I. SYNOPSIS

The preliminary stress analyses for the DAQ Electronics assemblies have been performed per the conditions specified in the Environmental Specification LAT-SS-00778. The analysis considered the loading conditions expected from Qualification level random vibration and static equivalent accelerations defined in the referenced environmental specification.

Results indicate that the DAQ Electronics box assemblies have been sufficiently designed to withstand the loads and stresses induced by these two load conditions.

II. GENERAL DESCRIPTION

The LAT Electronics consists of five distinct box assemblies as follows:

- Global Trigger Anti-Coincidence Detector Signal Distribution Unit (GASU)
- Power Distribution Unit (PDU)
- Event Processing Unit / Spacecraft Interface Unit (EPU/SIU)
- Tower Electronics Module (TEM)
- TEM Power Supply Unit (PSU)

The structural components of the assemblies, i.e. the enclosures and covers are machined from solid Aluminum 6061-T6 per QQ-A-250/11.

All fasteners and hardware are MIL-STD grade, typically 300 Series stainless steel (CRES) with a tensile strength of 80 ksi. Structural fasteners are specified as A286 high tensile strength,160 ksi steel. Fasteners are secured by means of locking helical inserts per MS21209, thread locker or bonding agent. Fasteners installed in locking helicoils are lubricated with Bracote.

Calorimeter Plate standoffs are Titanium Alloy 6Al-4V with a tensile strength of 130 ksi.

III. APPROACH AND PROCEDURE

Random vibrations during the Qualification test procedures will produce the most severe dynamic environments the units will experience. For this reason the dynamics analysis will be based primarily on the acceleration levels developed during the Qualification random vibration testing. Additionally, the static equivalent acceleration load cases will be evaluated for compliance to specification requirements.

Reference:
GLAST LAT Environmental Specification LAT-SS-00778

Section 8.1 Static-Equivalent Accelerations PFQ Level

Lift Off Loads/Air Loads:

Lateral	+/- 7.4 g
Axial	+8.5/-2.25 g
ROT X, Y, Z	0 g

The static equivalent accelerations loads were to be applied simultaneously or as resultant combinations which produced worst case loading conditions for the electronic boxes.

Section 9.2 Random Vibration

Figures 1 and 2 define the QUAL level PSD input values and total input energy level of the random vibration spectrum of 14.14 G_{rms}. Power spectral density (PSD) levels prescribed for the random vibration test were converted to response acceleration plots and were used to establish the input loads to each of the assemblies, Figure 3.

This conversion from power spectral density to accelerations is based on the following assumptions:

1. Single degree of freedom system
2. Sharpness of resonance factor Q=10 for all units
3. Damping factor of .05

f	PSD
Hz	*G2/Hz*
20	0.026
50	0.160
800	0.160
2000	0.026

Zone	Slope, N	Area
	db/oct	*G2*
1	5.973	2.507
2	0.000	120.000
3	-5.973	77.308
	TOTAL	**14.14** *Grms*

Figure 1
QUAL Level Input PSD Values

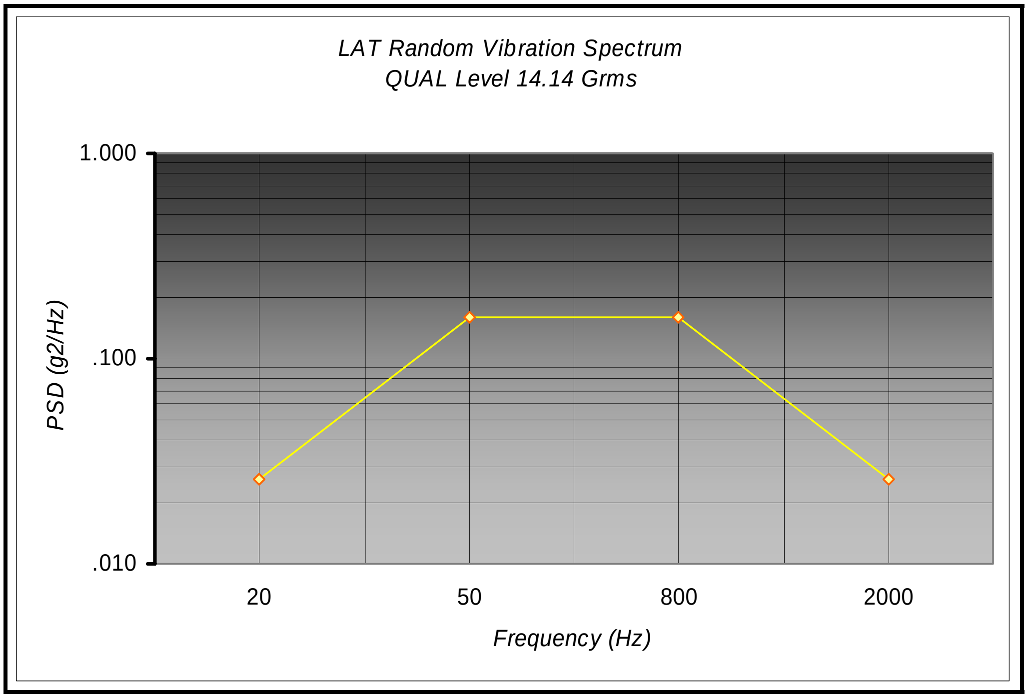


Figure 2
QUAL Level Random Vibration Spectrum

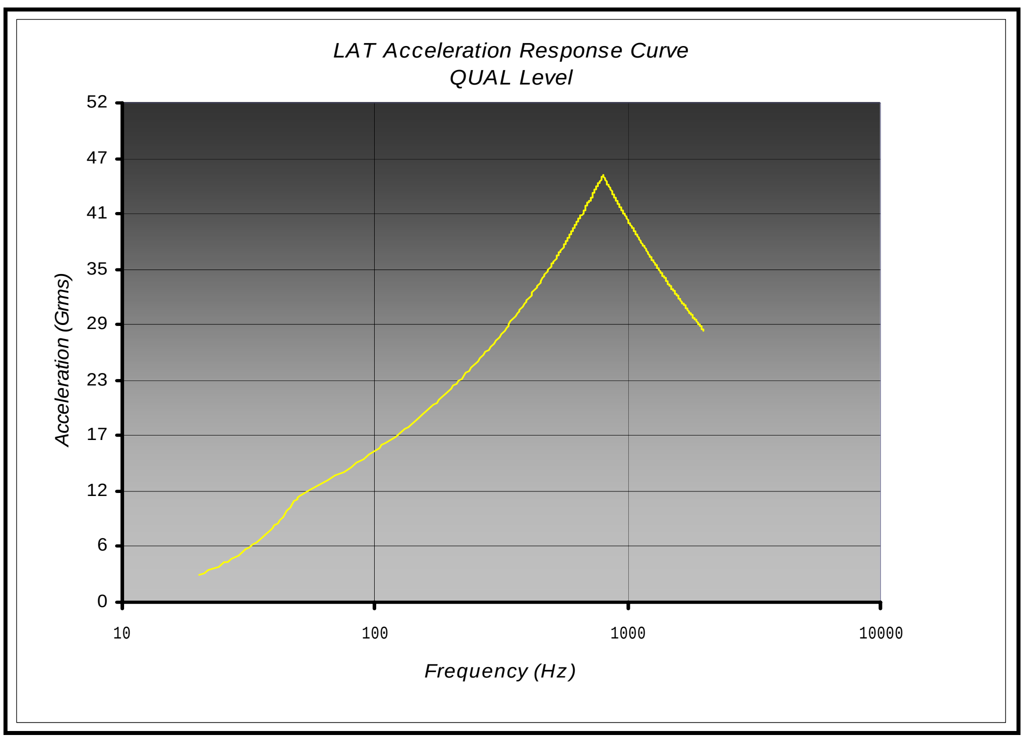


Figure 3
Acceleration Response Curve

In order to account for the probability of peak acceleration levels occurring during the random vibration testing, the RMS response acceleration level was multiplied by three to achieve 3-sigma probability deflections and stress levels.

In order to apply these acceleration levels, the natural frequencies of each assembly were determined using finite element methods. Corresponding accelerations levels are established and applied as a load case to the finite element model to determine expected stress levels and deflections during random vibration.

The TEM and PSU were treated as a single integral unit. Additionally, the TEM-PSU and EPU/SIU stack was analyzed as a single unit. The environmental specification is written such that each electronic box is to be evaluated independently against the environmental requirements. It is the contention of this analysis that the boxes are sufficiently robust and that the flange thickness and fastener quantities did not represent a risk in meeting the imposed loads. In reality, the box stacks are mounted on machined 6Al-4V titanium standoffs. This mounting configuration is addressed on two of the four different stack arrangements.

Preliminary analysis and testing were done prior to running the full FEA models to insure that reference data was available to validate the structural models.

The standoffs were modeled to determine their stiffness in order to approximate and verify the box natural frequencies by classical hand calculations and to validate assembly model integrity.

CAL-TEM Standoff	**LAT-DS-01554**
Material	Ti 6Al-4V
Young's Modulus	16.5E6 psi
Density	0.16 lbs/ft3
Yield Strength	120 ksi
Ultimate Strength	130 ksi
Thermal Conductivity	.19 W/in-C°

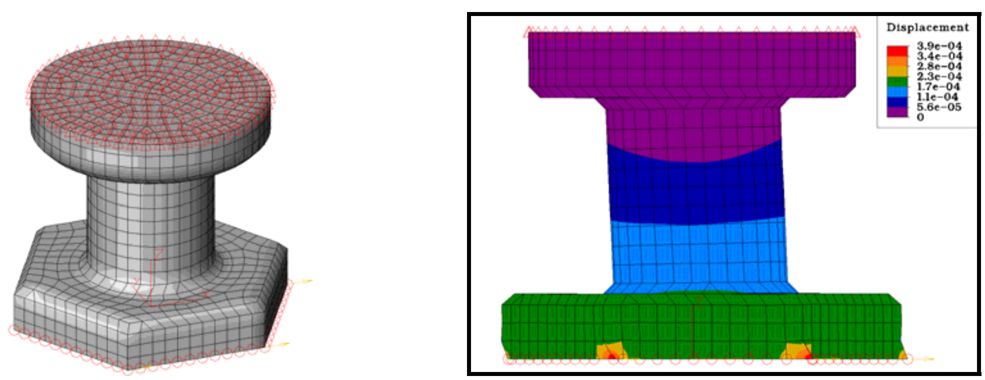


Figure 4
Titanium Standoff Model and Resultant Unit Deflection

The engineering unit for the TEM-PSU stack was subjected to the QUAL level random vibration test levels and accelerometers were positioned to measure the response of the unit due to the random excitation, Figures 6 and 7. The measured response frequencies correlated well with the predicted natural frequencies and verified the integrity of the numerical models. Figure 5 summarizes the results of the modal analysis.

NATURAL FREQUENCIES			Hz							
Mode	GASU	Axis	PDU	Axis	TEM-PSU-EPU/SIU	Axis	TEM-PSU *	Axis	TEM-PSU Measured	Axis
1	136.3	Z	180.2	Z	237.6	X	381.4	Z	348.0	Z
2	143.2	Z	186.1	Z	237.6	Y	475.4	X	448.0	X
3	159.7	Z	207.4	Z	366.5	Z	475.4	Y	450.0	Y
4	165.9	Z	210.0	Z	592.5	Z	718.7	Z	710.0	Z
5	264.7	Z	227.9	Z	615.4	ROTZ	963.2	Z	904.0	Z

Figure 5
Modal Search Results

.

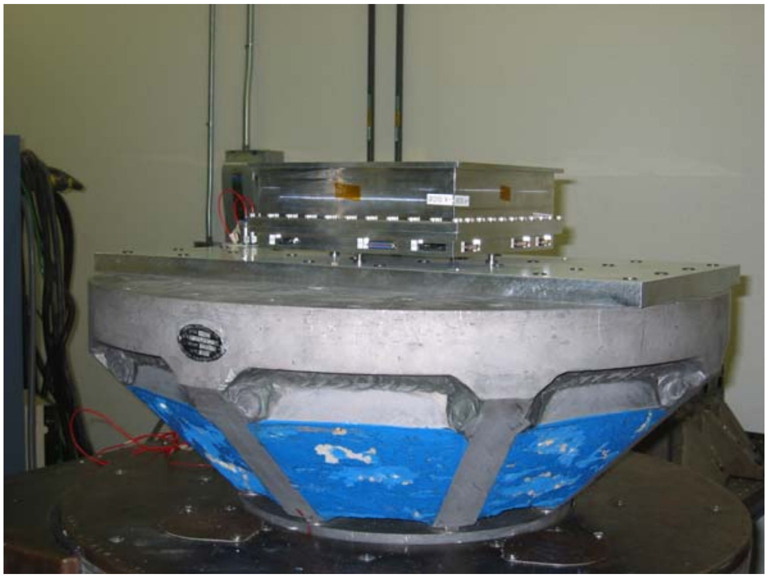


Figure 6
TEM-PSU on Shaker, Z-Axis

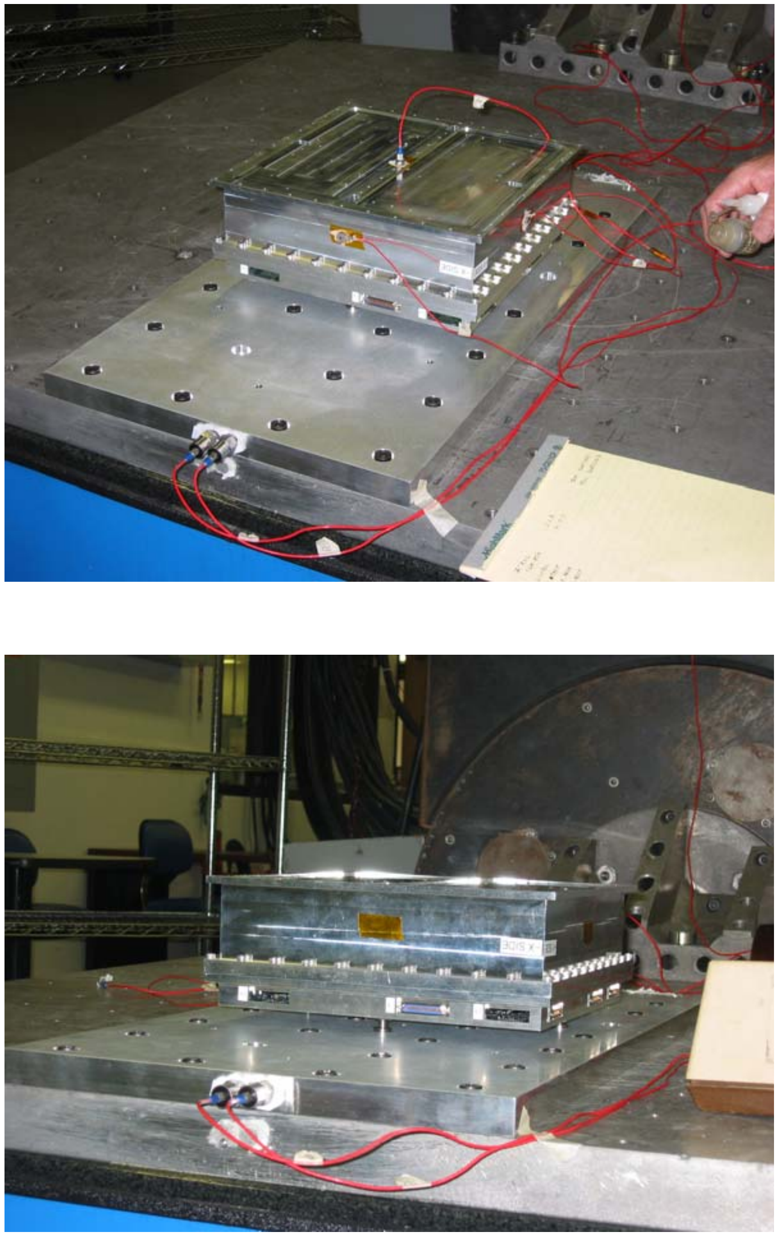


Figure 7
TEM-PSU on Shaker, X Axis

The finite element models of the LAT assemblies were created at a resolution that sufficiently addressed the objective of this analysis. The models used a combination of plate and brick elements to simulate the geometry of each electronics box. The Figures 8 through 11 depict the individual structural models and the solutions for each first mode natural frequency.

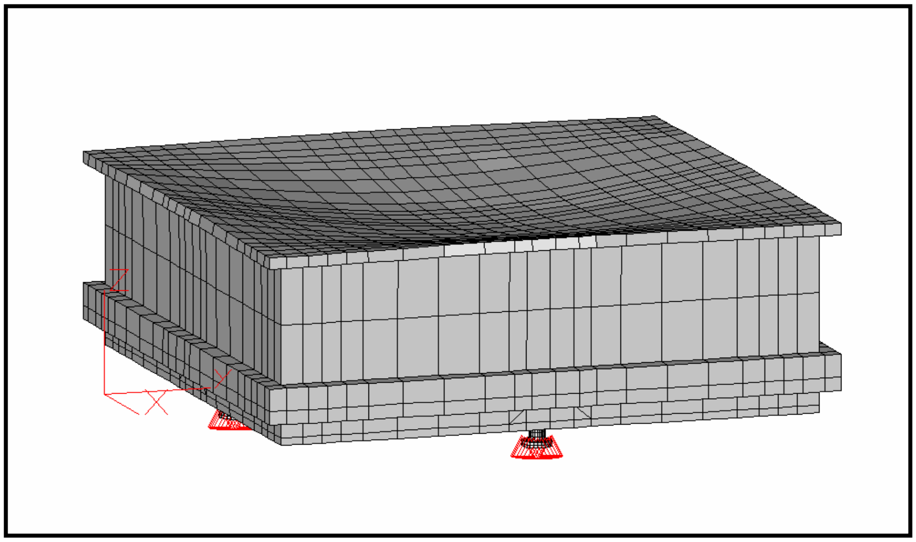


Figure 8
TEM and PSU Model
Natural Frequency 381.4 Hz.
*Note Titanium Standoffs

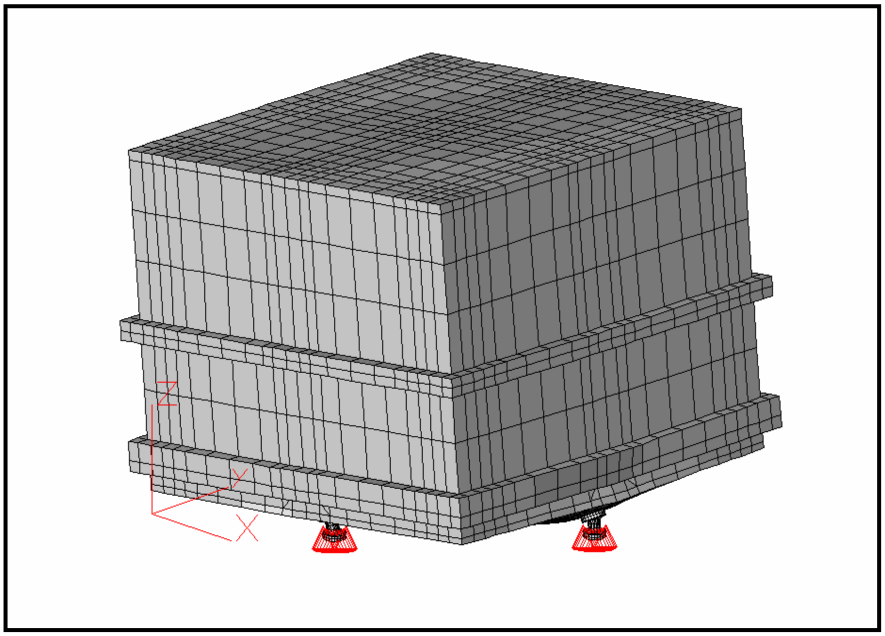


Figure 9
TEM, PSU and EPU/SIU Model
Natural Frequency 237.6 Hz.
*Note Titanium Standoffs

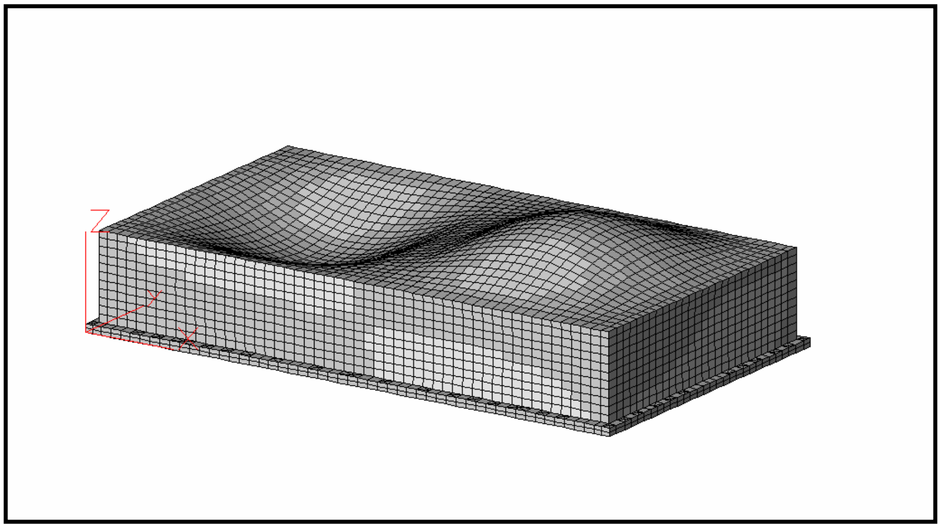


Figure 10
Natural Frequency 136.3 Hz.
GASU Model

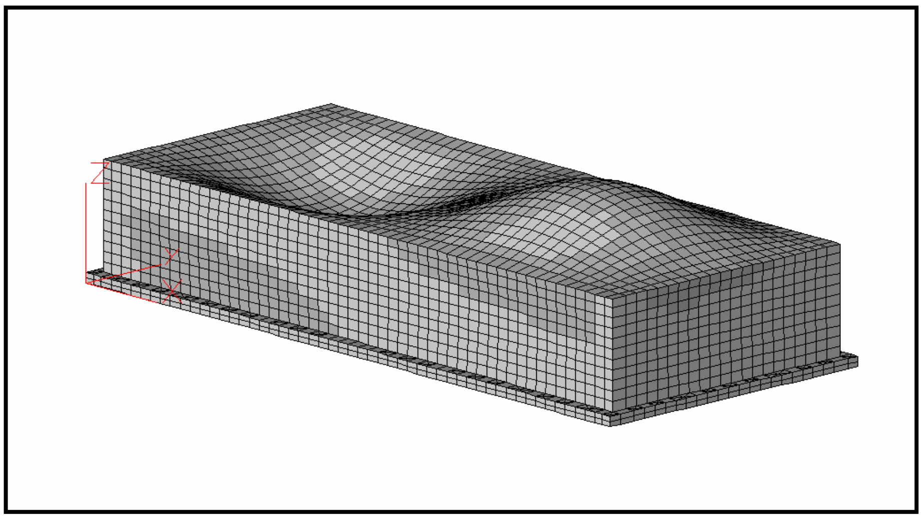


Figure 11
Natural Frequency 180.2 Hz.
PDU Model

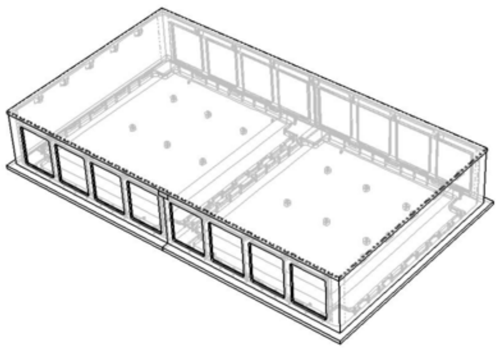
IV. RESULTS

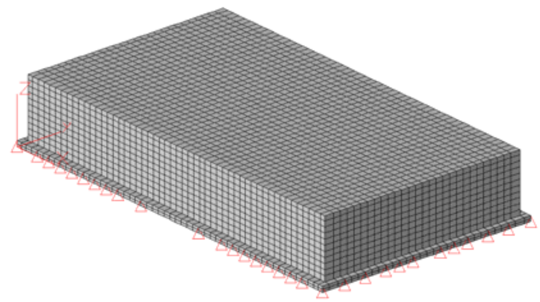
After the natural frequency analysis was completed, the numerical models were subjected to maximum expected 3-sigma level acceleration loads regardless of natural frequency. This is a very conservative approximation of the dynamic load factors. The following is a summary of the stress model assumptions for the GASU and PDU:

- Plate, Brick and Beam Elements
- Pinned Boundary Conditions
- Corresponding accelerations based on First Mode Natural Frequency
- Machined Aluminum 6061-T6
- Ultimate Strength 42000 psi
- Simplified Approach to Application of Dynamic Load Factor (DLF) defined by Miles Equation
- Applied Maximum Response at QUAL Level uniformly to each of the three orthogonal axes
- 3-sigma Dynamic Load Factors used to account for peak excitation.
- Ignored Mass Participation Effects and Non-uniform Distribution of acceleration loads throughout the structure.
- Q = 10
- Safety Factor of 1.4 x Ultimate Strength

GASU MODEL

Model Weight	31.4 lbs.
Natural Frequency	136.3 Hz
Dynamic Load Factor	134.52 Grms (Based on 44.84 Grms Maximum Response)





GASU ASSEMBLY SUMMARY			
Load Axis	Maximum Stress psi	Allowable psi	Margin
X	4054	30000	**6.40**
Y	3692	30000	**7.13**
Z	11380	30000	**1.64**

Figure 12
GASU Stress Summary

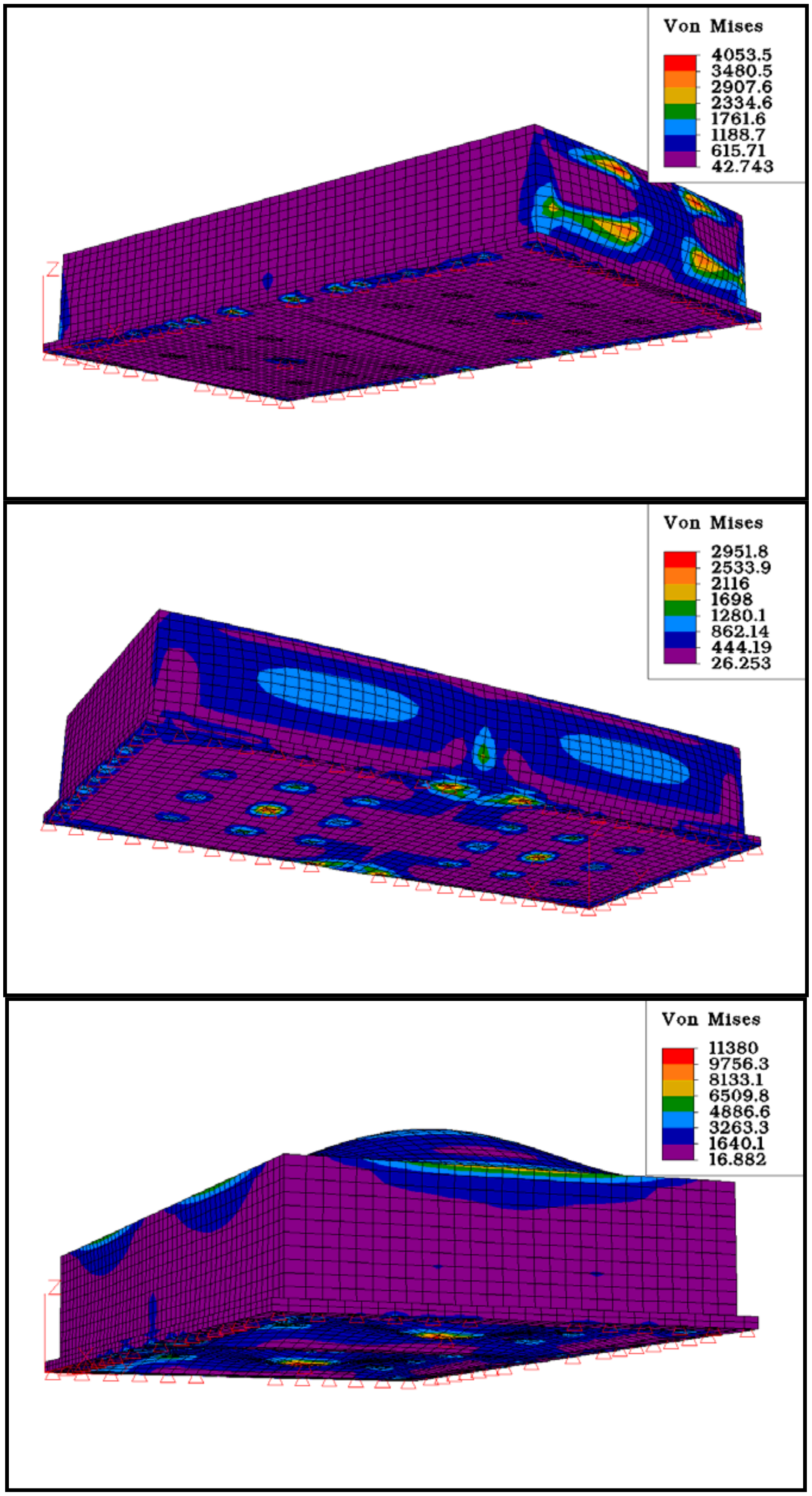
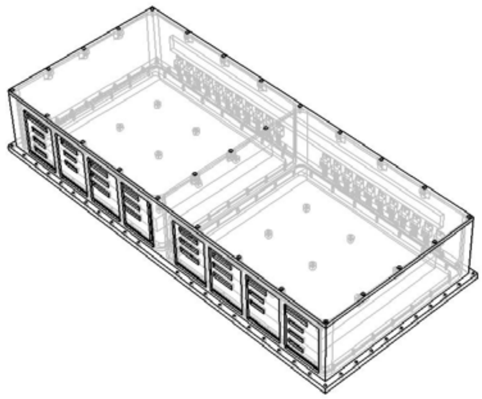
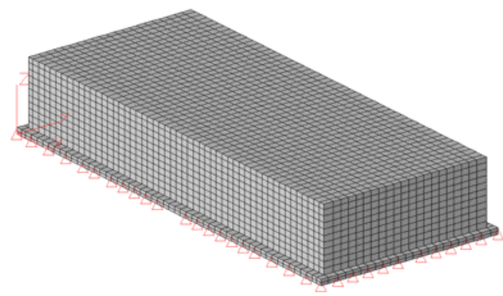


Figure 14
GASU X, Y and Z-Axis Deflected Shape and Stress

PDU MODEL

Model Weight	21.8 lbs.
Natural Frequency	180.2 Hz
Dynamic Load Factor	134.52 Grms (Based on 44.84 Grms Maximum Response)





PDU ASSEMBLY SUMMARY			
Load Axis	Maximum Stress psi	Allowable psi	Margin
X	1701	30000	**16.64**
Y	2952	30000	**9.16**
Z	11380	30000	**1.64**

Figure 15
PDU Stress Summary

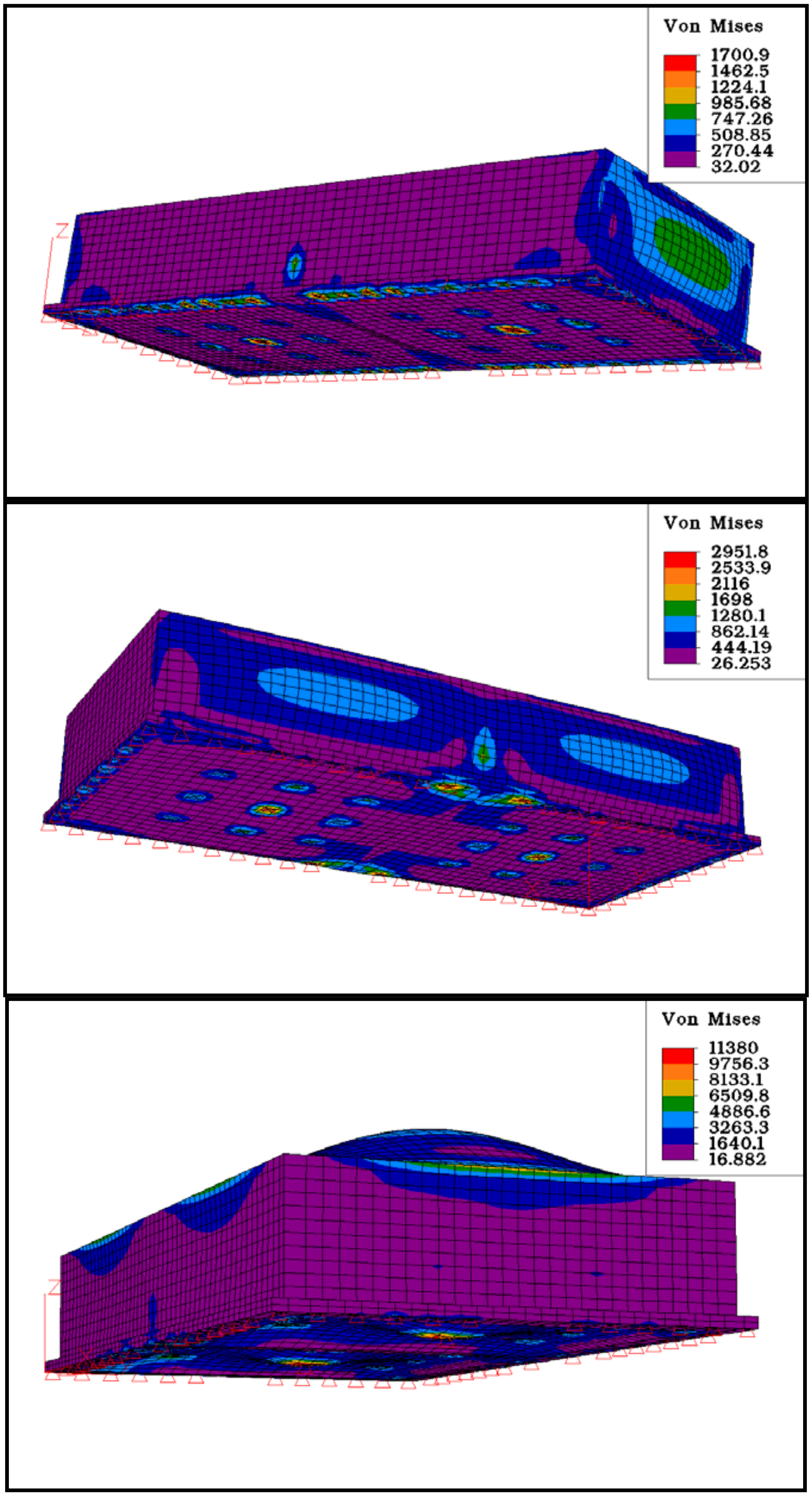
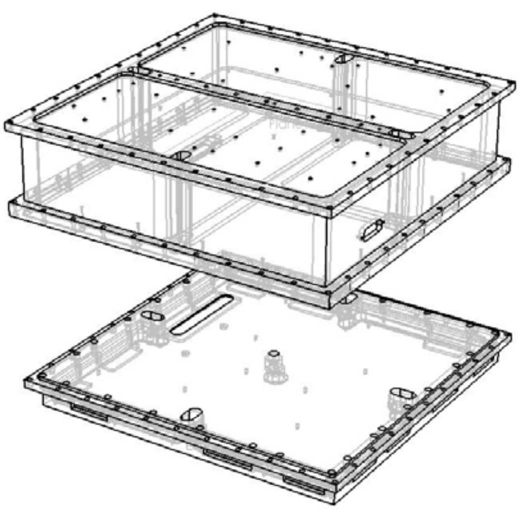


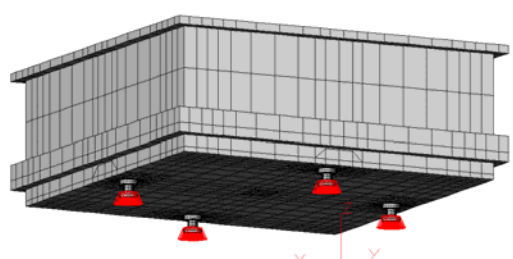
Figure 16
PDU X, Y and Z-Axis Deflected Shape and Stress

TEM-TPU
The TEM-TPU stack was analyzed through a modal survey analysis which solved for the first 30 modes. The results were used as input to an actual random input and analysis using the following assumptions:

- Plate, Brick and Beam Elements
- Model Weight 13.4 lbs. (6.10 kg)
- First Mode Natural Frequency = 381 Hz
- Machined Aluminum 6061-T6
- Ultimate Strength 42000 psi
- Modal Survey Run
- Applied QUAL Level Random Vibration Spectrum
- Results Show Combined Effects of Random Excitation
- 3-sigma Load Levels Used to Account for Peak Excitation.
- Damping = .05 (5 %)
- Safety Factor of 1.4 x Ultimate Strength
- 14.14 G_{rms} Input Level
- Ti 6Al-4V Standoffs
- Ti 6Al-4V M6x1 Socket Head Cap Screw Mounting Bolts
- Ultimate Strength 160ksi

The results of this analysis are based on an actual random power spectral density input to a modal analysis for the TEM-PSU unit. The analysis accounts for the mass participation factors associated with excitation frequencies of the model. The results for combined deflections and stress were scaled up to the 3-sigma level and compared to material allowable. Additionally, the model was analyzed for a worst case static equivalent combination load case.





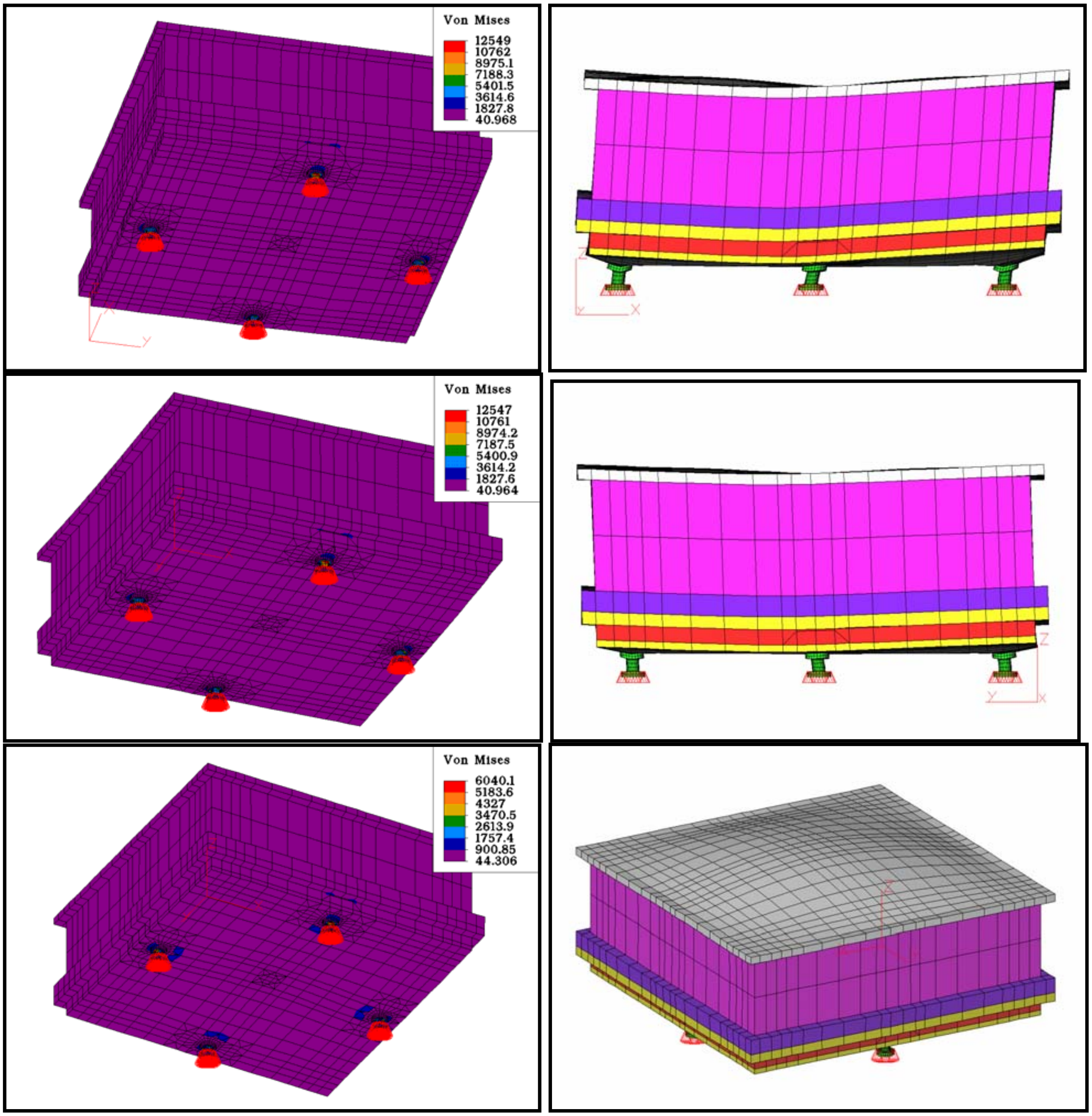


Figure 16
TEM-PSU X, Y and Z-Axis Deflected Shape and Stress

STANDOFF STRESS SUMMARY – TEM-TPU

- Maximum Stresses are produced in the Titanium Standoffs
- Stress Summary shows Standoff Stresses and Margins

STRESS SUMMARY							
Load Case	QUAL	Units		smax	dmax	Allowable	MARGIN
				psi	inch	psi	
RANDOM							
X	14.14	Grms		37782	.006	114286	**2.025**
Y	14.14	Grms		37641	.006	114286	**2.036**
Z	14.14	Grms		18120	.012	114286	**5.307**
STATIC							
Load Case	Y	Y	Z	smax	dmax	Allowable	MARGIN
Worst Combination	10.464	0	8.5	5288	.001	114286	**20.612**
Load Case	QUAL	Units		smax	dmax	Allowable	MARGIN
				psi	inch	psi	
MILES- RANDOM	3s						
X	134.52	Grms		61657		114286	**.854**
Y	134.52	Grms		61657		114286	**.854**
Z	134.52	Grms		35498		114286	**2.220**

TEM-TPU-EPU

The TEM-TPU-EPU stack was analyzed using the same approach as the TEM-TPU stack.

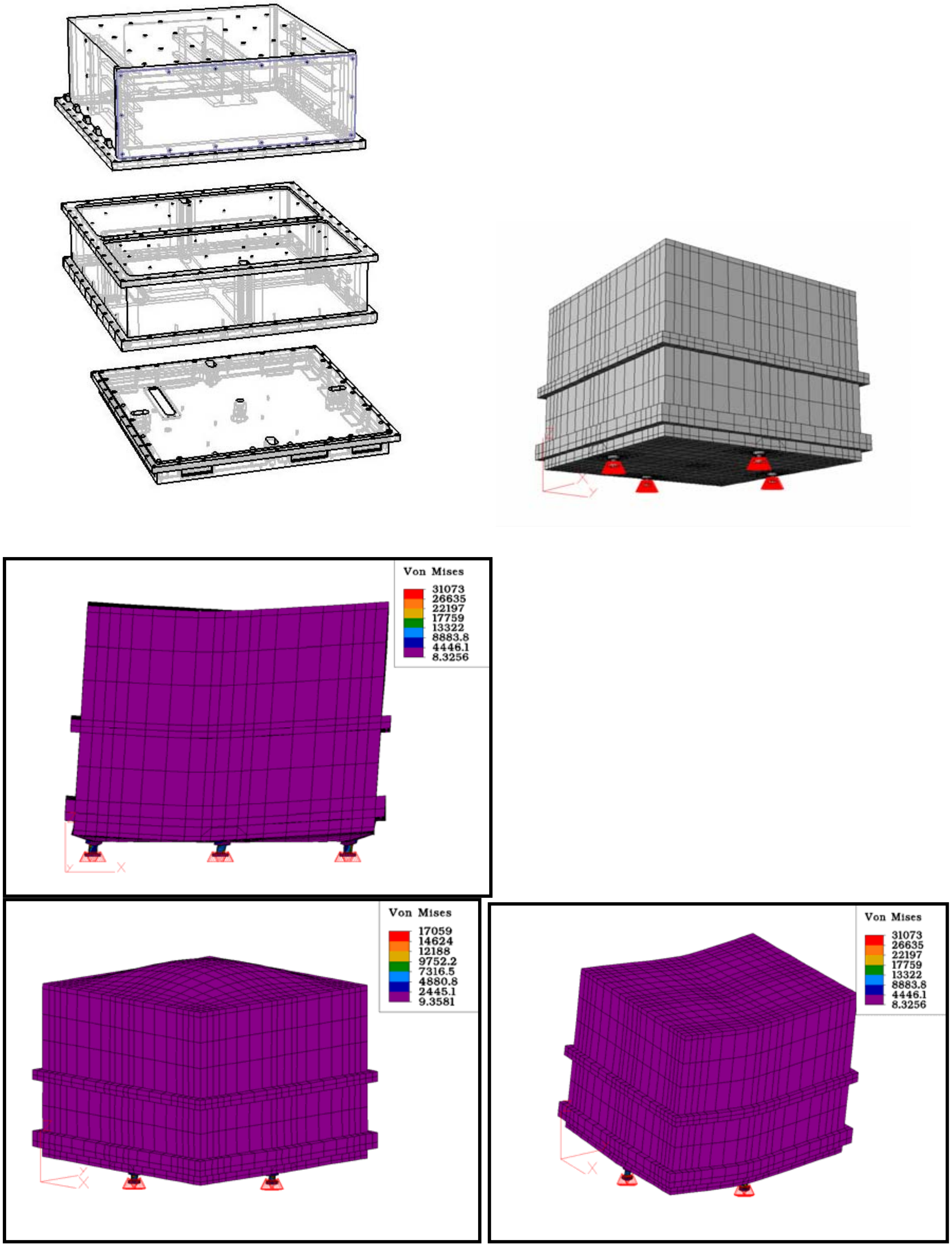


Figure 17
TEM-PSU-EPU X, Y and Z-Axis Deflected Shape and Stress

STANDOFF STRESS SUMMARY – TEM-TPU-EPU

- Maximum Stresses are produced in the Titanium Standoffs
- Stress Summary shows Standoff Stresses and Margins

STRESS SUMMARY							
Load Case	QUAL	Units		smax	dmax	Allowable	MARGIN
				psi	inch	psi	
RANDOM							
X	14.14	Grms		93219	.005	114286	**.226**
Y	14.14	Grms		93219	.005	114286	**.226**
Z	14.14	Grms		51177	.005	114286	**1.233**
STATIC							
Load Case	Y	Y	Z	smax	dmax	Allowable	MARGIN
Worst Combination	10.464	0	8.5	15676	.002	114286	**6.291**

V. BOLT STRESSES

Mounting Bolt Loads Summary

RANDOM VIBE EQUIVALENT

Component	Weight lbs.	Bolt Size	Quantity	Torque (Max) in-lbs.	Preload (max) lbs.	Bolt Material	Axial/Bending Stress psi	Shear Stress psi	Margin
GASU	29.30	# 8-36	56	24.0	732	A286	91854.1	6572.3	**.235**
PDU	21.66	# 8-36	62	24.0	732	A286	83674.2	4387.6	**.361**
SIU/EPU	14.79	# 8-36	40	24.0	732	A286	66438.5	4644.6	**.708**
PSU	7.31	# 8-36	40	24.0	732	A286	74728.1	6939.3	**.511**

Safety Factor	1.4	
Tensile Ultimate	160000	psi
Shear Ultimate	95000	psi

STATIC EQUIVALENT ACCELERATIONS

Component	Weight lbs.	Bolt Size	Quantity	Torque (Max) in-lbs.	Preload (max) lbs.	Bolt Material	Axial/Bending Stress psi	Shear Stress psi	Margin
GASU	29.30	# 8-36	56	24.0	732	A286	52100.1	723.1	**1.193**
PDU	21.66	# 8-36	62	24.0	732	A286	51531.9	482.7	**1.217**
SIU/EPU	14.79	# 8-36	40	24.0	732	A286	52959.2	1533.0	**1.155**
PSU	7.31	# 8-36	40	24.0	732	A286	51494.1	763.5	**1.219**

Safety Factor	1.4	
Tensile Ultimate	160000	psi
Shear Ultimate	95000	psi

VI. CCA EVALUATIONS

GASU Printed Wiring Assembly
Analysis of Populated Stand Alone Board Only

Board Thickness	.125 inches
Weight	3.0 lbs. (estimated)
Material	Polyimide (glass reinforced) MIL-P-13949 Type GIN (IPC-4104/40)
E (Modulus)	8.7e5 psi (8.7e5 to 2.12e6 REF: Mat Web Polyimide, Glass Filled)
Poisson Ratio	.45 (estimated)

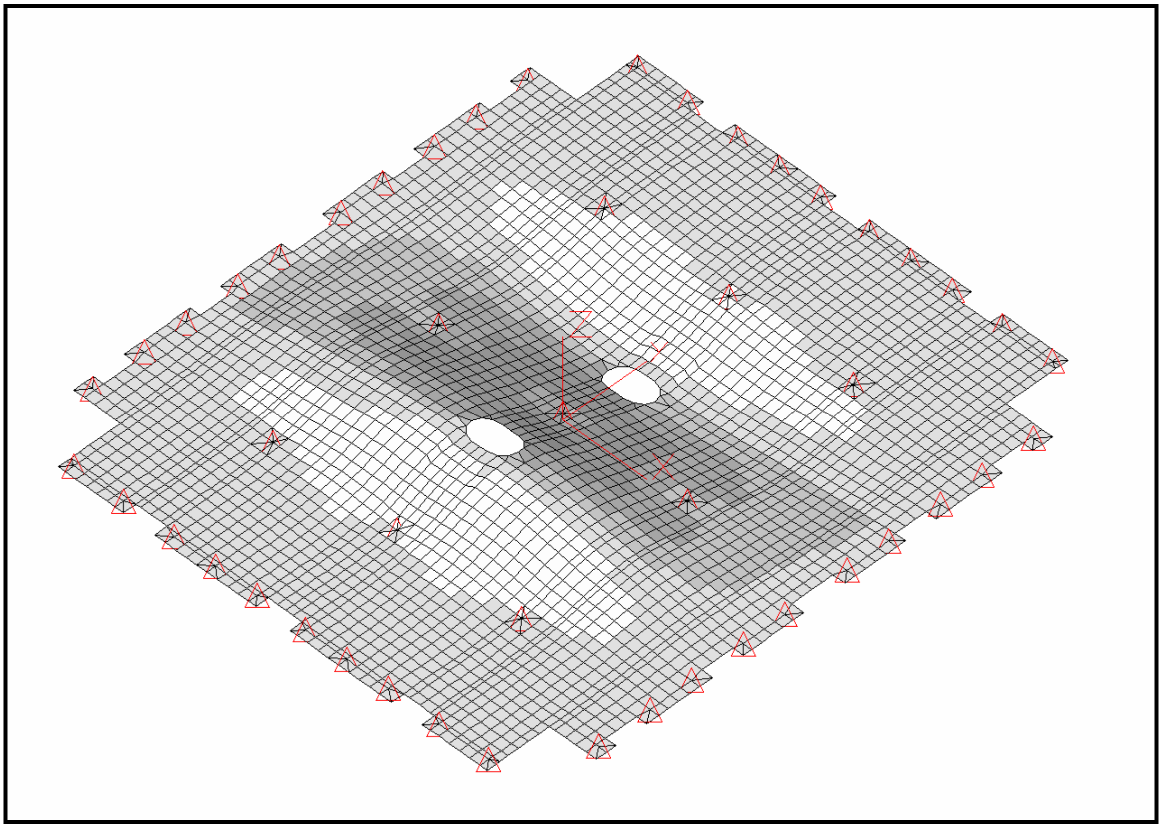


Figure 1
Mode Shape 1 - 321 Hz.

Mode	Frequency Hz	Input PSD g2/Hz	Modal Participation h	Transmissibility Q	Response Grms	Displacement 3s inches
1	321.2	.160	1.64	10	28.412	.013
2	340.1	.160	1.64	10	29.236	.012
3	392.9	.160	1.64	10	31.423	.010
4	405.3	.160	1.64	10	31.916	.009
5	463.5	.160	1.64	10	34.130	.008

PDU Printed Wiring Assembly
Analysis of Populated Stand Alone Board Only

Board Thickness	.093 inches
Weight	2.0 lbs. (estimated)
Material	Polyimide (glass reinforced) MIL-P-13949 Type GIN (IPC-4104/40)
E (Modulus)	8.7e5 psi (8.7e5 to 2.12e6 REF: Mat Web Polyimide, Glass Filled)
Poisson Ratio	.45 (estimated)

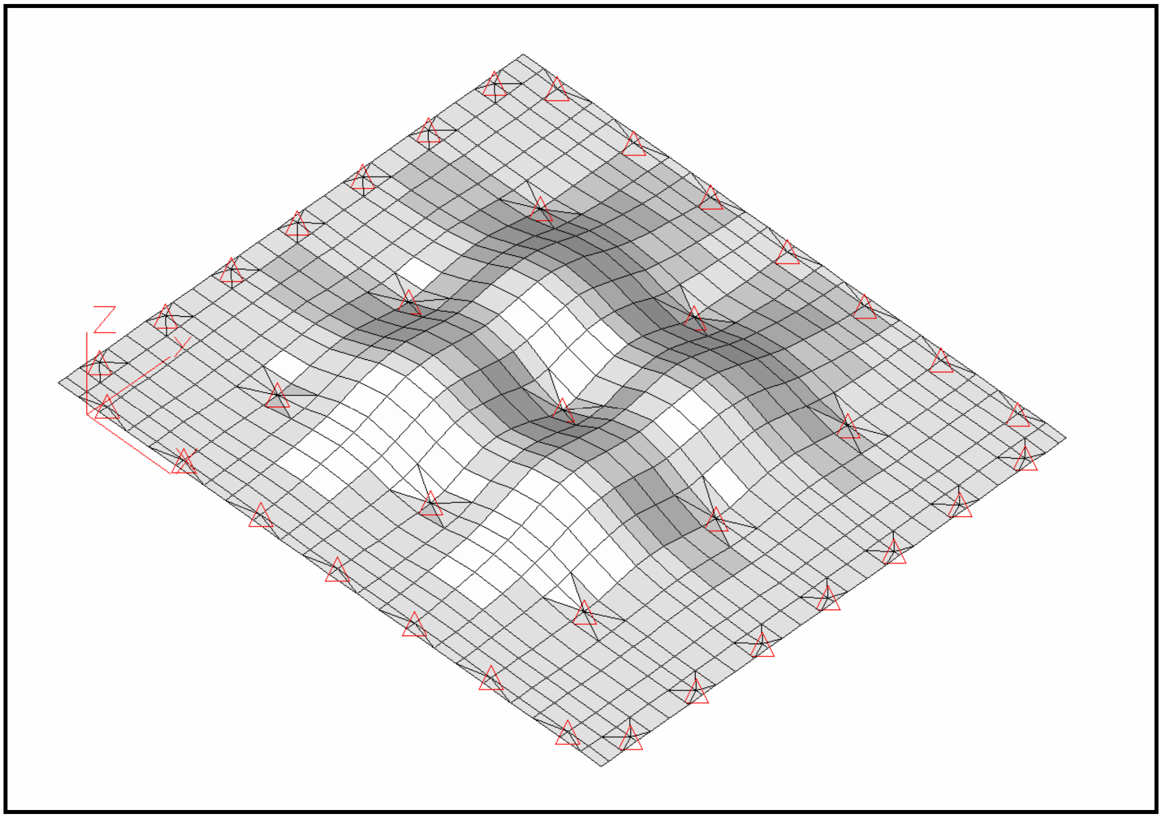


Figure 2
Mode Shape 1 - 351 Hz.

Mode	Frequency Hz	Response Grms	Modal Participation h	Transmissibility Q	Response Grms	Displacement 3s inches
1	351.5	.160	1.64	10	29.722	.012
2	356.6	.160	1.64	10	29.937	.011
3	389.2	.160	1.64	10	31.275	.010
4	437.5	.160	1.64	10	33.159	.008
5	593.0	.160	1.64	10	38.605	.005

SIB/LCB 6U Printed Wiring Assembly
Analysis of Populated Stand Alone 6U Module Assembly Only

Board Thickness .093 inches
Assembly Weight 2.1 lbs. (estimated)
Material PWA Polyimide (glass reinforced) MIL-P-13949 Type GIN (IPC-4104/40)
E (Modulus) 8.7e5 psi (8.7e5 to 2.12e6 REF: Mat Web Polyimide, Glass Filled)
Poisson Ratio .45 (estimated)
Stiffener/Wedge-Lock Aluminum 6061-T6
E (Modulus) 10e6 psi
Poisson Ratio .33
Connector LCP 30% Glass Filled (Liquid Crystal Polymer)
E (Modulus) 2.176e6 psi
Poisson Ratio .45 (estimated)

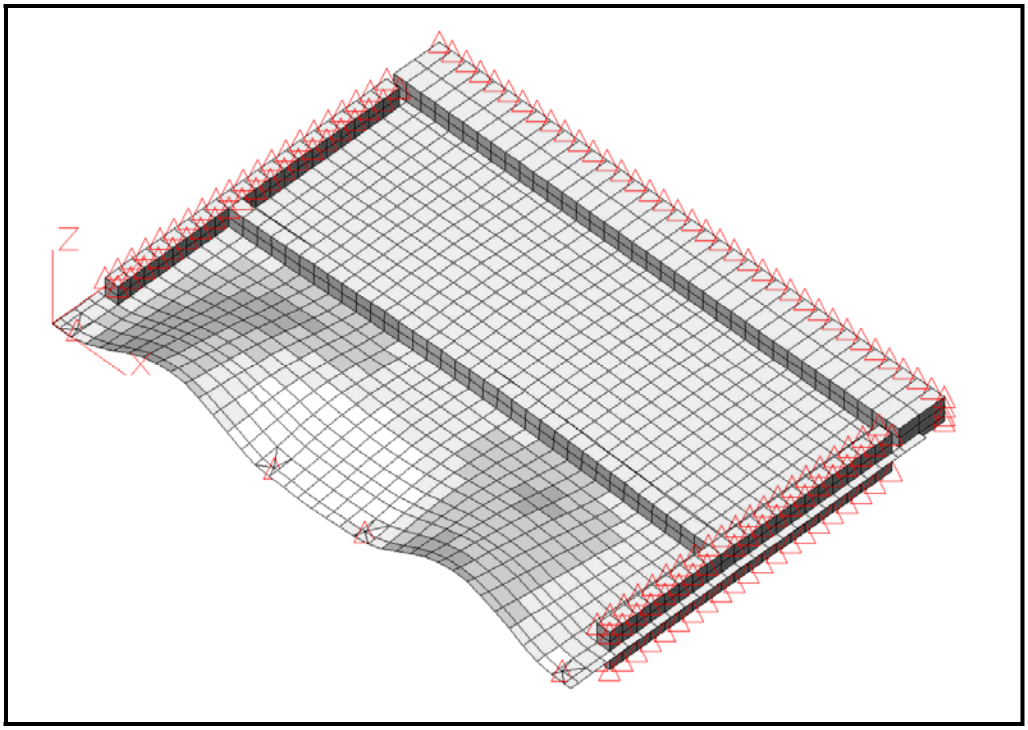


Figure 3
Mode Shape 1 - 173 Hz.

Mode	Frequency Hz	Response Grms	Modal Participation h	Transmissibility Q	Response Grms	Displacement 3s inches
1	274.5	.160	1.64	10	26.265	.017
2	282.3	.160	1.64	10	26.636	.016
3	305.7	.160	1.64	10	27.718	.014
4	375.6	.160	1.64	10	30.724	.010
5	423.8	.160	1.64	10	32.636	.009

The 6U CPCI was subjected to a modal analysis and subjected to the QUAL level random input PSD spectrum. The following figure represents the combined deflections due excitation of all the modes simultaneously.

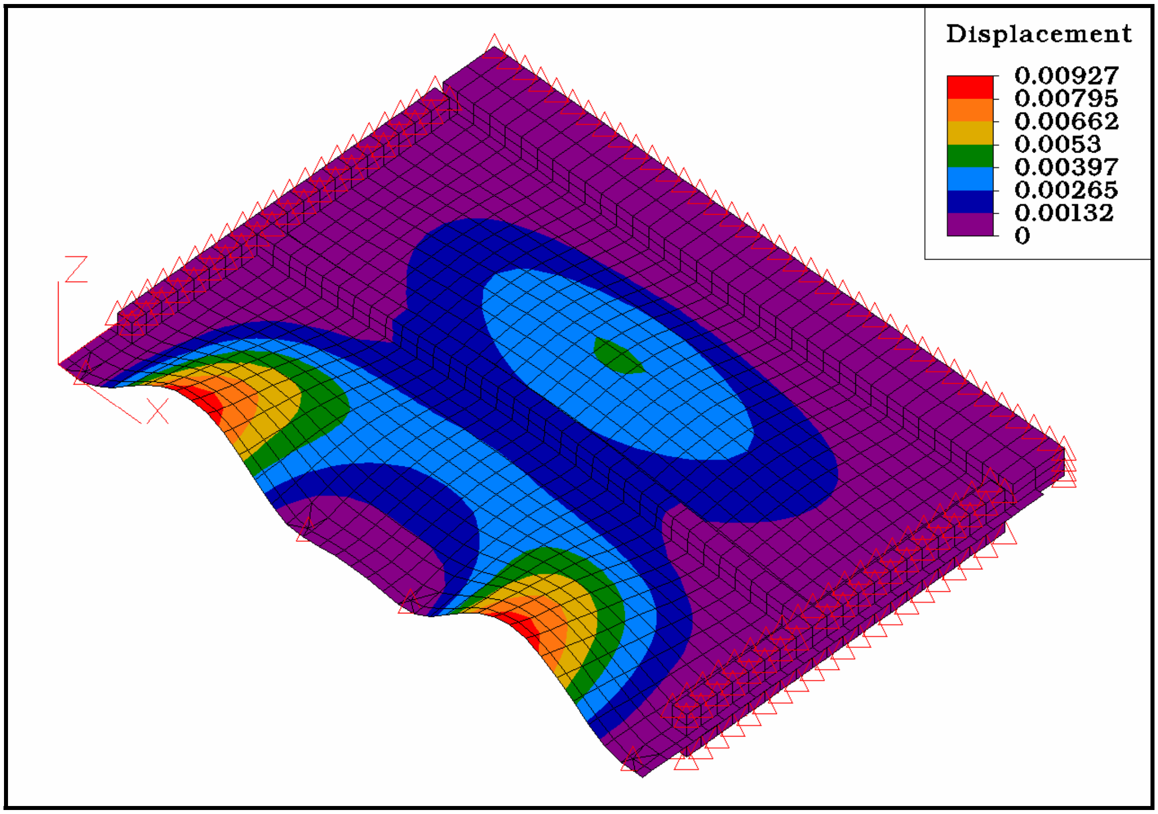


Figure 4
Combined Deflection due to 14.14 Grms Random Input

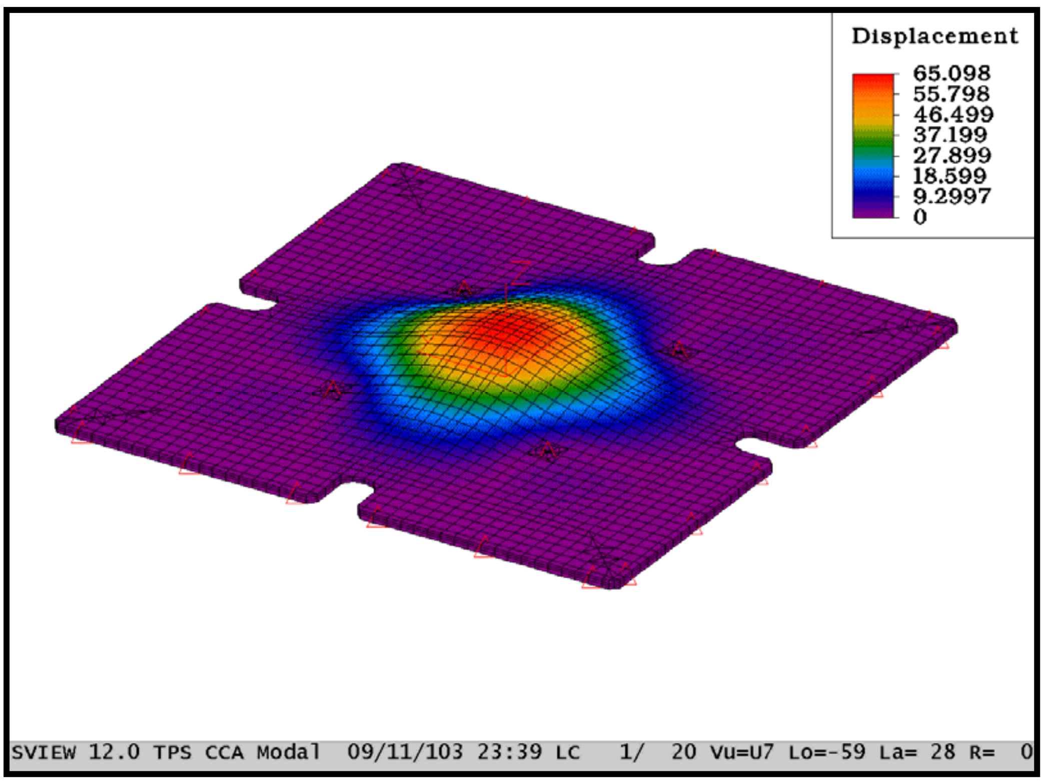
TPU Printed Wiring Assembly
Analysis of Populated Board with Heat Sinks

Board Thickness	.09 inches
Weight	1.7 lbs. (estimated) CCA plus Heat Sinks
Material	Polyimide (glass reinforced) MIL-P-13949 Type GIN (IPC-4104/40)
E (Modulus)	2.7e6 psi
Poissons Ratio	.120 (estimated)
Heat Sink Thickness	.064 inches
Material	Aluminum 6061-T6
E (Modulus)	10.0e6 psi
Poissons Ratio	.33

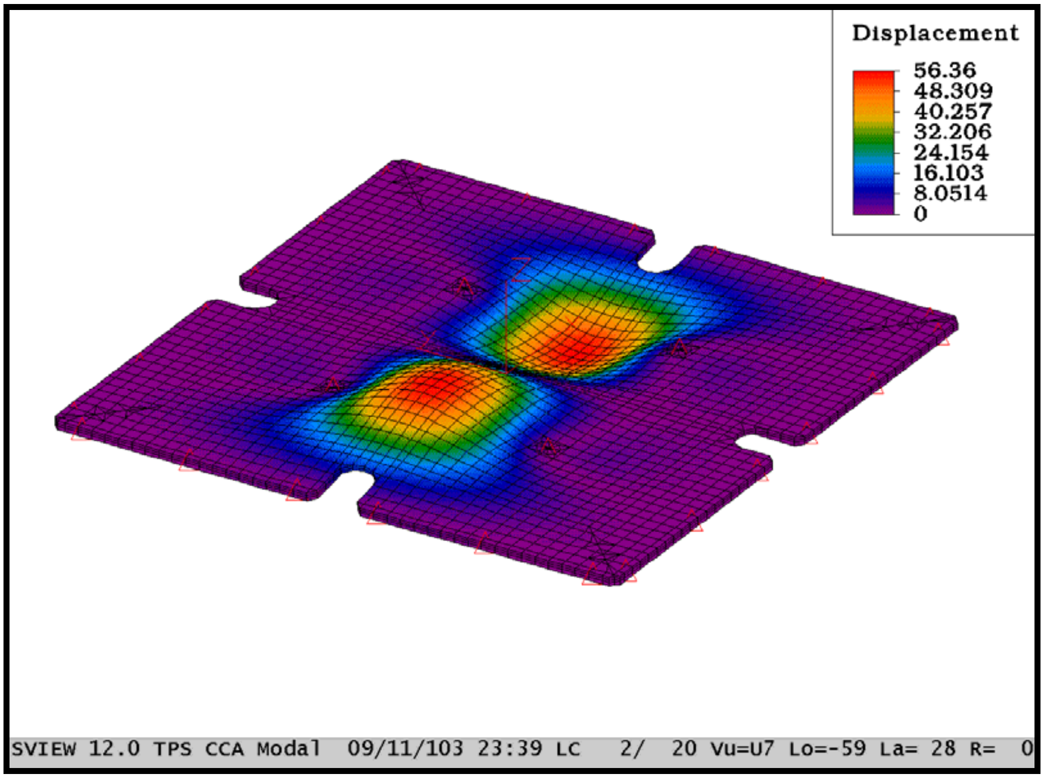
Random Vibration Run

Damping Ratio .05

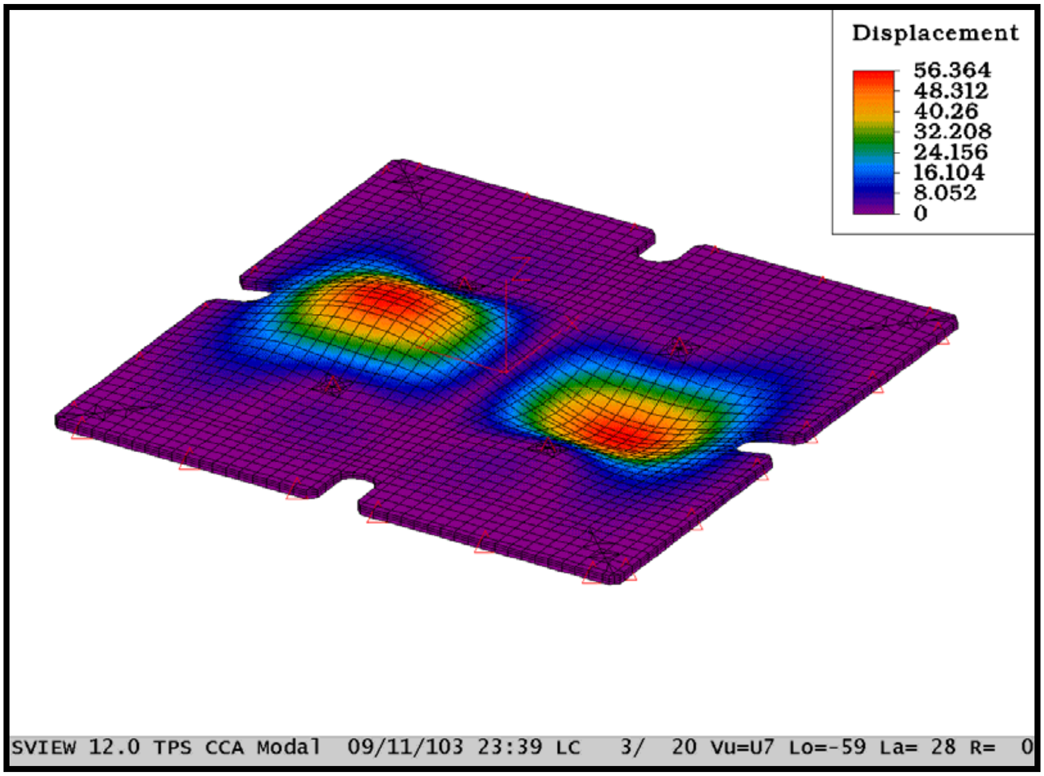
Solved for 15 modes.



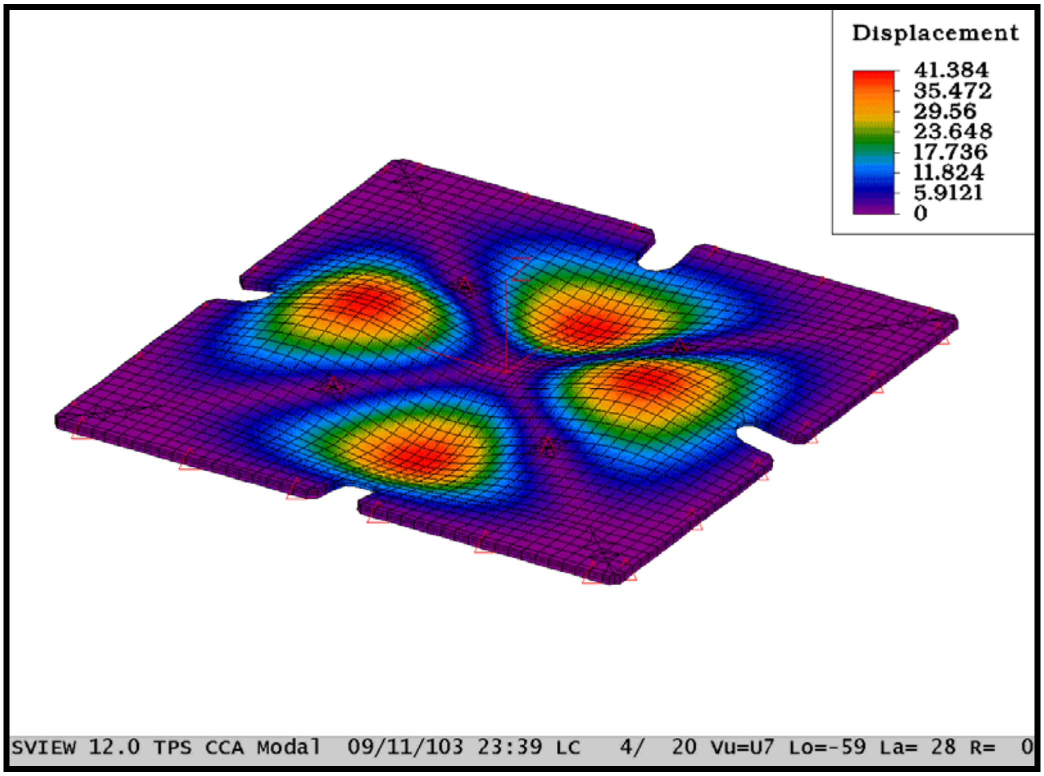
Fundamental Mode Shape 1



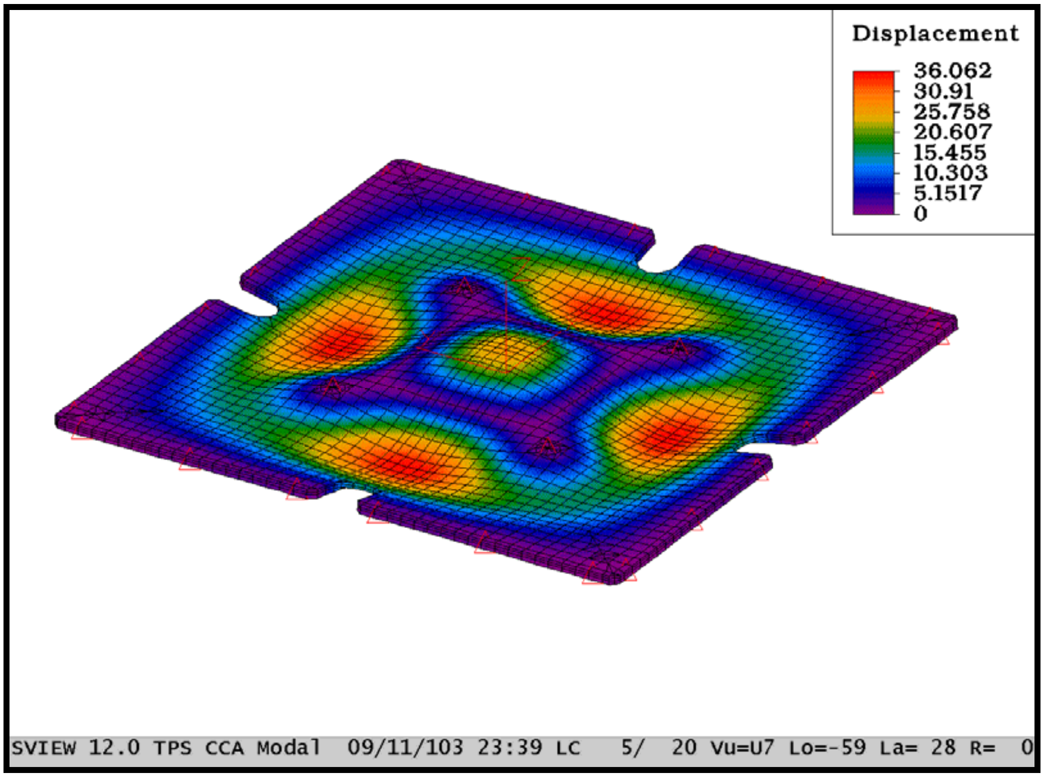
Mode Shape 2



Mode Shape 3



Mode Shape 4



Mode Shape 5

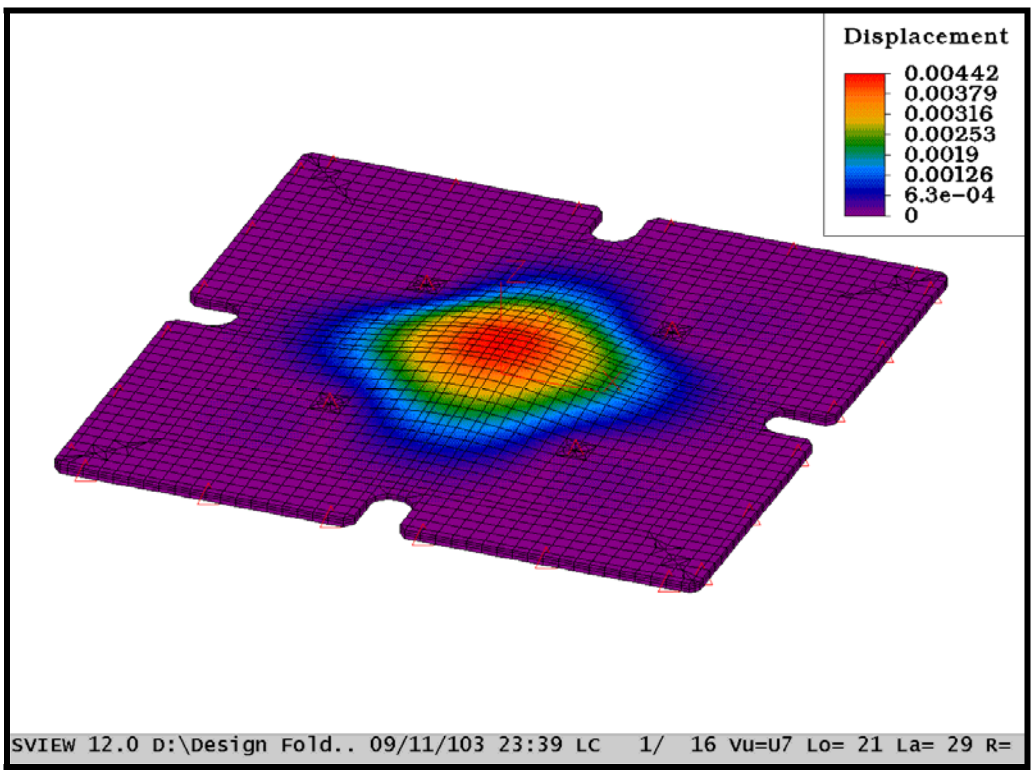
RESULTS FROM RANDOM INPUT

Attached Figures represent 1 Sigma combined stresses and displacement due to QUAL level random input spectrum. Multiply stresses and displacement by 3 to get 3 Sigma level predictions:

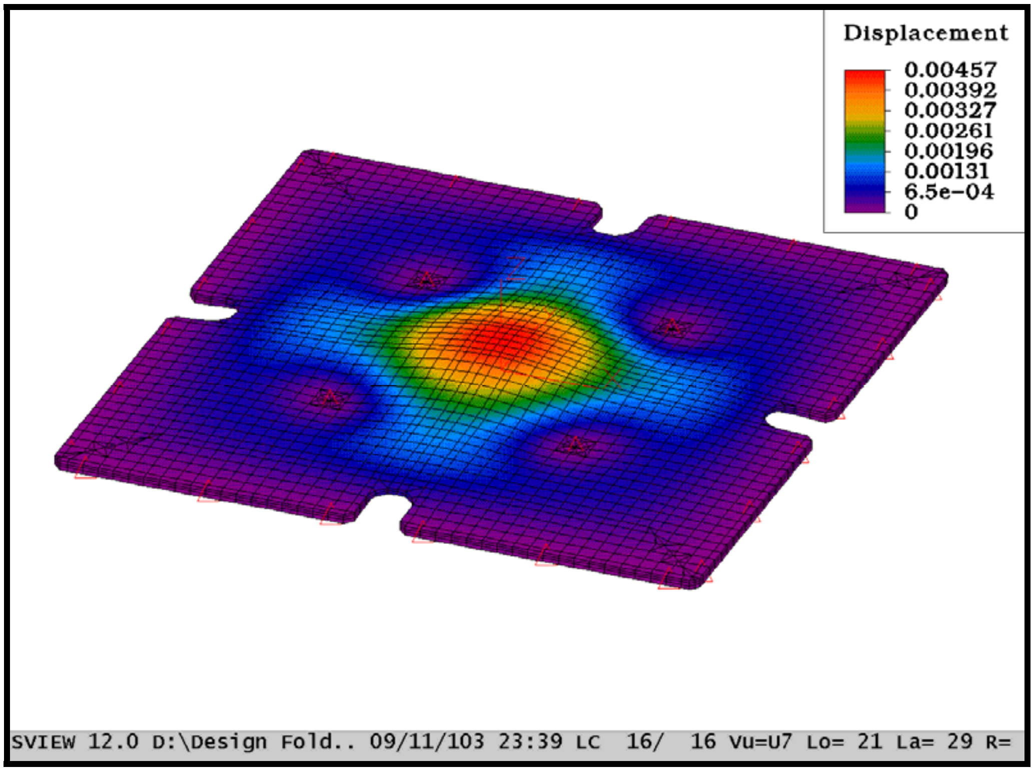
Displacement @ 3-Sigma Level: .014 inches
(Agrees with predicted displacement in Summary Chart)
Von Mises Stress @ 3-Sigma Level: 4654 psi

SUMMARY OF MODAL SEARCH (First 5 Modes)

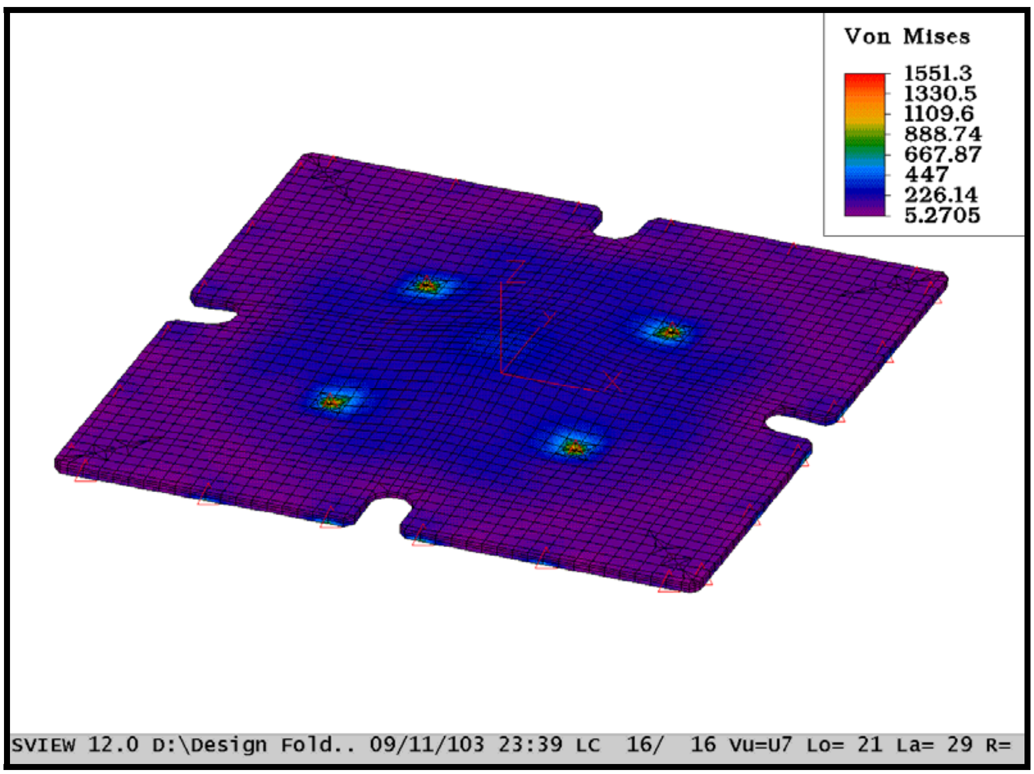
	Hz	Grms	h	Q	Grms	inches
1	337.4	.160	1.64	10	29.120	.012
2	565.6					
3	565.7					
4	608.4					
5	723.0					



Displacement of First Mode Due to Random Input at 1 Sigma Level



Combined Displacement Due to Random Input at 1 Sigma Level



Combined Von Mises Stress 1-Sigma Level, Top View