a CD or DVD → I&T, ET (ML)
  - Test data will be used to refine and validate the FEM of the LAT. This correlation is an important aspect of the test program and will be used for final coupled loads analysis → DI&A, SA (JK)

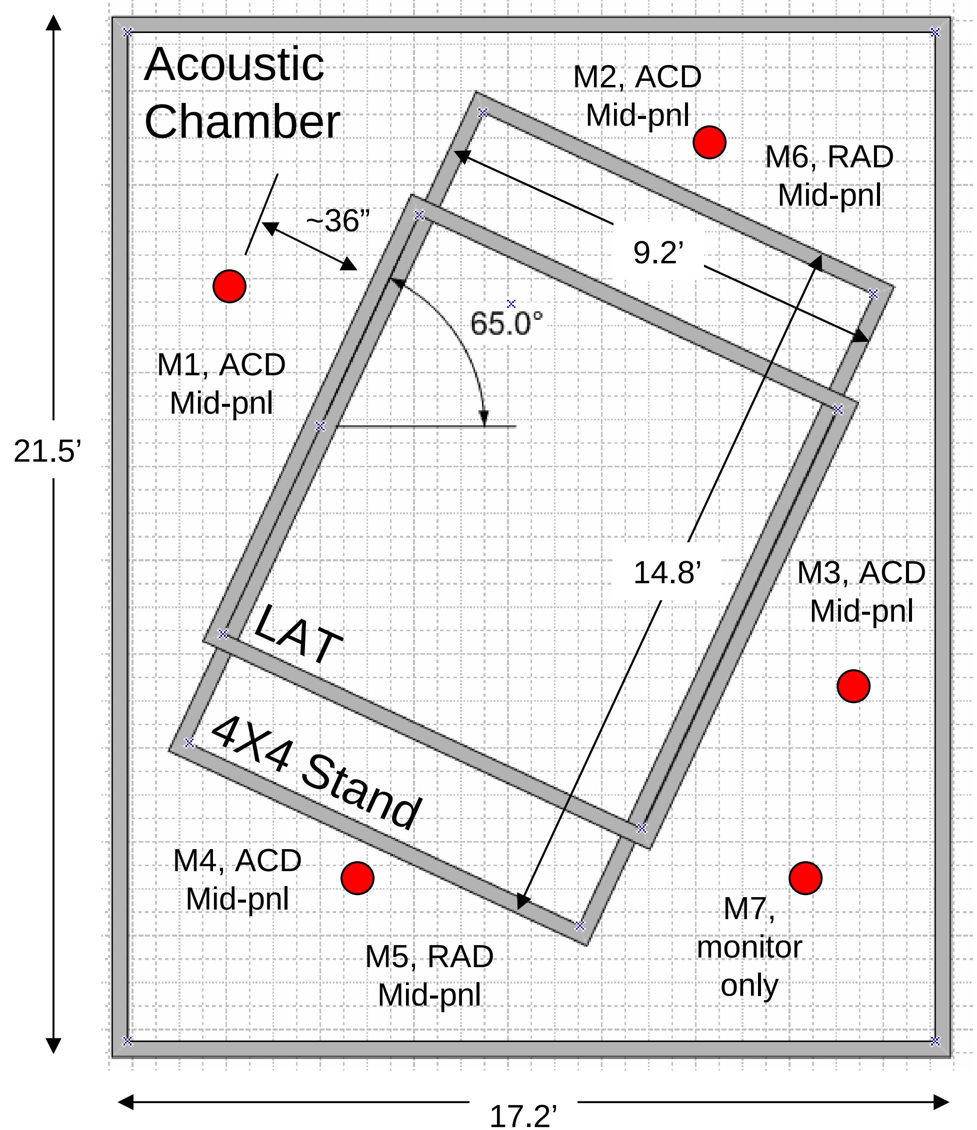
Specific Test Requirements: Modal Survey Test

- Per phone conversation with Farhad Tahmasebi on 1/29/04, the GSFC Mechanical Branch position on the requirement to modal test was conveyed.
  - It was the opinion of the experts within NASA/GSFC that the requirements set forth in the MAR are adequate, i.e. if the instrument modes are above 50 Hz, no modal correlation is needed.
  - However, it is important that the natural frequencies be demonstrated through test, and not analysis only.
    - Separate stiffness and mass correlation is acceptable and easy to implement
    - Direct frequency measurement would be better, but more difficult
- As the date for modal testing approaches, there will be ample opportunity to evaluate the LAT mass and stiffness characteristics.
  - All subsystem stiffness and mass test data will be available and incorporated into the LAT FEM.
  - Assembly level test data will be available, including the EM 1X4 (which already shows good correlation), FM2 Grid 4x4 Static data, and (possibly) FM1 LAT Twang Test data.
  - The accumulation of test data will give great confidence in the LAT natural frequency.

- If the fundamental frequency (measured in the sinusoidal vibration test) is determined to be above 50 Hz, the Modal Survey Test will be omitted.
- If the fundamental frequency is determined to be below 50 Hz, a modal survey test will need to be performed.
  - Current instrumentation channels are sufficient to yield mode shape data.
  - Since this path is a contingency, no work beyond initial proof of concept is planned.

Specific Test Requirements: Acoustic Test

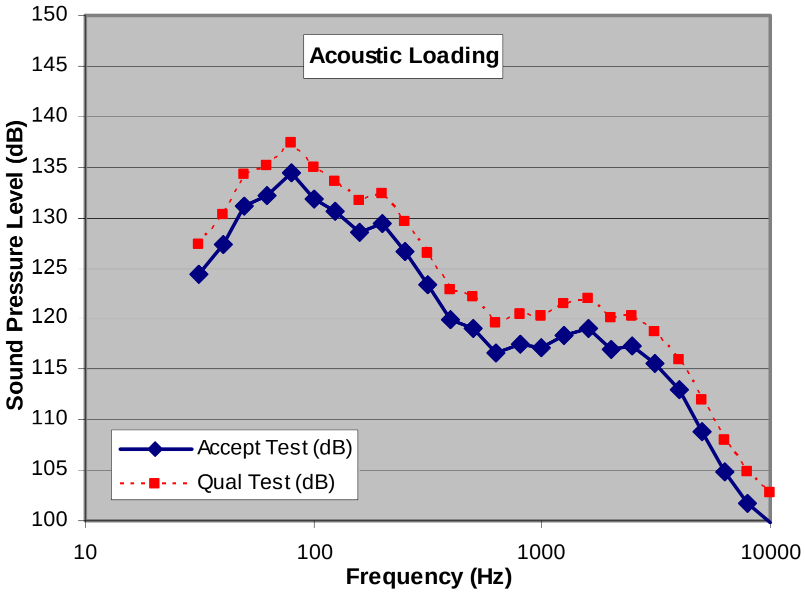
- Test Configuration (TBR)
  - Oriented with Z-axis facing up
  - Radiators attached
  - Held by GPR in 4x4 Rotation Stand (TBR)
  - Rotation stand mechanisms should be removed prior to test
- The LAT should be positioned such that the flat panels are a minimum of 15° (TBR) from parallel to any of the test cell walls. Maximum angle of 25° feasible (shown at right).



Specific Test Requirements: Acoustic Test

- 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 the figure at right. 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

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

Specific Test Requirements: Acoustic Test

- Objectives: The objective of the acoustic test is to demonstrate that the fully integrated LAT is capable of withstanding acoustic noise loads, simulating launch conditions. A secondary objective is to verify the acoustic analysis, i.e. that the LAT components were qualified to high enough levels of Random vibration
- Test Flow:
  - Chamber Setup and empty cell calibration. This is needed to verify the test cell is clean and ready to accept the LAT for testing. The empty cell calibration will verify that the specified sound pressure levels can be achieved.
  - Low-Level run at -7 dB for 40 seconds (establish pre-test signature, review data)
  - Mid-Level run at -3 dB for 20 seconds (check SPL average, linearity, review data)
  - Low-Level run at -7 dB for 40 seconds (Signature check, review data)
  - Full-Level run at -0 dB for 60 seconds (impart full SPL, check SPL, linearity, review data)
  - Low-Level run at -7 dB for 40 seconds (Signature check, review data, complete axis)
- Test Flow Philosophy: The LAT will be subjected to acoustic vibration of varying levels for the following reasons:
  - Since there is no heritage for the LAT acoustic response, it is important to proceed carefully.
  - Between the low-level and mid-level runs, the g_{rms} values should scale linearly, i.e. the +4 dB increase results in a 1.58 factor increase in the g_{rms} values (factor = $10^{(dB/20)}$). G_{rms} values for each channel should be checked against the theoretical increase. Non-linearities could indicate problems in the structure.
  - An intermediate low level run is performed to ensure there are no changes in the low level responses of the LAT. Experience shows that low level runs used as “signatures” are very effective.
  - If everything is okay, the full level run is performed. Again, g_{rms} values are checked against the mid-level run. The increase from mid-level to full level is +3 dB, which corresponds to a 1.41 factor increase. Non-linearities could indicate problems in the structure.
  - A final low-level signature is performed and overlaid with the previous two low level runs. Frequency shifts and magnitude changes are of particular interest.

Specific Test Requirements: Acoustic Test

- Success Critera: The outcome of the tests will be measured by the following criteria:
  - No failure or damage to the LAT assembly as determined by physical inspection.
  - Inspection of plastic sheet under LAT does not produce any fibers, chips or fasteners
  - No significant changes to the dynamic signature as determined by the pre and post low-level acoustic vibration inputs.
  - No permanent deformations in the LAT structure or of any subsystem or component.
  - No significant degradation of instrument or system performance.
- Test Instrumentation by subsystem, total of 64 Channels, installed by I&T, IFCT (LW), checkout by I&T, ET (ML)

– ACD	→	10 Accel Channels,	10 Uniax (9 FA),	0 Triax
– TKR	→	7 Accel Channels,	7 Uniax (7 FA),	0 Triax
– CAL	→	6 Accel Channels,	0 Uniax,	2 Triax (2 FA)
– E-Box	→	9 Accel Channels,	5 Uniax (3 FA),	2 Triax (2 FA)
– Mech	→	32 Accel Channels,	8 Uniax (1 FA),	8 Triax

- Data Out:
  - Microphones: Sound pressure levels in dB versus frequency shall be provided for each of the individual microphones and the average of all microphones. The data shall be based on a one-third octave band analysis → I&T, ET (ML)
  - Accelerometers: Power Spectral Density (PSD) plots (g^2/Hz versus frequency) shall be provided for each of the accelerometers. The plots shall be based on a 10 Hz bandwidth up to a frequency of at least 2000 Hz. RMS acceleration shall also be included in each plot. → I&T, ET (ML)
  - Pre-, Mid- and Post-test signature overlays for all channels → I&T, ET (ML)
  - Data review (real time) → DI&A, SA (JK)
    - Ensure levels properly induced into LAT, i.e. SPLs within prescribed test tolerances
    - Verify linearity
    - Ensure no frequency shifts or other structural problems
- Other Deliverables or Work:
  - Physical Inspection of LAT between Axes → I&T, IFCT (LW)
  - At end of test, all data and photos and set-up sheets should be concatenated into a binder → I&T, ET (ML)
  - All electronic data should be burned to a CD or DVD → I&T, ET (ML)
  - Test data will be used to refine and validate the acoustic analysis of the LAT → DI&A, SA (JK)

Latest Instrumentation List (as of 9/23/04)

LAT-SS-00890-01 LAT Instrumentation Plan

Table 2. Test Instrumentation - Accelerometers

Rev Date: 07-Sep-04
Print Date: 23-Sep-04

Line #	Chan #	Instr. #	SS	Location	Part No.	Sensitivity [mV/g]	Side of Shield	SS Mtd To	Install By	Vibe	Acoustic	Obs. Shock	Test Instrument. Fly-Away	Test Instrument. Remov.	Ch. Count	Installation Drawing	Notes
	1	A101X			7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
1	2	A101Y	ACD	TSA Top	7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
	3	A101Z			7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
2	4	A102X	ACD	TSA YZ Face -X side, panel center	7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
2	5	A103Y	ACD	TSA Top edge center nearest YZ face +Xside	7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
3	6	A104Z	ACD	TSA Upper -X+Y corner	7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
	7	A105X			7251A-100	100	Out	ACD	ACD	X	X		1		1		
4	8	A105Y	ACD	TSA midspan YZ face +X side, above Ti flexure	7251A-100	100	Out	ACD	ACD	X	X		1		1		Endevco Accel Installed on ACD Shell
	9	A105Z			7251A-100	100	Out	ACD	ACD	X	X		1		1		
5	10	A106X	ACD	BFA/ChassisAcoustic Accel	355M64	10	Out	ACD	I&T		X			1	1		PCB, Final Location TBD
6	11	A201X	TKR	Bay X center -Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
7	12	A202X	TKR	Bay X center +Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
8	13	A203Y	TKR	Bay X center -Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
9	14	A204Y	TKR	Bay X center +Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
10	15	A205Z	TKR	Bay X ,-X,-Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
11	16	A206Z	TKR	Bay X ,-X,+Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
12	17	A207Z	TKR	Bay X ,+X,-Y,+Z	355M64	10	Out	TKR	I&T	X	X		1		1		PCB
	18	A301X													1		
13	19	A301Y	CAL	CAL +X, +Y (Triax)	356M160	10	In	CAL	I&T	X	X		1		1		PCB
	20	A301Z													1		
	21	A302X													1		
14	22	A302Y	CAL	CAL -X, +Y (Triax)	356M160	10	In	CAL	I&T	X	X		1		1		PCB
	23	A303Z													1		
15	24	A401X	Elec	Bay X; -X,+Y,+Z		10	In	EBOX	I&T	X	X				1		Triax Accel with only two channels
16	25	A402Z	Elec	Bay X; -X,-Y,+Z	356M160	10	In	EBOX	I&T	X	X		1		1		used (third channel not connected)
17	26	A403X	Elec	Bay X; +X,-Y,+Z		10	In	EBOX	I&T	X	X				1		Triax Accel with only two channels
18	27	A404Z	Elec	Bay X; -X,+Y,+Z	356M160	10	In	EBOX	I&T	X	X		1		1		used (third channel not connected)
19	28	A405Z	Elec	ebox center -X;-Y +Z	355M64	10	In	EBOX	I&T	X	X		1		1		PCB
20	29	A406Y	Elec	ebox center +Z	355M64	10	In	EBOX	I&T	X	X		1		1		PCB
21	30	A407Z	Elec	ebox center, -Y, +Z	355M64	10	In	EBOX	I&T	X	X		1		1		PCB
22	31	A408Z	Elec	PDU Acoustic Accel	355M64	10	Out	EBOX	I&T		X		1		1		PCB
23	32	A409Z	Elec	GASU Acoustic Accel	355M64	10	Out	EBOX	I&T		X		1		1		PCB
24	33	A502X	Mech	Grid center,+X, +Z	355M64	10	Out	Mech	I&T	X	X		1		1		PCB
25	34	A503Y	Mech	Radiator +Y	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
26	35	A504Y	Mech	Radiator +Y	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
27	36	A505X	Mech	Radiator +Y	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
28	37	A506Y	Mech	Radiator +Y	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
29	38	A507Z	Mech	XLAT Center	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
30	39	A508Z	Mech	XLAT Center,-X	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
31	40	A509Z	Mech	XLAT Center,+X	355M64	10	Out	Mech	I&T		X	X		1	1		PCB
	41	A510X													1		
32	42	A510Y	Mech	Rad Mnt Bkt -X/-Y corner end (Triax)	356M160	10	Out	Mech	I&T	X	X			1	1		PCB
	43	A510Z													1		
	44	A511X													1		
33	45	A511Y	Mech	Rad Mnt Bkt +X/-Y corner end (Triax)	356M160	10	Out	Mech	I&T	X	X			1	1		PCB
	46	A511Z													1		
	47	A512X													1		
34	48	A512Y	Mech	Rad Mnt Bkt -X/+Y corner end (Triax)	356M160	10	Out	Mech	I&T	X	X			1	1		PCB
	49	A512Z													1		
	50	A513X													1		
35	51	A513Y	Mech	Rad Mnt Bkt +X/+Y corner end (Triax)	356M160	10	Out	Mech	I&T	X	X			1	1		PCB
	52	A513Z													1		
	53	A514X													1		
36	54	A514Y	Mech	S/C Flexure +X Face (Triax)	356M160	10	Out	Mech	I&T	X	X	X		1	1		PCB
	55	A514Z													1		
	56	A515X													1		
37	57	A515Y	Mech	S/C Flexure -X Face (Triax)	356M160	10	Out	Mech	I&T	X	X	X		1	1		PCB
	58	A515Z													1		
	59	A516X													1		
38	60	A516Y	Mech	S/C Flexure +Y Face (Triax)	356M160	10	Out	Mech	I&T	X	X	X		1	1		PCB
	61	A516Z													1		
	62	A517X													1		
39	63	A517Y	Mech	S/C Flexure -Y Face (Triax)	356M160	10	Out	Mech	I&T	X	X	X		1	1		PCB
	64	A517Z													1		
									Total	34	44	11	26	16	64		

Accel Type	Count
7251A-100	9
355M64	21
356M160	12
Total	42