

An Integrated Approach to Random Analysis Using MSC/PATRAN with MSC/NASTRAN

Written By

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Abstract

This paper describes an integrated and efficient approach to random analysis using MSC/PATRAN and MSC/NASTRAN. New enhancements available in MSC/PATRAN provide the analyst with an interactive pre- and post-processing environment for random analysis. These new features will be discussed and results presented demonstrating how the new capability was used on two different industry case studies. Performance improvements using the MSC/NASTRAN direct access results database (xdb) over the standard output2 file will also be presented.

Introduction

Anyone who has ever performed a random or acoustic analysis in MSC/NASTRAN knows of the amount of labor involved in creating a random or acoustic input deck. Typical input decks involve a tremendous amount of effort in creating XYPlot or XYPUNCH cards in order to obtain the desired results. These cards typically must be formed for every point of interest; whether it is stress, displacement, acceleration, force, etc. Herculean efforts are also required if the user would like to perform "what-if" scenarios on a model. As a rule, a user would need to make changes to their model and create restart decks, or run the harmonic solution from scratch. This wastes valuable time and money.

Over the past year a solution for simplifying random analysis has been in the works at MSC using several sites as beta testers; one being Northrop Grumman Corporation, Sensors and Systems Sector (ES³). The new solution is called MSC/Random. Using MSC/Random involves knowing MSC/PATRAN, understanding random and/or acoustic analysis and your mouse.

Basically, MSC/Random wraps the typical hand-manipulation of the input decks into an easy to follow Graphical User Interface (GUI) within MSC/PATRAN. This offers several advantages to the older method:

- Less errors in creating the deck = less wasted time and frustration
- Ability to apply different random or acoustic inputs to a harmonic solution
- Ability to tell MSC/NASTRAN exactly what solution you want without re-typing half of your model back into deck.
- Use of the xdb (direct access) file to speed access of the data
- Ability to create contour plots of RMS responses
- Eliminates the need to prepare xyplot/xypunch cards and allows conventional output request such as STRESS=ALL, ACCE=ALL
- Use log-log interpolation and integration scheme.

This paper contains two examples of how MSC/Random has saved valuable time and effort on two separate analyses at ES³. The first analysis is of an electronic board assembly (subunit), while the second is of a newly contrived design of a camera mount. The first analysis will show the older method of hand-manipulation of the MSC/NASTRAN Input Deck and the use of the new MSC/Random, while the second analysis only shows the use of MSC/Random.

Example 1: Electronic Subunit

Model Objective

The first model's objective is to determine the acceleration, frequency, and cumulative RMS displacement of a node located at the center of an electronic subunit. This information is needed for determining statistical fatigue damage of the components located on the polyamide during random vibration loading. The node is taken relative to the large mass, to exclude rigid body displacements of the model.

Model Description

Geometry

The model is comprised of an aluminum heatsink and cover. Both the cover and the heatsink contain ribs to stiffen the boards. The model also contains a polyamide printed wiring board (PWB) which is densely populated with components. The general dimensions of the board are 13.74 x 9.55 inches and can be seen below in Figure 1. Figure 2 shows the finite element model (FEM) of the subunit as displayed by MSC/PATRAN.

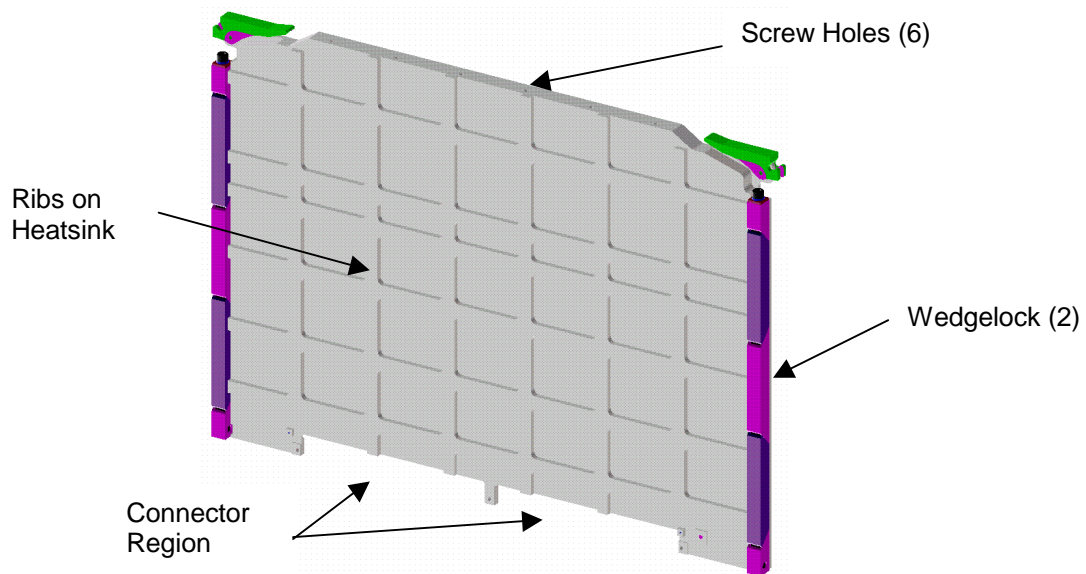


Figure 1: CAD Model Isometric View of Electronic Subunit

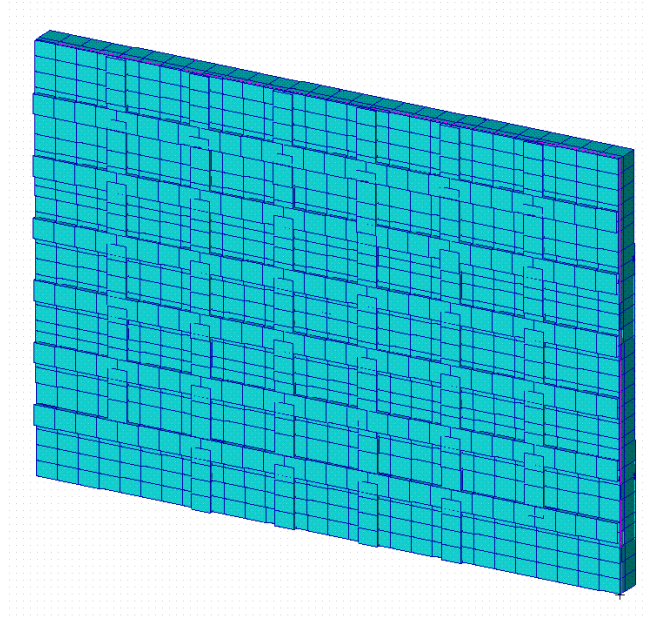


Figure 2: Finite Element Model Of Subunit

Material Properties

Each major structure within the model has the following general mechanical properties:

Table 1: Mechanical Properties of Subunit Finite Element Model

	Modulus of Elasticity		Poissons Ratio		Shear Modulus		Thickness	Weight
	[Mpsi]				[Mpsi]		[in]	[lb _f]
PWB	E ₁₁	2.46	ν ₁₂	0.129	G ₁₂	0.44	0.143	1.309
	E ₂₂	2.46	ν ₂₃	0.407	G ₂₃	0.35		
	E ₃₃	1.08			G ₃₁	0.35		
Cover		9.9		0.33			0.03	0.465
Heatsink		9.9		0.33			0.06	1.872

Please note that the weight of the PWB is comprised of both the polyamide and the component weight.

The total weight of the subunit assembly is 3.646 lb_f.

Boundary Conditions (Constraints)

The boundary conditions of the model are as follows:

- Rigid constraints along the short side to simulate a wedgelock configuration.
- Single point constraints along the top of the board to simulate screws tying the top of the subunit to a chassis cover.
- Several Points along the bottom constrained to represent the subunit connectors, which plug into a backplane.

Random Vibration Loading Conditions

The Random Vibration inputs were supplied from a customer specification. They are as follows (Table 2, Figure 3):

Table 2: Acceleration Power Spectral Density

Frequency	PSD
[Hz]	[G ² /Hz]
20	0.0015
200	0.09
2000	0.09

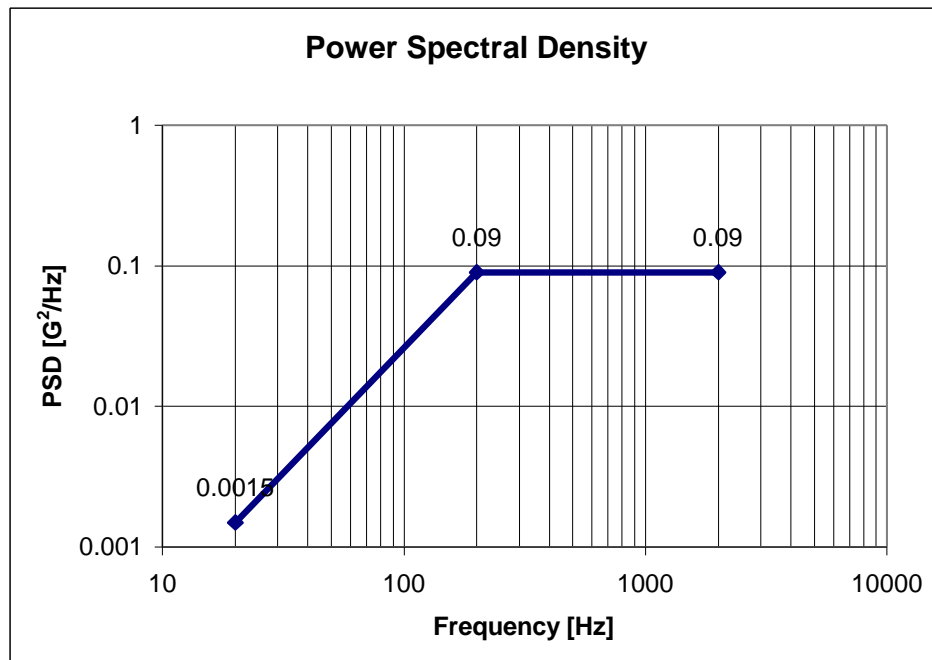


Figure 3: Acceleration Power Spectral Density

The G_{rms} of the input PSD is 13. This can be calculated by taking the square root of the area under the acceleration spectral density curve.

Mode Plots

The plot below (see Figure 4) represents mode 5 (353 Hz). It is this mode that contributes the most to the displacement of the center of the subunit during random vibration loading. This plot was derived from a modal analysis of the subunit. Mode 5's contribution is quantified by the use of a DMAP alter called myeffmass.v70 provided by MSC. This DMAP alter provides a normalized mass participation factor, which is useful in determining which modes are the largest contributors to the subunit's displacement.

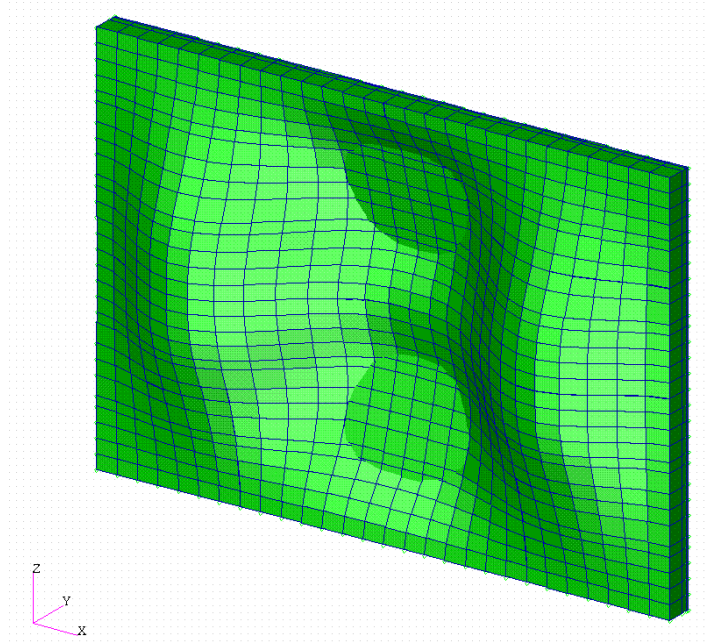


Figure 4: Subunit - Mode 5, 353 Hz

Old Method (XYPlot/XYPunch)

Example Input Deck

The following is an example input deck for recovering acceleration and displacement data for a given bandwidth from a random input deck. This method is considered the “Old Method”.

Note: Comments are **highlighted**, while areas of concern are in *Italics*.

```
ID SEMINAR, RANDOM
$ Modal Frequency Response (111)
SOL 111
$ Maximum time to allow the job to run
TIME 60000
$ Designates the end of the Executive Control Statement
CEND
TITLE= RANDOM ANALYSIS - BASE EXCITATION
SUBTITLE= USING THE MODAL METHOD WITH LANCZOS
$ Print the sorted Bult Data deck (UNSORTED for printing unsorted deck)
ECHO= SORTED
$ Select a single point constraint set to be applied - see RBE below
SPC= 101
$ Method is used to request eigenvalue extraction for set 100
METHOD= 100
$ Call the Damping Input (TABDMP1)
SDAMP= 100
$ Set of forcing frequencies to be solved for in problem
FREQUENCY= 100
$ Set the MPC for Relative Displacement Calculations
MPC= 100
$ Selects the RANDPS and RANDT1 bulk data entries to be used in random run.
RANDOM= 100
$ Selects the Dynamic or Acoustic loading to be used in the analysis
DLOAD= 100
$
```

```

$ Start of xyplot function for viewing results
OUTPUT(XYPLOT)
$
$ Create Output of ACCELERATION for Each NOC
$ Accel PSD at large mass
XYPUNCH ACCEL PSDF / 9999(T2)
$ Accel PSD at subunit center
XYPUNCH ACCEL PSDF / 10001(T2)
$ Accel PSD at subunit center
XYPUNCH ACCEL PSDF / 10002(T2)
$
$ Create Output of DISPLACEMENT for Each NOC
$ DISP PSD AT LARGE MASS
XYPUNCH DISP PSDF / 9999(T2)
$ DISP PSD AT SUBUNIT CENTER
XYPUNCH DISP PSDF / 10001(T2)
$ DISP PSD AT SUBUNIT CENTER
XYPUNCH DISP PSDF / 10002(T2)
$
$ Send the Displacement RMS Data to F06 file
XYPEAK DISP PSDF /9999(T2) /10001(T2) /10002(T2)
$
BEGIN BULK
PARAM, AUTOSPC, YES
PARAM, COUPMASS, 1
PARAM, K6ROT, 1.
PARAM, WTMASS, 1.
PARAM, GRDPNT, 0
PARAM, NOCOMPS, -1
PARAM, DDRMM, -1
$
$ Include Model Here
INCLUDE 'harmonic.bdf'
$
$ Single Point Constraint in all but D.O.C.
SPC1, 101, 13456, 9999
$
$ Concentrated Large Mass at a point
CONM2, 6000, 9999, , 1.0E8
$
$ Perform a real eigenvalue analysis with Lanczos
EIGRL,100,-.1,2000.
$
$ SPECIFY MODAL DAMPING
TABDMP1, 100, CRIT,
+,0.01000, 0.02000, 2000.00, 0.02000, ENDT
$
$ Frequency Dependent Dynamic Load where
$ 100: SID
$ 600: DAREA ID (see below)
$ 310: Damping table
$
RLOAD2, 100, 600, , , 310
$
$ Dynamic Loading table, note that it is the same across the entire frequency
TABLED1, 310,
+, 0., 1.0, 10., 1., 9000., 1., ENDT
$
$ Scale factor for dynamic loads. In this case it is used to create the
$ large mass in the Y-direction (node 9999 in the 2(Y) direction by 1.E8)
DAREA, 600, 9999, 2, 3.864+10
$
$ SPECIFY FREQUENCY STEPS

```

```

FREQ2, 100, 0.0100, 2000.00, 100
FREQ4, 100, 0.0100, 2000.00, 0.100, 3
$
$ SPECIFY SPECTRAL DENSITY
RANDPS, 100, 1, 1, 1., 0., 100
$
$ Power spectrum density curve
TABRND1, 100, LOG, LOG
+, 20.0, 0.0015, 200.00, 0.09, 2000.00, 0.09, ENDT
$
ENDDATA

```

Acceleration

The chart below shows the acceleration power spectral density response of the subunit's center. It can be seen that the first mode response is roughly 204 Hz; however, this mode is primarily a mode created by the subunit's cover. Additionally, it can be seen that mode 5 (353 Hz) is a large contributor to the acceleration of the subunit. This typically will point to a large displacement response.

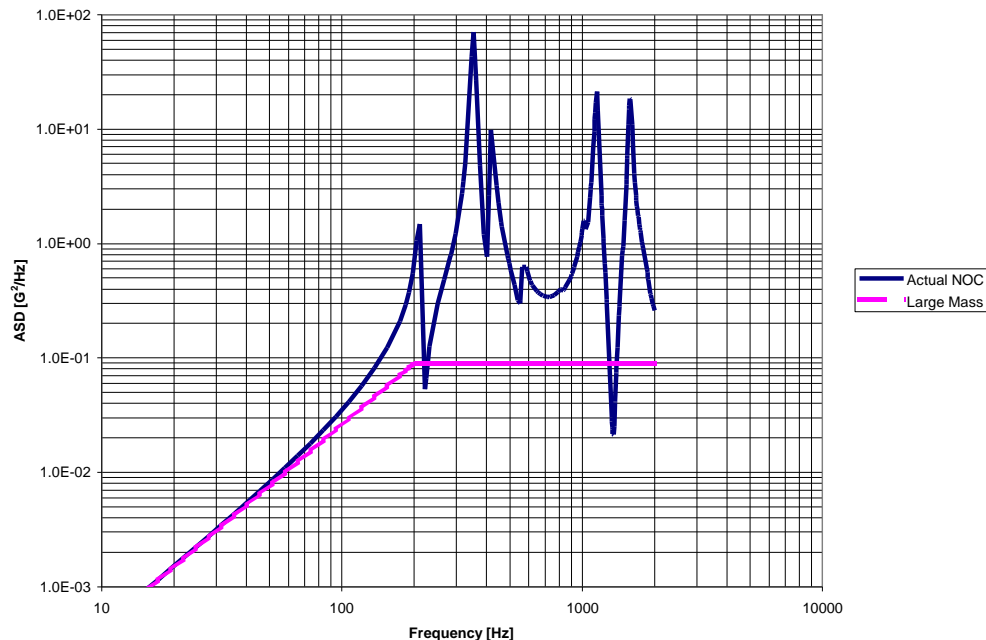


Figure 5: Acceleration Power Spectral Density

Displacement

Figure 6 shows the “Old Method” of creating plots from data acquired from MSC/NASTRAN. As can be seen, the data is sorted and brought into Microsoft Excel, then manipulated until the proper plot is created. For the problem at hand, the Relative, Actual, and Large Mass curves are data acquired directly from the MSC/NASTRAN *.pch file (referenced by the XYPunch command in the example input deck). The Cumulative curve (uses right Y-Axis) is a curve that is typically used to give a more precise understanding which mode contributes the most to the overall cumulative deflection. If the board is failing, it is these frequencies where the largest gain on the cumulative curve is found, that a designer would want to attempt to reduce. This can be typically done by stiffening the board (assuming that the PSD input does not rise at higher frequencies), requesting for a “notched” input, or by applying damping methods to the subunit

For the subunit being studied, the mode at frequency 353 Hz contributes approximately 25% to the overall displacement of the center of the subunit for analyzed bandwidth (20 – 2000 Hz). The overall cumulative 1σ displacement across the entire bandwidth is 3.53×10^{-3} in.

An additional note, is that the cumulative displacement curve is a derived curve from the relative displacement data output by MSC/NASTRAN in the *.pch file. This curve is created by numerically integrating the data over the given frequency bandwidth.

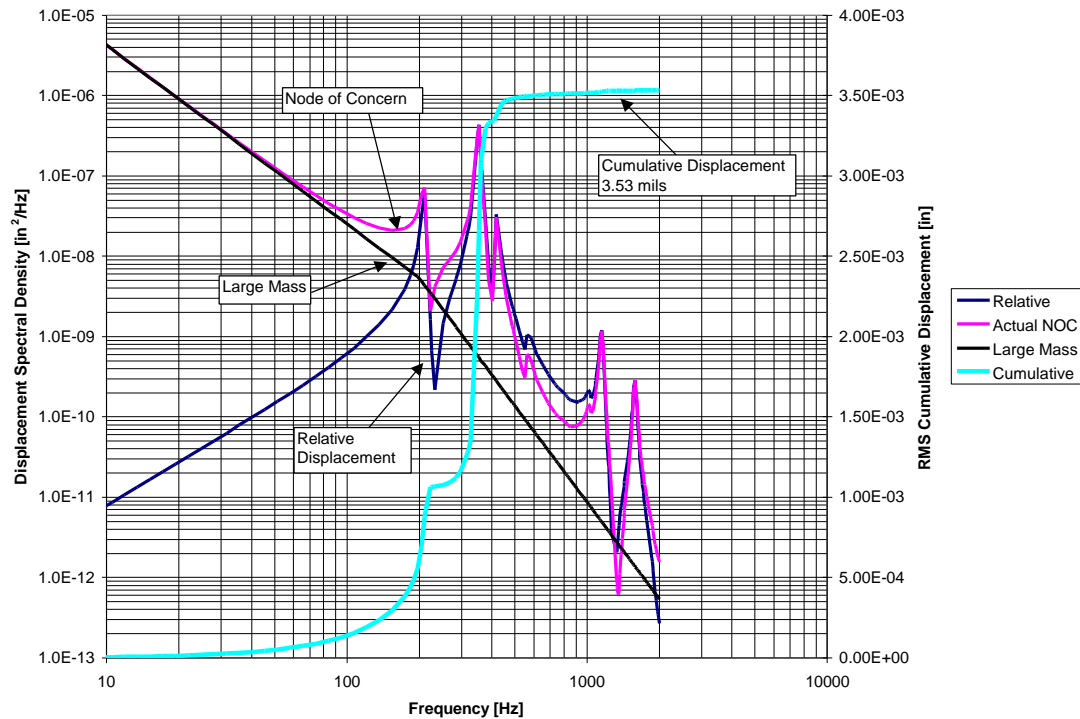


Figure 6: Displacement Results from "Old Method" Output – Created in Excel

Results

From the above analysis, a typical use of the displacement and frequency data is to feed it into a set of calculations used to determine a Critical Damage Index (CDI) of its component's solder joints under vibration loading. This method, although not shown, can be derived from David Steinberg's book *Vibration of Electronic Components 2nd ed.*, and Robert Blevin's book *Formula's For Natural Frequency and Mode Shape*. In general, a CDI calculation will give the analyst an understanding of the chances for failure of the component's solder joints, which for an electronic structure under random vibration loading, is a major failure mode.

New Method (MSC/Random)

Objective-wise, our model is exactly the same as before. However, in this example, MSC/Random will be demonstrated, and it will become apparent how easy it is to use.

Commands Used

For MSC/Random, there is no input deck manipulation involved. The entire random vibration run can be produced within MSC/PATRAN. This saves valuable time for the user. Additionally, it drastically decreases the chances for typos in the input deck. In general, the following procedure is used:

1. Create Model as you would normally do in MSC/PATRAN
2. Create a large mass node away from model off in space. Do not assign a large mass element to the node (CONM2). This will be created by MSC/Random
3. Attach the large mass node to the model with RBE2's (typically 6 DOF); however, do not assign a constraint or SUPORT card to the large mass (MSC/Random will do it for you).

Note: At this point the model is exactly how it is in the "old model" method.

4. Enter your damping and acceleration power spectral density curves into the model under "Field, Create, Non-Spatial, Tabular" - using Frequency based input.
5. Click on MSC/Random in the Toolbar
6. Change to Frequency Response Analysis

Under Harmonic Analysis, selections can be made to include:

- Name of harmonic analysis
 - Specifying the large mass node
 - Selecting the direction(s) of concern
 - Specifying the Damping Input Curve
 - Specifying the bandwidth
 - Selecting data recovery methods by FREQ cards
 - Selecting types of data recovery (Displacement, Acceleration, Stress, Force, and Velocity).
7. Once the above are selected, click on Apply to bring up the analysis form.
 8. At this point, running the harmonic analysis is almost identical to running a modal analysis. Select the harmonic analysis, then run full analysis from MSC/PATRAN or output an input deck for MSC/NASTRAN analysis in batch mode.

At this point, the job may be started in MSC/NASTRAN by whatever method you usually use. This will create a jobname.xdb file, where jobname is the name of the harmonic analysis. With the harmonic analysis complete, the real power of MSC/Random will become apparent in the following steps.

9. Return to MSC/Random, and select RMS Analysis.
10. Type in a jobname (does not have to be the same as the harmonic analysis)
11. Select an xdb file
12. Select Random Input
13. Select the subcase for which you would like to perform a random vibration analysis.
14. Select the random vibration input – either from MSC/PATRAN or from a file.
15. Select Automatic RMS Import in order to attach the xdb to MSC/PATRAN if you want to automatically import the created xdb file.

Please note that steps 9 through 15 can be repeated as many times as the user would like for the harmonic case created. This is a major advantage over the previous method where restarts would need to be created by hand. This allows the user to perform case studies for different random inputs with little lost time. In fact, solutions can be created from the xdb file on the fly. A full random analysis need to be performed only if you are interested in RMS contour plots that will help identify highly stressed areas.

16. Results can now be viewed by either selecting nodes or elements to graph in terms of an XY plot (acceleration vs. frequency, cumulative displacement vs. frequency, etc.), or by selecting groups of elements to graph under Results.

The following is an example of the input deck created by the harmonic analysis portion of MSC/Random.

Note: Comments are highlighted, while areas of concern are in *Italics*

```

init master(s) $ do not save database
$ Frequency Response Analysis, Modal Formulation, Database
SOL 111
TIME 60000
$ Direct Text Input for Executive Control
$
CEND
SEALL = ALL
SUPER = ALL
TITLE = Job Created by msc_random
ECHO = NONE
MAXLINES = 999999999
MPC = 3
$ Direct Text Input for Global Case Control Data
SDAMP = 10003
SUBCASE 1
$ Subcase name : msc_random_base_Y
  SUBTITLE=msc_random_base_Y
  METHOD = 1
  FREQUENCY = 2
  SPC = 2
  DISPLACEMENT(PLOT,SORT2,REAL)=ALL
  ACCELERATION(PLOT,SORT2,REAL)=ALL
  STRESS(PLOT,SORT2,REAL)=ALL
$ Direct Text Input for this Subcase
  DLOAD = 22201
BEGIN BULK
PARAM      POST      0
PARAM      AUTOSPC YES
PARAM      COUPMASS -1
PARAM      K6ROT      1.
PARAM      WTMASS      1.
PARAM      GRDPNT      0
PARAM,NOCOMPS,-1
PARAM      DDRMM      -1
PARAM      PRTMAXIM YES
EIGRL      1          -.1          2000.          0
$ Direct Text Input for Bulk Data
$
$ =====
$ ===== Bulk data cards created by msc_random =====
$ ===== Base Input =====
$ =====
$
$
$ large mass at input node.
CONM2      9999      9999          1.+8
$ Damping table from MSC/PATRAN Field:Damping
TABDMP1 10003 crit
+          0.01000 0.02000 2000.00 0.02000 endt
$
$ Freq cards created by msc_random
FREQ2      2          20.0000 2000.00          100
FREQ4      2          20.0000 2000.00 0.10000          3
$
$
$ Y DIRECTION 1G LOAD
RLOAD1,22201,22205,,,11111
DAREA      22205      9999          2 3.864+10
$

```

```

$ INPUT TABLE FOR ALL SUBCASES, CALLED BY RLOAD1 CARDS
TABLED1 11111
      0.      1.0      10.      1.0      9000.      1.0      ENDT
$
$ SUPORT card to remove rigid body modes
SUPORT,9999,123
$
$ ===== End of msc_random Created Cards =====
$
$ Input Model Data here
INCLUDE 'harmonic.bdf'
$
$ Loads for Load Case : msc_random_base_Y
SPCADD  2      100
$ Displacement Constraints of Load Set : msc_random_Hold_Rotation.100
SPC1    100      456      9999
$ Referenced Coordinate Frames
ENDDATA 8b36bf55

```

Acceleration

From the MSC/Random run, Figure 7 shows the acceleration response of the node of concern (grid 10001) and the large mass (grid 9999). As expected, the large mass's response curve took on the shape of the input curve. Although not shown below, the G_{rms} value of both the large mass and the node of concern can be found easily in MSC/Random by plotting one curve at a time. For the large mass, the G_{rms} value is 13.0, which matches the G_{rms} of the input. For the center node, the G_{rms} is 69.5.

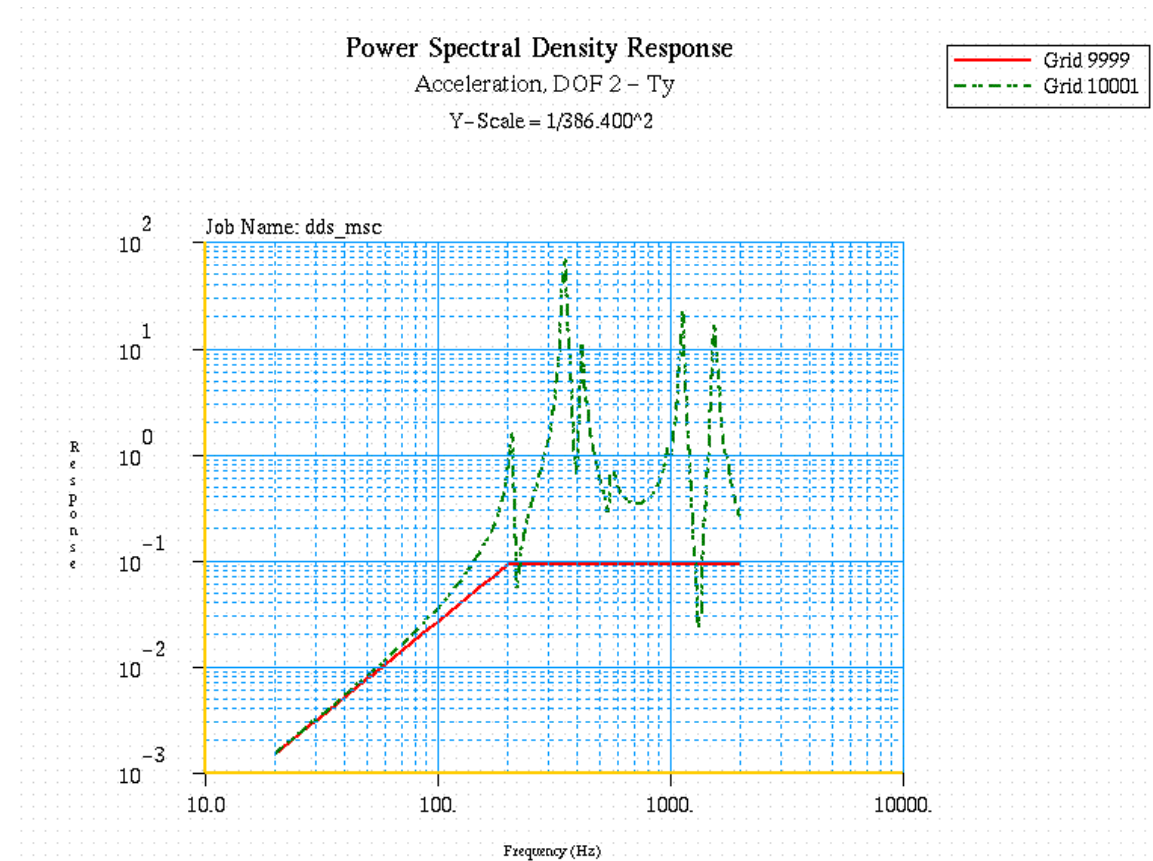


Figure 7: Acceleration Response of Large Mass & Subunit Center created in MSC/PATRAN

Displacement

The displacement plot below (see Figure 8) shows the large mass node (grid 9999), the subunit's center node (grid 10001) and the relative node (grid 10002). This plot was created very simply in MSC/Random by selecting these 3 nodes and asking for PSD displacement. As can be seen, this plot (Figure 8) matches the plot created from the "old method" very closely (Figure 6).

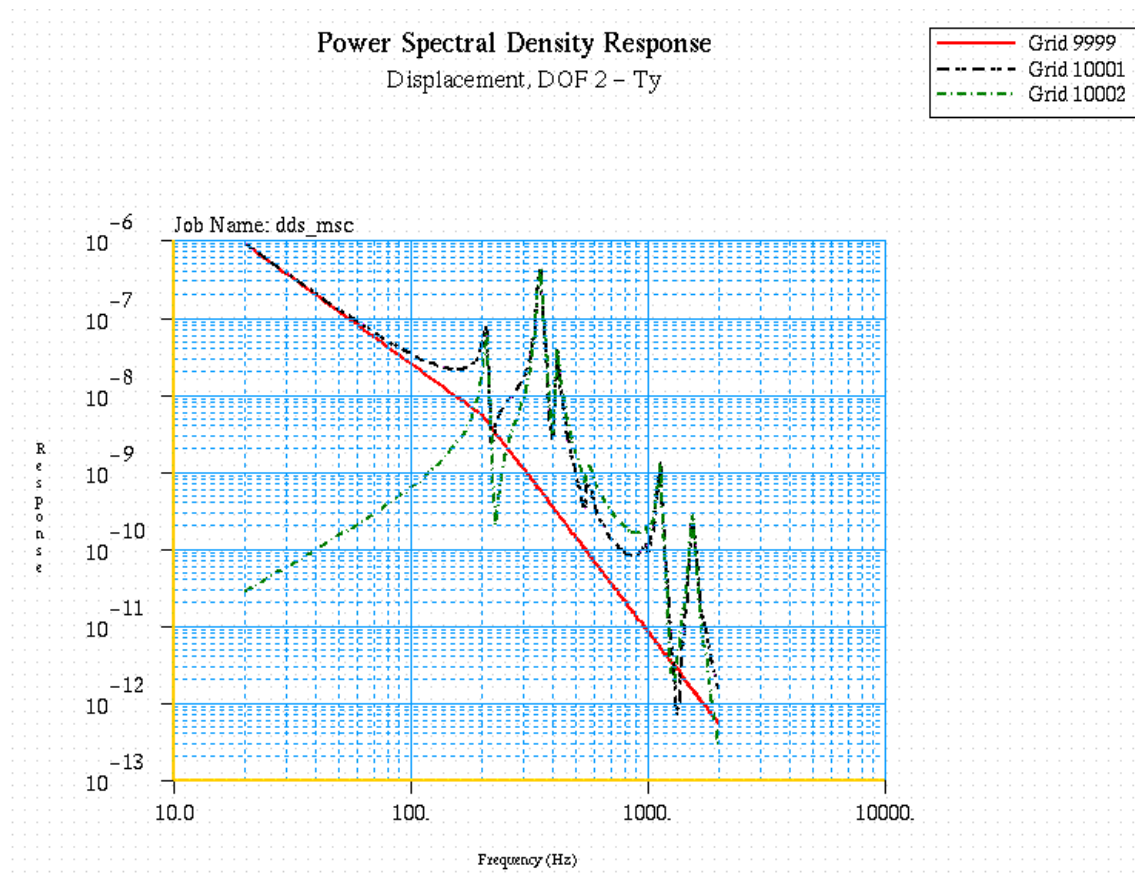


Figure 8: Displacement Response of Nodes of Concern created in MSC/PATRAN

Figure 9 shows the relative cumulative displacement response of the subunit's center node. The relative response is obtained by creating an MPC equation between the large mass and the node of concern. MSC/Random calculates cumulative displacement using phase and logarithmic interpolation. For this reason, the solution is slightly more accurate than the old method, which only uses linear interpolation. This explains the difference of 0.29 mil in the solution (3.53×10^{-3} in $- 3.24 \times 10^{-3}$ in).

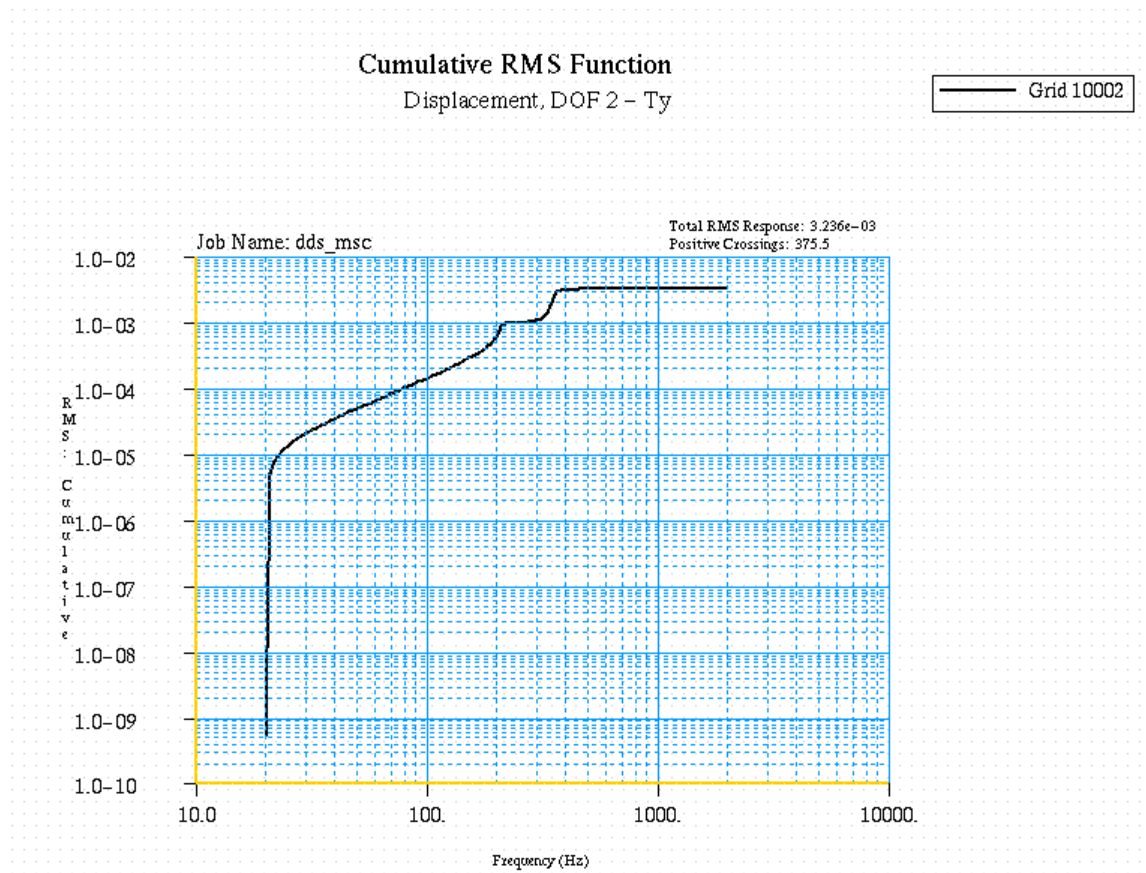


Figure 9: RMS Displacement of Subunit Center from MSC/Random created in MSC/PATRAN

Stress

Using MSC/Random makes it very easy to extract stress data from almost any type of element. A cumulative 1σ stress x plot is shown below (Figure 10) because the subunit cover seems to move the most in the system. From the plot it can be seen that the maximum 1σ stress X (1541 psi) occurs in the center of the cover around a boss, that connects the cover to the heatsink. Because MSC/Random can only calculate RMS Von Mises for individual elements, a search around the area of concern revealed the 1σ Max RMS Von Mises stress to be 1759 psi at quadrilateral element 1955 (see Figure 11). This is low enough to survive the random vibration loading ($S_y = 35\text{ksi}$).

An important note is that the Von Mises stress is derived cumulatively over the bandwidth. This implies that the Von Mises calculation takes into account magnitude as well as phase, which is the case in MSC/Random. *Note: This can only be done on a per element bases, and should not be used for Contour Plots.*

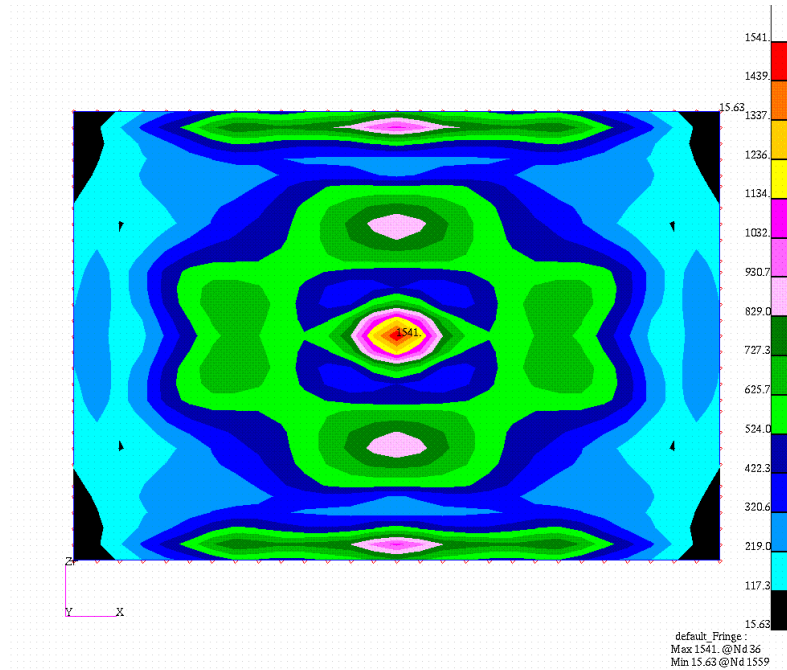


Figure 10: Subunit Stress X of Cover created in MSC/PATRAN

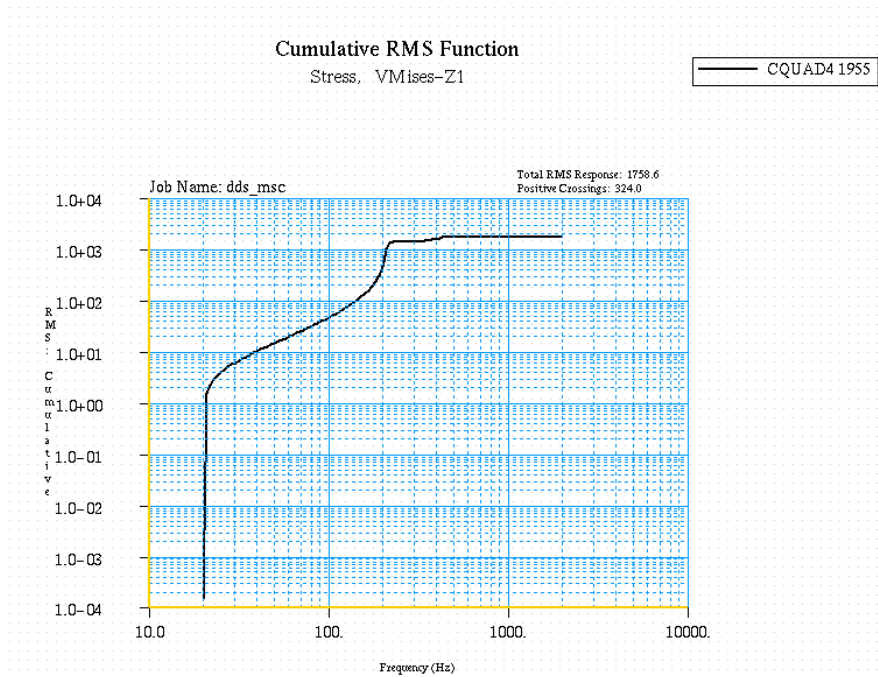


Figure 11: Subunit Element 1955 RMS Von Mises Stress created in MSC/PATRAN

Result Comparison/Summary

As can be seen in the plots above, the “old method” and MSC/Random methods for performing random analysis in MSC/NASTRAN give very similar results. However, with the advent of a random analysis graphical users interface (GUI) in MSC/PATRAN, MSC/Random makes performing the proper steps in setting up the MSC/NASTRAN input deck much easier.

The “ease of use” concept is proven in the next example concerning a new camera mount design.

Example 2: Conceptual Camera Mount Design

Model Objectives

The objectives of the camera mount design were as follows:

- Show trends in design changes to the camera mount that will reduce the camera's overall rotational displacement. From the Line of Sight Error Equation, the primary degrees of freedom of concern are Rotation X and Rotation Y per the camera's frame of reference.
- Ensure that the load path from the center of gravity of the camera to the optical bench is minimized (most direct).
- Create a product that is as light as possible. This objective is used in order to reduce displacement carried by a low frequency brought on by a part that weighs more than it needs to be.

Model Description

Geometry

The Camera mount is comprised of approximately 8 main components (see Figure 12). The camera is modeled as a point mass with inertia components. The point mass representing the camera is attached to 3 trunions via an RBE2. The trunions are attached to a large ring via an RBE2 with certain degrees of freedom released to provide a kinematic mount. The kinematic mount is to ensure that loads are not passed from the camera mount to the camera. In essence, the trunions allow the camera to almost float in the mount. For calculation and orientation reasons, the camera mount's point mass is referenced to its own analytical coordinate system. This is done to ensure that regardless of the configuration that the camera mount is placed, the camera data will always be referenced in the same coordinate system. This becomes very important if Line of Sight Equations are used at a system level.

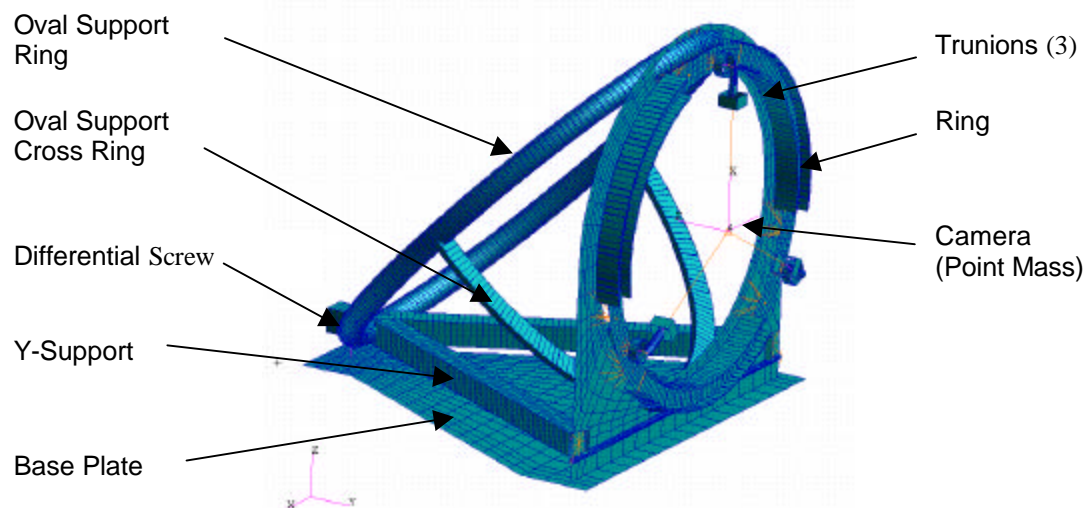


Figure 12: Camera Mount

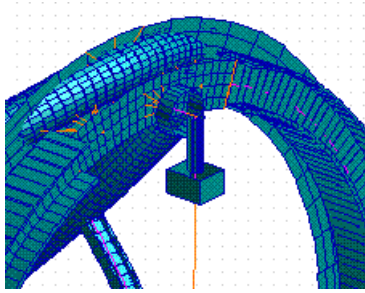


Figure 13: Close Up of Trunion

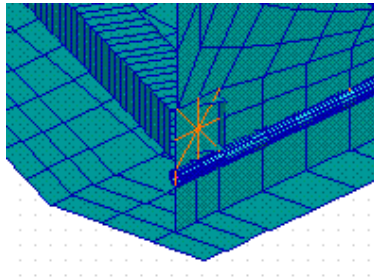


Figure 14: Close Up of Rocker Beam

A large ring (27.6 in average diameter) is attached to the trunions (see Figure 13). The large ring provides planarity and a means to rotate the camera should the tester decide to examine possible gravity affects. A large “tombstone” shaped wall (2 inches thick), that has several bearings, supports the ring. The tombstone wall is attached to the base plate via RBE2’s that release rotations in X (see Figure 14). Protruding from tombstone are three supports. The oval ring and the Y-support provide support to reduce the rocking of the tombstone, while the oval support cross ring provides secondary support to the tombstone by reducing the amount of bowing that the oval support may have. The tombstone must have the ability to rock about the x-rotation (global coordinate system) so that adjustments may be made during testing.

Finally, a differential bolt provides a means to adjust x-rotations. This bolt provides extremely small displacements with slight adjustments in the screw.

Material Properties

The camera mount is designed from a generic stainless steel with the following material properties:

Table 3: Material Properties for Camera Mount

Modulus Of Elasticity	25.8	Mpsi
Poisson's Ratio	0.27	
Density	0.283	lb/in ³

All of the components are stainless steel.

Boundary Conditions (Constraints)

The camera mount is attached to an optical bench via 4 heel clamps. The locations are 2 around the differential bolt, and 2 behind the rocker beam on the base plate.

Random Vibration Loading Conditions

Table 4 represents the acceleration power spectral density values used for input into the camera from the optical bench. A “white noise” input was chosen until further testing of the optical bench could be performed. A white noise input has the advantage of allowing the engineer to see the effect of changes on the model without having to worry about reactions caused from the PSD input. Since optical benches typically have a large PSD roll-off, a white noise input, if chosen properly, will more than likely be conservative.

Table 4: Camera Mount Acceleration Spectral Density Input

Frequency	PSD
[Hz]	[G ² /Hz]
0.001	1.00E-07
2000	1.00E-07

Table 5 represents the critical damping values used for all of the random vibration runs:

Table 5: Critical Damping Values

Frequency	Critical
[Hz]	Damping
0.01	0.02
2000	0.02

MSC/Random

MSC/Random was used to complete the 2 runs shown below. The benefit of MSC/Random manifested itself in the reduced amount of required in creating the random vibration input decks. In addition, the use of the *.xdb file, which contains the results, is easily “attached” to the MSC/PATRAN database. This allows the user to readily review results in already established groups.

Optimization

From Table 6, it can be seen that in changing the cross-section of the Y-Bar, the camera mount becomes sturdier and lighter. However, this is a relatively small change in the $1\sigma R_{ss}$ response. To further decrease the rotational displacement of the camera, a more detailed analysis of the camera mount needs to be completed. This is accomplished by viewing the cumulative displacement plot of the node of interest in both the rotational x and rotational y directions. These plots should show one or two modes as being the largest contributors to the displacement. Once the mode(s) are discovered, a modal-strain energy run is completed. This run will show the areas where the designer should look to improve the model.

Table 6: Changes to the Original Camera Mount

	Results				Oval			
	RotX	RotY	1s R _{ss}	System Mass	Cross Section	I _{yy}	I _{zz}	I _{yz}
Job Name	[rad]	[rad]	[mrad]	[lb _m]	Description	in ⁴	in ⁴	in ⁴
Harmonic 1	1.09E-07	5.33E-07	0.54	1.6922	Tube	0.5369	0.5369	1.0738
Harmonic 2	9.03E-08	5.05E-07	0.51	1.6737	Tube	0.5369	0.5369	1.0738
	Y-Bar				Cross Support			
	Cross Section	I _{yy}	I _{zz}	I _{yz}	Cross Section	I _{yy}	I _{zz}	I _{yz}
Job Name	Description	in ⁴	in ⁴	in ⁴	Description	in ⁴	in ⁴	in ⁴
Harmonic 1	Box	0.9115	0.9115	1.3998	Tube	0.0356	0.0356	0.0671
Harmonic 2	Tube	0.5369	0.5369	1.0738	Tube	0.0356	0.0356	0.0671

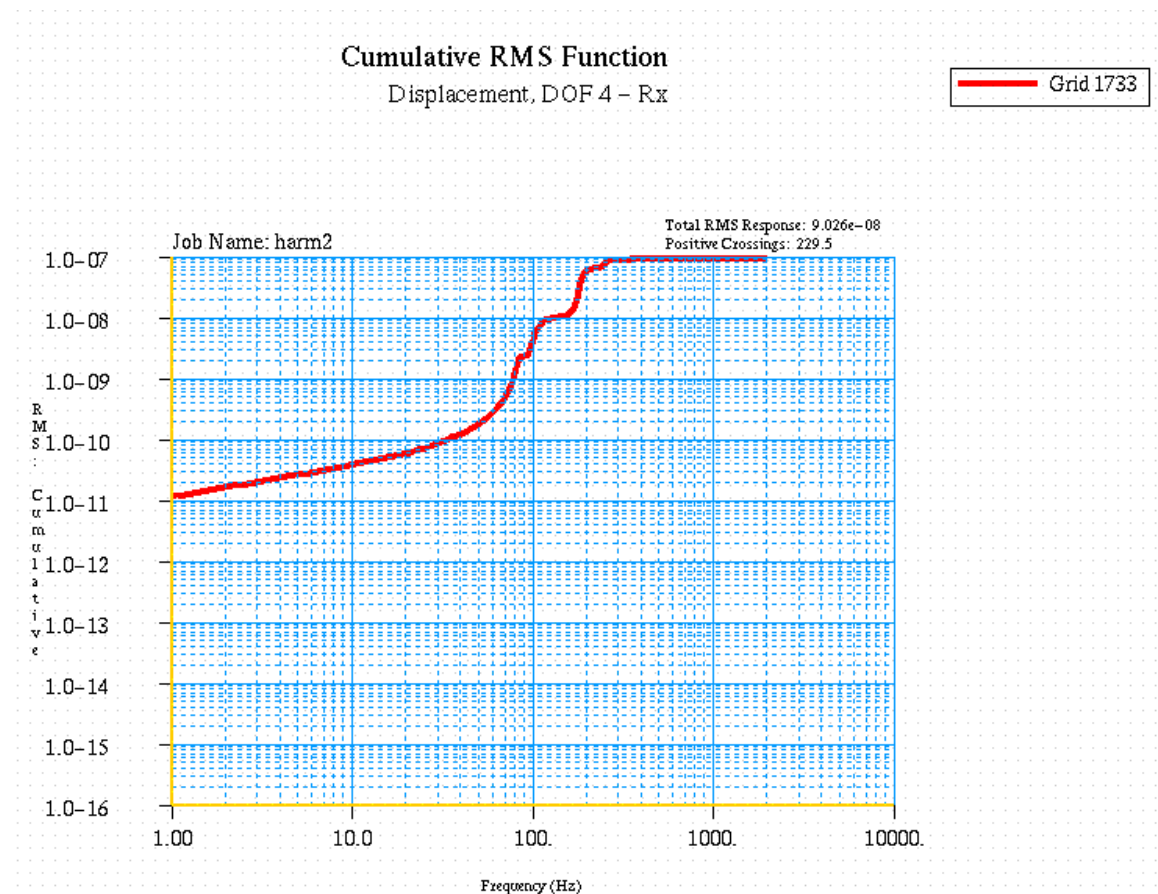


Figure 15: Camera Mount Rotation X Direction Displacement

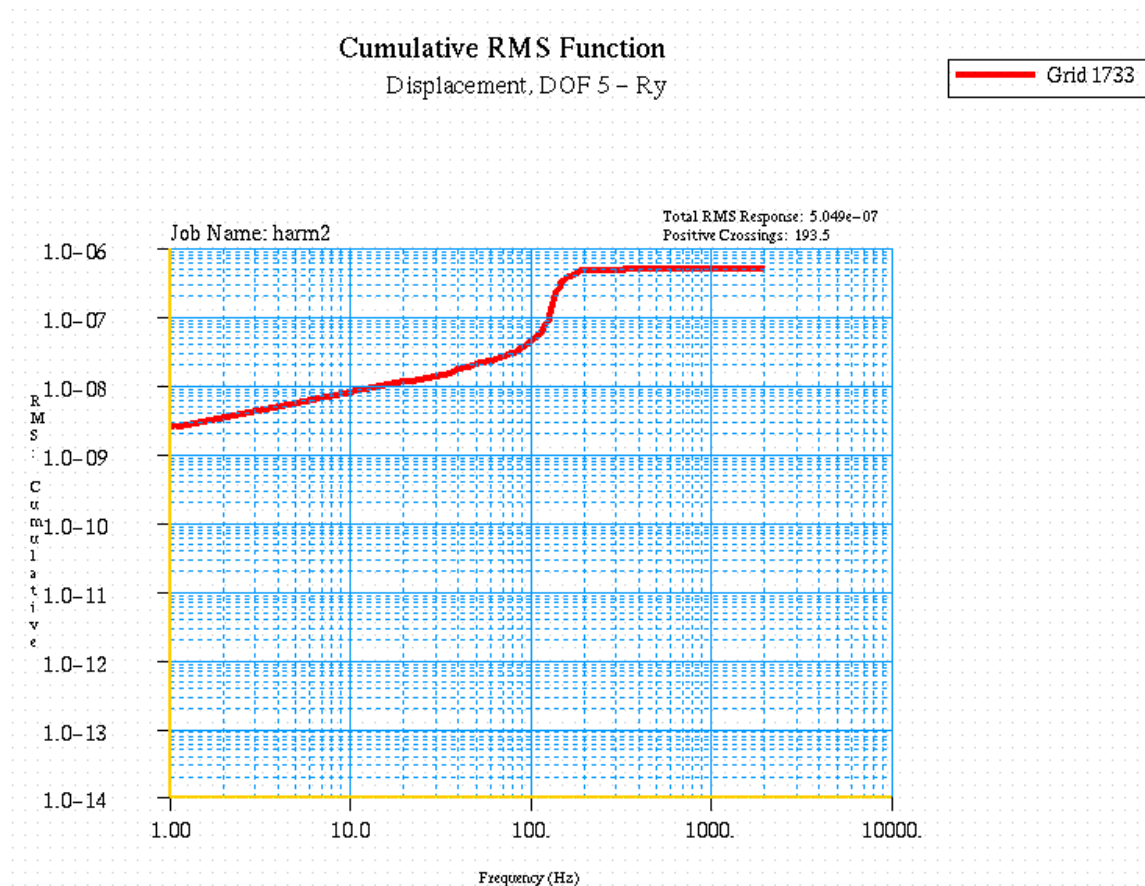


Figure 16: Camera Mount Rotation Y Direction Displacement

From Table 6, it can be seen that the largest rotational displacement contribution is from the Y-direction rotation. In Figure 16, mode 8 (180 Hz) shows the largest rotational displacement participation. In order to determine where the largest gain in decreasing rotation will occur, a modal-strain energy analysis needs to be run.

The percentage of total strain energy plot shown in Figure 17. Although this plot is difficult to read, it can be seen that the majority of the strain is coming from one of the trunion mounts (see area labeled: Area of Highest Strain). Therefore, a possible solution would be to increase the dimensions of the mount, or to change the material property.

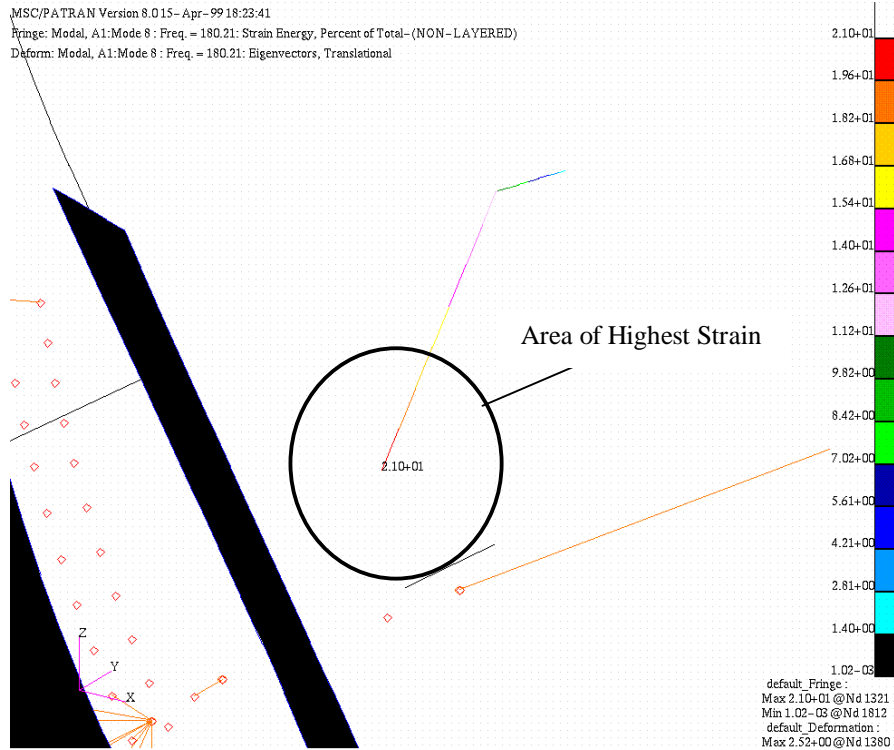


Figure 17: Percent of Total Strain Energy of Camera Mount

Results/Summary

Once the cause of the largest displacement has been found, then it is only a matter of determining a method to reduce it. For this example, it was decided that the best method to reduce the displacement is to increase the thickness of the trunion from $\frac{5}{8}$ inch to 1 inch. Once this is accomplished, the random vibration analysis is again performed. Table 7 shows these results.

Table 7: 1s R_{ss} Response from Increasing Trunion Diameter

RotX	RotY	1s R_{ss}
[rad]	[rad]	[mm]
2.59E-07	8.92E-08	0.27

This reduction constitutes more than a 50% reduction in 1s R_{ss} displacement of the camera over the original camera mount design. In terms of optics, this could mean the difference between being in focus or not.

Conclusion

As can be seen above, the use of MSC/Random allows the user the flexibility of running MSC/NASTRAN from MSC/PATRAN with little or no hand manipulation of the input deck. This provides faster, more accurate methods of setting up a complicated analysis. MSC/Random also adds in reducing the chances for syntax errors that always waste the most time and effort for any analytical engineer. Finally, MSC/Random provides a fast easy method to review data within MSC/PATRAN.

Bibliography

Blevins, Robert D., Formulas For Natural Frequency and Mode Shape, Krieger Publishing Company, 1995.

Steinberg, David S., Vibration Analysis For Electronic Equipment, 2nd ed., Wiley, 1988.