NASA/TM–2000-209585

MSC/NASTRAN Stress Analysis of Complete Models Subjected to Random and Quasi-Static Loads

Roy W. Hampton

January 2000

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January 2000

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Summary

Space payloads, such as those which fly on the Space Shuttle in Spacelab, are designed to withstand dynamic loads which consist of combined acoustic random loads and quasi-static acceleration loads. Methods for computing the payload stresses due to these loads are well known and appear in texts and NASA documents, but typically involve approximations such as the Miles' equation, as well as possible adjustments based on "modal participation factors." Alternatively, an existing capability in MSC/NASTRAN may be used to output exact root mean square [rms] stresses due to the random loads for any specified elements in the Finite Element Model. However, it is time consuming to use this methodology to obtain the rms stresses for the complete structural model and then combine them with the quasi-static loading induced stresses. Special processing was developed as described here to perform the stress analysis of all elements in the model using existing MSC/NASTRAN and MSC/PATRAN and UNIX utilities. Fail-safe and buckling analyses applications are also described.

Introduction

Typical space payloads, such as those which fly on the Space Shuttle in Spacelab, are designed to withstand dynamic loads as specified in the Spacelab Payload Accommodation Handbook (SPAH) Main Volume, SLP/2104 July 8, 1993 issue. These loads consist of quasi-static acceleration loads, which are imposed as acceleration body forces in a static analysis, and as acoustic random loads, which are specified as Power Spectral Density (PSD) levels for different SPAH payload locations in x, y, and z axes in g^2/Hz for a frequency range from 20 to 2000 Hz. The methods of computing the payload stresses due to these random loads and the combination of them with the quasi-static accelerations to produce element stresses and margins of safety, are commonly obtained by using the Miles' relationship which is described in documents such as the *Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures*, SSP 52005B. However, these analyses are usually found to be conservative in that the Miles' relationship doesn't account for the effects of partial participation of the structural mass in modes of interest. Due to the approximate and non-rigorous nature of the available corrections for modal mass participation, other methods are sometimes needed. One alternative is to use the existing XYPLOT capability in MSC/NASTRAN solution 111, Modal Frequency Response, to output exact root mean square [RMS] stresses due to the random loads and all modal responses for any desired element. However, it is time consuming to apply this methodology for large Finite Element Analysis [FEA] structural models. To make this process more convenient, special processing was developed as described here to automate the analysis.

Miles' Relationship

One commonly used method to account for random loads applies Miles' relationship for a single degree of freedom resonator to compute a random equivalent quasi-static acceleration to be added to the other quasi-static loads. This method is documented in the SPAH and elsewhere. It requires first computing the primary mode frequencies in each of the three load directions. This frequency is then used to compute the acceleration, Nr, with a 3 sigma reliability factor, according to the equation:

Nr = +/- 3sqrt[FrAQpi/2]

where Fr is the major mode frequency in direction r, A is the PSD amplitude at frequency Fr, Q is dynamic magnification [which is typically taken as 10] and pi is 3.1416. While straightforward, this method requires the identification of a "major" mode in each direction and implies one should ignore other, lesser modes. But there is no guidance on how to select the principal mode out of the many diverse modes that are commonly found in a complex structure and FEM analysis. Different answers are obtained depending on the analyst's choice of primary modes and the payload modeled, and sometimes extremely conservative quasi-static loadings are obtained with this method. To account somewhat for this problem, analysts sometimes compute "participation factors" to guide and correct application of the Miles equation results.

Participation Factors

Sometimes only a portion of the payload modal mass participates at the vibration frequencies that may found to be of structural importance. One commonly used method to account for this effect is to compute the ratio of effective modal mass in each mode as compared to the total available mass, and reduce the Miles equation result (which is for a single degree of freedom model) by this fraction. An alter for MSC/NASTRAN modal analysis solution 103, which was written by Ted Rose (MacNeal Schwendler Corp.), exists which will perform this task and has been used to output these fractions for a typical payload, the ARC Standard Interface Glovebox (SIGB). The matrix of these factors, which is called "effwfract" in the alter, are tabulated for the principal modes in each of the three translation degree of freedom (dof) directions in the following table.

mode no.	freq. Hz	dof	effwfract	MERT
1	38.987	Y	0.782	0.458
2	53.707	Z	0.587	0.397
4	81.651	X	0.673	0.425
6	98.784	X	0.12	0.179

Another participation factor is also available, which may be more relevant. It is the modal participation factor commonly used in earthquake engineering to represent a general structural response through a summation and integration of all modal responses. If all modes in a model are used, then this method is fairly rigorous in terms of overall response. Commonly, however, only the most active modes are used, and the response is thus approximated by this approach. This participation factor is defined as PHI-transpose times M times a unit direction vector, where PHI is the respective mode eigenvector, M is the modal mass (for the analysis normalized by mass) and direction vectors are chosen to correspond to the vibration environment direction of interest. After conversations with Ted Rose, his alter was changed to output this participation factor as well, which is called the matrix MERT in his alter, and these factors also appear in the table above. It is believed that these factors are more likely to be representative of a true response, and they should be used instead of the effective mass factors if a participation factor approach is to be followed. However, the reader can see that there are now two different values available to choose for a payload, even with these fairly well-defined methods, and the analyst must choose which value to utilize. Note that both of these methods "smear" the payload random response into a single correction factor, which may or may not reflect the true local stresses in the elements.

Random Load RMS Response

There is a capability in MSC/NASTRAN to compute local element rms response due to random PSD loads acting over the entire frequency range on all or selected FEM modes. If fully used, there is no longer a need to compute equivalent quasi-static loadings or participation factors. Pursuing this solution 111 modal frequency response method, a model can be modified by attaching all the interface points to a common grid with rigid elements, assigning a huge mass at that grid and applying a corresponding large 1 g force [including the random PSD loading] in successive analyses of each orthogonal direction to obtain the FEM model rms random responses. The standard MSC/NASTRAN XYPLOT output capability can be used to obtain grid rms accelerations and/or element rms stresses in each orthogonal direction.

If a typical grid point is selected in the payload FEM model for study, the XYPLOT output can be used to obtain the rms acceleration response. One can compare these to the quasi-static accelerations computed by the Miles' relationship with or without participation factors. Unfortunately, the analyst soon discovers that the proper selection of this typical grid point becomes a problem in itself. For example, if one conservatively chooses the grid with the largest random rms displacement, huge rms accelerations are obtained. These motions do not mean the elements attached to those points have huge stresses in them. If there is a point near the cg of the payload with a large mass at it, that point may be representative, or it may not be, again leaving the analyst with an unknown approximation to the exact situation.

Complete Random RMS Element Response

An alternative has been developed by Mladen Chargin at NASA Ames that utilizes solution 111 in MSC/NASTRAN with a special DMAP program to compute ALL the model element rms stresses, not just the few selected by the XYPLOT routines. This has the advantage that no guessing of what modes and response are representative is required of the analyst. Studies of element stresses have shown also that these results are typically lower stresses than those produced by the Miles' relationship and participation factor approach. For example, one model that was studied to verify the methodology had 10% or more reduction in many reported element stresses and 25% reduction in peak stresses. Of course, since ALL element are processed, and modal shapes now dictate element stresses in an rms manner, one finds that different elements are more highly stressed than those identified with quasi-static loading methods.

The next step is what to do with all this rms stress element data. To address that, another DMAP was written by Chargin to take in these random load rms stresses in a MSC/NASTRAN solution 101 statics analysis and combine them as directed by the analyst with the quasi-static loads. For the analyses being performed for the Neurolab mission, 43 load cases are being computed in solution 101 at one time, and sorted through more DMAP via element and maximum stress in the output. The 43 load cases consisted of the 3 random (x, y, z), the 8 unique quasi-static acceleration loads, and the 32 possible random plus liftoff and then landing load cases. [While the first 11 load cases are not required output for the analysis, they were produced anyway to aid the analyst in identifying which loads contribute the most to element stresses.] These 43 load cases are too much output for an analyst to utilize, so a procedure was developed wherein these 43 load cases are imported into MSC/PATRAN and sorted into output files by material. Then these files are post processed with a UNIX AWK utility to give the maximum stress of all element types for each material and the corresponding margins of safety, which is the final goal. Test cases utilizing two bars are given in Appendices A1 and A2, respectively, showing the typical MSC/NASTRAN files used for the analysis along with the DMAP listings for both solutions 111 and 101 in Appendices B1 and B2, respectively. A list of the post processing steps using MSC/PATRAN and UNIX AWK programs also is given in Appendix C.

Note that the procedures can be modified easily for other situations as follows:
The random environment is easily defined by the TABLED1 cards in the solution 111 deck, and fewer FREQ points may be used to minimize the computing time required,

depending on particular analysis requirements. However, the number of modes used to represent the dynamic response should always be large since this is "cheap" in computing time, and if desired, the analyst can perform a sensitivity analyses, where one analysis has fewer modes, to ensure an adequate number of modes and frequency cards have been used to obtain a good representation of the dynamic response. Finally, the quasi-static loads to be combined with the random loads in solution 101 can be changed as required. The example has 11 defined loads, including the three (x, y, z) random loads from solution 111. The DMAP is general with respect to loading matrix, as long as the DMI header correctly describes the matrix row and column sizes. The DMI header card and the contents of the DMI cards are documented in the MSC/NASTRAN Quick Reference Manual. An Excel spreadsheet was used to advantage to determine the required DMI matrix for load combinations, and a sample for the example in Appendix A2 is also given in Appendix A2.

The user will note that a large multiplying factor, namely 1159.2, is used in solution 101 DMI to multiply the random rms stresses from solution 111. This is needed because in solution 111 we use the WTMASS parameter to convert weight to mass units for the modal analysis, and because we wish to input the random loads in units of g^2/hz. To keep the conversions consistent, a WTMASS factor of Gc of 386.4 in/sec^2 is used AND the required spacehab 3 sigma multiplier on random loads, for a net factor of 386.4*3 = 1159.2. If the analyst views the stress output from solution 111, this 1159.2 factor should be used to convert output to be consistent with the stress output from solution 101 used for stress analysis. Also, the analyst must be sure the following occurs: in solution 111 all support points must be tied to the large mass grid point to receive the random loadings. Constraints (SPC's) may remain in the bulk data deck so long as their SETID does not get invoked by the solution 111 case control deck. Also, as noted above, the WTMASS parameter is needed in solution 111. In solution 101, we are performing a static analysis and applying accelerations in g's so we do not want a WTMASS factor in the solution 101 bulk data deck. We do want to impose the constraints (SPC's) in the BULKDATA deck and invoke them in the case control deck. Finally, the user should note that the examples only request stress output, and specify stress = all. The DMAP's are set up for only this output request at the present time.

Buckling Analysis

For buckling analysis MSC/NASTRAN solution 105 is available. However, it requires a static load for computation of the eigenvalue. Most likely the dynamic loading from a random environment will not be coherent enough across the structure to produce buckling. Therefore, one approach is to simply use the lowest margin of safety load case found as described above using solution 101, and apply the associated quasi-static loads to the FEM model in solution 105 to compute eigenvalues. This assumes that the worst buckling will be associated with the load cases producing the worst stresses for the materials. If that assumption is not a good one for a particular model, then alternatively the analyst can search for the peak stress from solution 101 [as opposed to lowest margin of safety] and identify that loading case as likely to be the most critical for use in buckling analysis.

The eigenvalue from the buckling analysis is the ratio of linear-predicted buckling load to applied load, which is the safety factor on buckling. A margin of safety is computed as this number minus 1. If a negative eigenvalue is found, then the analyst may simply reverse the complete set of associated quasi-static loads and recompute the eigenvalue to obtain the [same magnitude] positive value if desired. However, where the quasi-static loads change in magnitude as their direction is changed, like in a SPAH example for x axis lift-off, then the appropriate negative quasi-static loads should be used for the reversed directions, which will then give a different positive eigenvalue for this case than the negative one obtained previously.

Conservative Buckling Analysis and Force, Other Outputs

For extra conservatism, one may include the random loading effects on buckling or statics by assuming the random loads are coherent across the structure as follows. Identify the load case in solution 101, including random combinations, with the highest stress or lowest margin of safety on stress. Then obtain a scaled "random-equivalent" quasi-static load as follows: for a case where the maximum combined solution 101 stresses occur with, say, a random x axis loading combination, then the analyst looks up the same element stress under pure random x loading (solution 111 and 101 SUBCASE 1) and also finds the stress in the same element due to a x acceleration (solution 101 SUBCASE 4 at +8 g's in the example). Then the analyst ratios these stresses to get an x axis acceleration that will produce the same stress in this highest stressed element as the random x environment. [This is easily performed in MSC/PATRAN by putting this one element into a separate group and printing out the results as a text report for this group with the stress results load cases of interest.] Call this ratioed acceleration the "equivalent-random" quasi-static acceleration, and then apply it plus the other quasi-static accelerations for the load case identified previously in solution 101 for the desired analysis. This will provide a loading for buckling (sol 105) analysis, and also may be used for statics (sol 101) to get element forces, displacements, etc., for the worst loading case for needed output such as fastener forces. The input data for a sample case for buckling is given in Appendix D for a case using all three methods. There is also a sample statics analysis data deck.

Finally, the analyst needs to evaluate the buckling modes produced. Many buckling modes may be minor, with only a panel "oil-canning" or some other small part moving. Typically panels can continue to carry load after their initial buckling. Therefore the analyst needs to view the buckling mode shapes in PATRAN and compute the safety and margin of safety on just the modes with a global mode shape implying some sort of general collapse.

Fail-Safe Analyses

The procedures described above lend themselves easily to performing fail-safe payload analyses. The procedure is very automated, and the analyst can perform two or more analyses with slightly different bulk data files to describe a normal and a failed condition of a payload. If the complete analysis is performed for each payload condition (intact, and for each failed element condition) the solution is rigorous in terms of complying with requirements for accounting for effects of changes in the load paths [i.e., model] on the model natural frequency modes and thence on the dynamic loading.

However, the most costly computing part of this process is the first, solution 111 analysis. For example, a problem with 1692 nodes and 1544 elements, and computing all modes up to 1100 Hz [this is "cheap" in CPU time] and then computing responses at the following frequencies [this is the expensive part since all element stresses are recovered and used for each frequency analyzed]:

```
$ INCLUDES 5 POINTS ABOUT FIRST RANGE STARTING AT 20HZ RESONANCES USING
$  DOUBLE HALF-POWER POINT DF, AND 3 POINTS AT PEAK AND HALF-POWER
$  POINTS FOR HIGHER MODAL RANGE RESONANCES
FREQ4,103,20.,300.,0.10,5
FREQ4,103,300.,600.,0.05,3
$ FILL IN THE REST OF THE FREQUENCIES
$ 5 HZ STEPS 20 TO 50HZ, THEN 10HZ STEPS TO 100HZ, THEN 25HZ STEPS TO 500HZ,
$   THEN 50HZ STEPS TO 1000HZ, THEN 100 HZ STEPS TO 2000HZ
```

```
FREQ1,103,20.,5.,5
FREQ1,103,50.,10.,4
FREQ1,103,100.,25.,15
FREQ1,103,500.,50.,9
FREQ1,103,1000.,100.,10
```

will take the following CPU seconds on a Cray C-90: solution 111 takes 385 sec, and solution 101 takes 87 sec. For other models, with more modes at lower frequencies to be analyzed, the solution 111 time has taken up to 2600 sec while the solution 101 time remains less than 200 sec.

Therefore, the analyst may want to do solution 111 only once for the stress analysis and then change the model in solution 101 for computing fail-safe conditions. While not rigorous, this method may be adequate for many models. For example, for a box-like drawer model these two conditions were checked and the results from a complete re-analysis including solution 111 were found to change the lowest margin of safety on the most critical element from 0.131 with the approximate method to 0.155 with the rigorous re-analysis.

Appendix A1

Solution 111 MSC/NASTRAN version 69 sample file

```
$ MSC/NASTRAN VERSION 69 ANALYSIS
$nastran system(2)=4    $ put output file in f04 instead of f06
assign output4='save/fort.11.test',unit=11   $ assign an rms stress output file in /save
ID TEST CASE
SOL 111 $ MODAL FREQUENCY RESPONSE RIGID FORMAT
TIME 30
diag 8,13
include 'save/sol111z.v69'     $ read in the v69 dmap from /save directory
CEND
$
TITLE = 2 DOF FREQUENCY RANDOM EXCITATION RESPONSE
SUBTITLE = DEMO
ECHO = UNSORT
METHOD = 101  $  THIS CALLS THE MODAL ANALYSIS EIGL CARD
FREQ = 103 $ THIS DEFINES THE FREQ* BULK DATA CARD SID TO "SHAKE" AT
$
STRESS = ALL
SUBCASE 1
LABEL = X RANDOM LOADS
DLOAD = 104
$
SUBCASE 2
LABEL = Y RANDOM LOADS
DLOAD = 114
$
SUBCASE 3
LABEL = Z RANDOM LOADS
DLOAD = 124
$
BEGIN BULK
param,dfreq,1.-30
$param,post,-1
param,ddrmm,-1
$ USE WTMASS TO CONVERT LBS TO MASS UNITS
$ NOTE: THIS RESULTS IN ACCELERATIONS IN G'S, BUT
$  STRESSES, DISPLACEMENTS ARE TOO SMALL BY 1/WTMASS FACTOR
PARAM,WTMASS,2.5907-3
$
$ SPECIFY EIGRL TO EXTRACT ALL MODES OF INTEREST, INCLUDING RIGID BODY MODE
EIGRL,101,0.,250.,,,,,MASS
$
$ PLACE A LARGE MASS AT ENFORCED MOTION POINT, AND PUT DOF ON SUPORT CARD
$  ACCOUNT FOR THE PARAM,WTMASS FACTOR SINCE IT WILL BE APPLIED TO THIS MASS
CONM2,20,10,,386.+6
SUPORT,10,1
$ DEFINE THE DAMPING; USE COMMONLY ACCEPTED Q VALUE OF 10 FOR PAYLOADS
$ STRUCTURAL DAMPING, G, EQUAL TO 1/Q = 0.1 PER SPAH
PARAM,G,0.1
$
$FREQ = 103 $ THIS DEFINES THE FREQ* BULK DATA CARD SID TO "SHAKE" AT
$ INCLUDES 5 POINTS ABOUT FIRST RANGE STARTING AT 20HZ RESONANCES USING
$  DOUBLE HALF-POWER POINT DF, AND 3 POINTS AT PEAK AND HALF-POWER
$  POINTS FOR HIGHER MODAL RANGE RESONANCES
```

```
FREQ4,103,20.,300.,0.10,5
FREQ4,103,300.,600.,0.05,3
$ FILL IN THE REST OF THE FREQUENCIES
$ 5 HZ STEPS 20 TO 50HZ, THEN 10HZ STEPS TO 100HZ, THEN 25HZ STEPS TO 500HZ,
$   THEN 50HZ STEPS TO 1000HZ, THEN 100 HZ STEPS TO 2000HZ
FREQ1,103,20.,5.,5
FREQ1,103,50.,10.,4
FREQ1,103,100.,25.,15
FREQ1,103,500.,50.,9
FREQ1,103,1000.,100.,10
$
$ DEFINE PSD LOADS BY DLOAD, RLOAD1, DAREA, AND TABLED1 ON S POINT 999999
SPOINT,999999
$ DEFINE THE LOAD CASE LINEAR COMBINATIONS OF RLOAD2, ETC.
DLOAD,104,1.0,1.0,105,1.0,205
DLOAD,114,1.0,1.0,115,1.0,215
DLOAD,124,1.0,1.0,125,1.0,225
$ RLOAD1 GENERATES HARMONIC LOAD AMPLITUDE FROM
$    DAREA, FACTOR BY TABLED1
RLOAD1,105,106,,,131
RLOAD1,115,116,,,132
RLOAD1,125,126,,,133
RLOAD1,205,206,,,130
RLOAD1,215,216,,,130
RLOAD1,225,226,,,130
tabled1,130
+,0.,1.,10000.,1.,endt
$  USE DAREA SCALE FACTOR TO MAKE A 1 G LOADING ON THE LARGE MASS
$  SIZE FORCE FOR 1. G ACCELERATION (INCLUDING PARAM,WTMASS FACTOR)
$  EXCITE IN DOF OF INTEREST
DAREA,106,999999,1,1.
DAREA,116,999999,1,1.
DAREA,126,999999,1,1.
DAREA,206,10,1,1.+6
DAREA,216,10,2,1.+6
DAREA,226,10,3,1.+6
$ SPAH RANDOM ENVIRONMENT FOR RACK MOUNTED EQUIPMENT
$ SLP/2104 ISSUE 3, REV. 0, 8 JULY 1993, PAGE 5-3
$  USE LOG-LOG TABLE INTERPOLATION
$  TABLED1 131 FOR X PSD LOADS IN G^2/HZ
TABLED1,131,LOG,LOG,,,,,,+TAB131A
+TAB131A,20.,.005,80.,0.02,200.,0.02,2000.,.00093,+TAB131B
+TAB131B,ENDT
$  TABLED1 132 FOR Y PSD LOADS IN G^2/HZ
TABLED1,132,LOG,LOG,,,,,,+TAB132A
+TAB132A,20.,.002,55.,0.015,150.,0.015,2000.,.00047,+TAB132B
+TAB132B,ENDT
$  TABLED1 133 FOR Z PSD LOADS IN G^2/HZ
TABLED1,133,LOG,LOG,,,,,,+TAB133A
+TAB133A,20.,.002,53.,0.01,250.,0.01,2000.,0.002846,+TAB133B
+TAB133B,ENDT
$
$ DEFINE THE MODEL
$  2 DOF MODEL: BASE IS AT GRID 10, FIXTURE IS AT GRID 1, PAYLOAD IS AT GRID 2
GRDSET,,,,,,,23456
GRID,10
GRID,1,,1.
GRID,2,,2.
```

```
CONM2,21,1,,5.
CONM2,22,2,,1.
CBAR,1,1,10,1,1.,0.,1.
PBAR,1,11,3.273,1.,1.,1.
CBAR,2,2,1,2,1.,0.,1.
PBAR,2,11,0.1253,1.,1.,1.
MAT1,11,1.+3,,0.33
$
ENDDATA
```

Appendix A2

Solution 101 MSC/NASTRAN version 69 sample file

```
$nastran system(2)=4 $
assign inputt4='save/fort.11.test',unit=11 $  assign  rms stress input file in /save

ID TEST MESH
SOL 101
DIAG 8,13
TIME 100
$
include 'save/sol101z.v69'    $ read in the v69 dmap from /save directory
$
CEND
$
TITLE = 2 DOF FREQUENCY RANDOM EXCITATION RESPONSE
SUBTITLE = STRESSES COMB., SORT
ECHO = UNSORT
SEALL = ALL
SUPER = ALL
SPC = 2
$
SET 1 = ALL
STRESS = 1
$
SUBCASE 1
 LOAD = 1
 LABEL = RANDOM X RMS STRESS (WITH 3 SIGMA FACTOR)
SUBCASE 2
 LOAD = 2
 LABEL = RANDOM Y RMS STRESS (WITH 3 SIGMA FACTOR)
SUBCASE 3
 LOAD = 3
 LABEL = RANDOM Z RMS STRESS (WITH 3 SIGMA FACTOR)
$
SUBCASE 4
 LOAD = 4
 LABEL = +X LIFTOFF +8.0 G
SUBCASE 5
 LOAD = 5
 LABEL = -X LIFTOFF -5.0 G
SUBCASE 6
 LOAD = 6
 LABEL = +/-Y LIFTOFF 6.2 G
SUBCASE 7
 LOAD = 7
 LABEL = +/-Z LIFTOFF 6.5 G
SUBCASE 8
 LOAD = 8
 LABEL = +/-X LANDING 6.0 G
SUBCASE 9
 LOAD = 9
 LABEL = +/-Y LANDING 6.3 G
SUBCASE 10
 LOAD = 10
 LABEL = +Z LANDING 4.7 G
SUBCASE 11
 LOAD = 11
```

```
 LABEL = -Z LANDING -7.1 G
$
SUBCASE 12
 LOAD = 12
 LABEL = SUBCOM 12
SUBCASE 13
 LOAD = 13
 LABEL = SUBCOM 13
SUBCASE 14
 LOAD = 14
 LABEL = SUBCOM 14
SUBCASE 15
 LOAD = 15
 LABEL = SUBCOM 15
SUBCASE 16
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 LABEL = SUBCOM 42
SUBCASE 43
 LOAD = 43
 LABEL = SUBCOM 43
$
$
BEGIN BULK
$
PARAM,NEWSEQ,-1
PARAM,PRGPST,NO
$
$  THE FOLLOWING CARDS GO IN THE BULK DATA DECK FOR SPECIAL SORTING
$  SEE THE OLD APPLICATION MANUAL, SECTION 4.2-99 FOR A COMPLETE DESCRIPTION.
$  OR SEE OLD USER MANUAL VOL 2, SECT. 3.5-42, OR END OF QUICK REF. GUIDE
$  SPECIFY 5 LARGEST ELEMENT STRESS OUTPUTS
PARAM,NUMOUT,5
$ DO TWO SORTS, GIVING 2X NUMBER OF SUBCASES
$ SPECIFY FILTER/SORT ON MAXIMUM STRESS VALUE BY DEFAULT
$ SORT CBAR 34 AT ITEM CODE 9 AND QUAD4, AND
$  TRIA3 Z1 SURFACE VON-MISES ITEM CODE
$ DO NOT SORT CELAS1 NOR BEAMS (NASTRAN V69 PROBLEM WITH BEAM SORTING)
DTI,INDT1,1,34,7,2,-1,33,9,+INDT1A
```

```
+INDT1A,74,9,11,-1,ENDREC
$ SORT CBAR 34 AT ITEM CODE 9 AND QUAD4, AND
$  TRIA3 Z2 SURFACE VON-MISES ITEM CODE
DTI,INDT2,1,34,14,2,-1,33,17,+INDT2A
+INDT2A,74,17,11,-1,ENDREC
$
$ END OF THE BULK DATA CARDS FOR STRESS SORTING.
$
$********************************
$ G UNIT LOADS
GRAV,111,,1.,1.,0.,0.          $  X-AXIS
GRAV,112,,1.,0.,1.,0.          $  Y-AXIS
GRAV,113,,1.,0.,0.,1.          $  Z-AXIS
$
$ Spacelab loads
LOAD,4,1.,8.0,111
LOAD,5,1.,-5.0,111
LOAD,6,1.,6.2,112
LOAD,7,1.,6.5,113
LOAD,8,1.,6.0,111
LOAD,9,1.,6.3,112
LOAD,10,1.,4.7,113
LOAD,11,1.,-7.1,113
$
$********************************
$  THE FOLLOWING DMI LOADCOMB IS THE 11 ROWS X 43 COL. ANALYSIS CASE MATRIX
$  IT ASSUMES RANDOM X, Y, AND Z ARE LOAD CASE 1, 2, 3, AND
$  LIFTOFF +X, -X, +Y,AND +Z LOAD FACTORS ARE LOAD CASES 4, 5, 6, 7, AND
$  LANDING +X, +Y, +Z AND -Z LOAD FACTORS ARE LOAD CASES 8, 9, 10, 11
$ SUBCASE 12 WILL BE XRANDOM AND +X, +Y, +Z LIFTOFF COMBINED, ETC...
$  NOTE USE OF 3*1/WTMASS FACTOR TO OBTAIN 3 SIGMA RMS STRESSES IS REQUIRED
$   SINCE PREVIOUS SOL 111 OUTPUT STRESS WERE SMALL BY WTMASS FACTOR
DMI,LOADCOMB,0,2,1,1,,11,43
DMI,LOADCOMB,1,1,1159.2
DMI,LOADCOMB,2,2,1159.2
DMI,LOADCOMB,3,3,1159.2
DMI,LOADCOMB,4,4,1.
DMI,LOADCOMB,5,5,1.
DMI,LOADCOMB,6,6,1.
DMI,LOADCOMB,7,7,1.
DMI,LOADCOMB,8,8,1.
DMI,LOADCOMB,9,9,1.
DMI,LOADCOMB,10,10,1.
DMI,LOADCOMB,11,11,1.
DMI,LOADCOMB,12,1,1159.2,4,1.,6,1.
+,1.
DMI,LOADCOMB,13,1,1159.2,5,-1.,1.,1.
DMI,LOADCOMB,14,1,1159.2,4,1.,6,-1.
+,1.
DMI,LOADCOMB,15,1,1159.2,5,-1.,-1.,1.
DMI,LOADCOMB,16,1,1159.2,4,1.,6,1.
+,-1.
DMI,LOADCOMB,17,1,1159.2,5,-1.,1.,-1.
DMI,LOADCOMB,18,1,1159.2,4,1.,6,-1.
+,-1.
DMI,LOADCOMB,19,1,1159.2,5,-1.,-1.,-1.
DMI,LOADCOMB,20,2,1159.2,4,1.,6,1.
+,1.
```

```
DMI,LOADCOMB,21,2,1159.2,5,-1.,1.,1.
DMI,LOADCOMB,22,2,1159.2,4,1.,6,-1.
+,1.
DMI,LOADCOMB,23,2,1159.2,5,-1.,-1.,1.
DMI,LOADCOMB,24,2,1159.2,4,1.,6,1.
+,-1.
DMI,LOADCOMB,25,2,1159.2,5,-1.,1.,-1.
DMI,LOADCOMB,26,2,1159.2,4,1.,6,-1.
+,-1.
DMI,LOADCOMB,27,2,1159.2,5,-1.,-1.,-1.
DMI,LOADCOMB,28,3,1159.2,1.,6,1.,1.
DMI,LOADCOMB,29,3,1159.2,5,-1.,1.,1.
DMI,LOADCOMB,30,3,1159.2,1.,6,-1.,1.
DMI,LOADCOMB,31,3,1159.2,5,-1.,-1.,1.
DMI,LOADCOMB,32,3,1159.2,1.,6,1.,-1.
DMI,LOADCOMB,33,3,1159.2,5,-1.,1.,-1.
DMI,LOADCOMB,34,3,1159.2,1.,6,-1.,-1.
DMI,LOADCOMB,35,3,1159.2,5,-1.,-1.,-1.
DMI,LOADCOMB,36,8,1.,1.,1.
DMI,LOADCOMB,37,8,-1.,1.,1.
DMI,LOADCOMB,38,8,1.,-1.,1.
DMI,LOADCOMB,39,8,-1.,-1.,1.
DMI,LOADCOMB,40,8,1.,1.,11,1.
DMI,LOADCOMB,41,8,-1.,1.,11,1.
DMI,LOADCOMB,42,8,1.,-1.,11,1.
DMI,LOADCOMB,43,8,-1.,-1.,11,1.
$
$********************************
$ THE MODEL DECK GOES HERE; MAKE SURE NO PARAM, WTMASS IS PRESENT
$
$  2 DOF MODEL: BASE IS AT GRID 10, FIXTURE IS AT GRID 1, PAYLOAD IS AT GRID 2
GRDSET,,,,,,,23456
SPC1,2,1,10
GRID,10
GRID,1,,1.
GRID,2,,2.
CONM2,21,1,,5.
CONM2,22,2,,1.
CBAR,1,1,10,1,1.,0.,1.
PBAR,1,11,3.273,1.,1.,1.
CBAR,2,2,1,2,1.,0.,1.
PBAR,2,11,0.1253,1.,1.,1.
MAT1,11,1.+3,,0.33
$
ENDDATA
```

load case no.	loading	load factor G's	Subcase Number										
			1	2	3	4	5	6	7	8	9	10	11
1	Xrandom	Rx	X	0	0	0	0	0	0	0	0	0	0
2	Yrandom	Ry	0	X	0	0	0	0	0	0	0	0	0
3	Zrandom	Rz	0	0	X	0	0	0	0	0	0	0	0
4	+Xliftoff	8	0	0	0	1	0	0	0	0	0	0	0
5	-Xliftoff	- 5	0	0	0	0	1	0	0	0	0	0	0
6	Yliftoff	6.2	0	0	0	0	0	1	0	0	0	0	0
7	Zliftoff	6.5	0	0	0	0	0	0	1	0	0	0	0
8	Xlanding	6	0	0	0	0	0	0	0	1	0	0	0
9	Ylanding	6.3	0	0	0	0	0	0	0	0	1	0	0
10	+Zlanding	4.7	0	0	0	0	0	0	0	0	0	1	0
11	-Zlanding	-7.1	0	0	0	0	0	0	0	0	0	0	1

X = 3 sigma * Gc = 386.4*3 = 1159.2

load case no.	Subcase Number								Subcase Number							
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	X	X	X	X	X	X	X	X
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
6	1	1	- 1	- 1	1	1	- 1	- 1	1	1	- 1	- 1	1	1	- 1	- 1
7	1	1	1	1	- 1	- 1	- 1	- 1	1	1	1	1	- 1	- 1	- 1	- 1
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Subcase Number								Subcase Number							
28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X	X	X	X	X	X	X	X	0	0	0	0	0	0	0	0
1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0
0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0
1	1	- 1	- 1	1	1	- 1	- 1	0	0	0	0	0	0	0	0
1	1	1	1	- 1	- 1	- 1	- 1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	- 1	1	- 1	1	- 1	1	- 1
0	0	0	0	0	0	0	0	1	1	- 1	- 1	1	1	- 1	- 1
0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

Appendix B1

Solution 111 MSC/NASTRAN version 69 DMAP sol111z.v69 Listing

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ THIS ALTER WILL READ-IN A SET OF PSD MATRICES
$ AND PRODUCE STANDARD OUTPUT WHICH IS THE RMS RESPONSE
$ MSC/N V69
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
COMPILE  SEDRCVR, NOLIST, NOREF $
alter 'PJ1,QG,UG' $ after SDR2 for DDRMM=-1
$
TYPE  PARM,,I,N, NFREQ, NSUB, nr31, nf, zero $
$
$ Get the PSD definition by extracting the row of the PJ1 matrix
$ corresponding to SPOINT 999999 which must be the LAST point.
$
paraml   PJ1//'trailer'/1/s,n,nf3 $ number of columns in PJ1
paraml   PJ1//'trailer'/2/s,n,nr3 $ number of rows    in PJ1
$
$ Exctract the real part of PJ1
$
matmod   pj1,,,,,/pj1c,/10 $ complex conjugate
add5     pj1,pj1c,,/pj1rr/(0.5,0.0)/(0.5,0.0) $
modtrl   pj1rr/////1 $
add      pj1rr,/pj1r $

$
$ Get the last row of PJ1R
$
nr31 = nr3 - 1
nf = nf3/3
matgen   ,/pj11/6/nr3/nr31/nr3 $
partn    pj1r,,pj11/,pjj1,,/1 $
trnsp    pjj1/pjj1t $

$
$ Loop to extract the load data (TABRND) for each subcase
$ and append into a single matrix
$
zero = -nf
file     psdt=append $
do while ( zero<2*nf )
  zero = zero + nf
  matgen   ,/pjcol/6/nf3/zero/nf/nf3 $
  partn    pjj1t,,pjcol/,pjj1c,,/1 $
  append   pjj1c,/psdt/2 $
enddo $
matprn   psdt// $

$
```

```
$ Get the number of forcing frequencies and subcases
$
paraml   ug //'trailer'/1/s,n,nfns $
paraml   ol2//'trailer'/1/s,n,nfreq $
nsub = nfns/nfreq
tabpt    ol2// $
$
$ CHECK INPUT FOR COMPATIBLE SIZE
$
CALL  CHCKINPT  PSDT/PSD/NFREQ/NSUB $
$
$ INTEGRATE PSD MATRICES OVER FREQUENCY RANGE
$
CALL  FINT PSD,OL2/PSDINT/NFREQ/NSUB $
$
$ CONVERT OUTPUT TABLES TO TABLE/MATRIX FORMAT
$
DRMH1    ,,,OES1,/,,,,TSTRESS,MSTRESS,,/ $
$
$ FORM RMS OF OUTPUT QUANTITIES
$
CALL   CALCRMS  MSTRESS,PSDINT/STRSRMS $
$
$ Output the matrices to OUTPUT4    RMS OUTPUT BACK TO TABLE FORMAT
$
DRMH3    ,,,,,TSTRESS,STRSRMS,,,,/,,OES1NEW,/'STATICS' $

$
EQUIVX OES1NEW /OES1 /-1 $
output4  strsrms//-1/11 $
$exit $
$
$ USE SORT1 OUTPUT AND BY-PASS DDRMM
$
$ALTER 'SORT2=NOT(ANDL(NOSORT2,NOSTR2))',''  $
SORT2= FALSE $
APP1= 'FREQRESP' $
$
message //' ' $
message //' response output are rms results' $
message //' ' $
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
COMPILE  CHCKINPT  NOLIST, NOREF $
SUBDMAP  CHCKINPT  PSD/PSDT/NFREQ/NSUB $
$
$ CHECK INPUT FOR COMPATIBILITY
$
TYPE  PARM,,I,N, NFREQ, NSUB, NFNS, i, j $
$
PARAML   PSD//'TRAILER'/1/S,N,NSCOL $
PARAML   PSD//'TRAILER'/2/S,N,NSROW $
```

```
$
IF ( NFREQ<>NSROW ) THEN $

  MESSAGE //' ' $
  MESSAGE //' ERROR: NUMBER OF ROWS IN PSD MATRIX IS' $
  MESSAGE //'       NOT AN EQUAL TO THE NUMBER OF FREQUENCIES' $
  MESSAGE //'       NUMBER OF ROWS        : '/NSROW $
  MESSAGE //'       NUMBER OF FREQUENCIES: '/NFREQ $
  MESSAGE //' ' $
  EXIT $

ENDIF $
$
IF ( NSUB<>NSCOL ) THEN $

  MESSAGE //' ' $
  MESSAGE //' ERROR: NUMBER OF COLUMNS IN PSD DOES' $
  MESSAGE //'       NOT MATCH THE NUMBER OF' $
  MESSAGE //'       INPUT SUBCASES' $
  MESSAGE //'       NUMBER OF PSD COLUMNS   : '/NSCOL $
  MESSAGE //'       NUMBER OF INPUT SUBCASES: '/NSUB $
  MESSAGE //' ' $
  EXIT $
$
ENDIF $
$
file psdt=append $
purgex   /psdt,,,,/ $ satisfy the DMAP compiler
i = 1
nfns = nsub*nfreq
do while ( i<=nsub )
  j = nfreq*(i-1) + 1
  matmod   psd,,,,,/psdi,/1/i $
  matgen   ,/pvec/4/1/nfns/0/nfreq/nfns/j $
  merge    ,,psdi,,,,pvec/psdx/1 $
  append   psdx,/psdt/2 $
  i = i + 1
enddo $
$matprn   psdt// $

RETURN $
END $
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
COMPILE  SUBDMAP= FINT, NOLIST, NOREF $
SUBDMAP  FINT   PSD,FOL/PSDINT/NFREQ/NSUB $
$
$ FORM A MATRIX WITH NFREQ ROWS AND (NFREQ*NSUB) COLUMNS
$ THE MATRIX IS FORMED BY APPENDING NSUB (NFREQ X NFREQ) MATRICES
$ THESE MATRICES HAVE THE DELTA BETWEEN FREQUENCIES ON THE FOL
TABLE
$ ALONG THE DIAGONAL.  Calculate the DFi for the trapezoidal rule, i.e,
```

```
$ DF1=F2-F1, DF2=F3-F1, DF2=F4-F2, ..., DFN=FN-F(N-1)
$
$                                     T
$ N |DF1 DF2 DF3 . . |
$ S |            DF1 DF2 DF3 . . |
$ U |                          DF1 DF2 DF3 . . |
$ B |
$
$  |------NFREQ-----|
$  |------------------NSUB*NFREQ------------------->|
$
$
TYPE  PARM,, I,N, NFREQ, NSUB , NFNS , I    , IWRD $
TYPE  PARM,,RS,N, FREQ1, FREQ2, FREQ3 $
TYPE  PARM,,CS,N, DFREQ $
$
FILE  ONE=OVRWRT/ONEX=OVRWRT/IFREQ=OVRWRT $
$
NFNS = NFREQ*NSUB
MATGEN   ,/ONEX/4/3/NFNS/0/1/NFNS/1/NFREQ/3 $
diagonal onex/one/'whole'/0.0 $
$matprn   one// $
$
$ CALCULATE DELTA FOR FIRST FREQUENCY
$
PARAML   FOL//'DTI'/0/3/S,N,FREQ2 $
PARAML   FOL//'DTI'/0/4/S,N,FREQ3 $
DFREQ = CMPLX(0.5*(FREQ3-FREQ2), 0.0) $
ADD5     ONE,,,,/DFCOL/DFREQ $
$
$ CALCULATE DELTA FOR FREQUENCY LIST
$
I = 2 $
DO WHILE ( I<NFREQ ) $

  FREQ1 = FREQ2 $
  FREQ2 = FREQ3 $
  IWRD  = I+3 $
  PARAML   FOL//'DTI'/0/IWRD/S,N,FREQ3 $
  DFREQ = CMPLX((0.5*(FREQ3-FREQ1)), 0.0) $
  MATGEN   ,/ONEX/4/3/NFNS/0/1/NFNS/I/NFREQ/3 $
  diagonal onex/one/'whole'/0.0 $
  ADD5     ONE,DFCOL,,,/IFREQ/DFREQ $
  EQUIVX   IFREQ/DFCOL/-1 $
  I = I+1 $

ENDDO $
$
$ CALCULATE LAST FREQUENCY
$
DFREQ = CMPLX(0.5*(FREQ3-FREQ2), 0.0) $
MATGEN   ,/ONEX/4/3/NFNS/0/1/NFNS/NFREQ/NFREQ/3 $
diagonal onex/one/'whole'/0.0 $
ADD5     ONE,DFCOL,,,/IFREQ/DFREQ $
```

```
EQUIVX   IFREQ/DFCOL/-1 $
$matprn  dfcol// $
$
ADD      DFCOL,PSD/PSDINT///1 $
$
RETURN $
END $
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
COMPILE  SUBDMAP=CALCRMS, NOLIST, NOREF $
SUBDMAP  CALCRMS  PHI,PSDREAL/PHIRMS $
$
$ CALCULATE RMS VALUE OF RESPONSE
$
matmod   phi,,,,,/phic,/10 $
ADD      PHI,phic/PSP///1 $
MPYAD    PSP,PSDREAL,/PHIPSD $
$
DIAGONAL PHIPSD/PHIRMS/'WHOLE'/0.5 $
$matprn  PSDREAL,psp,phirms// $
$
RETURN $
END $
```

Appendix B2

Solution 101 MSC/NASTRAN version 69 DMAP sol101z.v69 Listing

```
$
compile subdmap=phase0,souin=mscsou,nolist,noref $
$alter 'DTIIN    DTI,DTINDX'
alter 30
type db zuzr11
type parm,nddl,char8,n,zname $
zname ='dti'
equivx  dti   /zuzr11/always $
zname ='dtindx'
equivx  dtindx/zuzr11/always $

$
compile subdmap=sedrcvr,souin=mscsou,list,noref $
alter 278,280
$ 278       EQUIVX    OES1X/OES1X1/S1 $
$ 279       IF ( S1 >= 0 ) STRSORT  OES1X,INDTA/OES1X1/NUMOUT/BIGER/
$                          SRTOPT/SRTELTYP $  ELEMENT STRESS SORTING
$ 280       OFP     OES1X1,,,,,,
$                 CSTMS,EPTS,GEOM1VU,ERROR1//
$                 S,N,CARDNO//PVALID $
$
type db zuzr11
type parm,nddl,char8,n,zname $
zname = 'dti'
equivx  zuzr11/dti/always $
zname = 'dtindx'
equivx  zuzr11/dtindx/always $
DTIIN   DTI,DTINDX/INDT1,INDT2,,,,,,,,/ $
$
$ EXTRA SORTING TO OUTPUT OTHER STRESS SORTS
$ AS SPECIFIED BY BULK DATA CARDS DTI, INDT1 THRU INDT3
$  SEE OLD USER MANUAL, VOL 2, SECT. 3.5-42
$ (NOTE THE FIRST SORT IS STILL ON THE DEFAULT CONDITIONS)
$
STRSORT  OES1X,INDT1/OES1X1/NUMOUT/BIGER /SRTOPT/SRTELTYP $
OFP     OES1X1//S,N,CARDNO $
$
STRSORT  OES1X,INDT2/OES1XA/NUMOUT/BIGER /SRTOPT/SRTELTYP $
OFP     OES1XA//S,N,CARDNO $
$
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ THIS ALTER WILL READ-IN A SET OF PSD MATRICES
$ AND PRODUCE STANDARD OUTPUT WHICH IS THE RMS RESPONSE
$ MSC/N V69
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
COMPILE  SESTATIC, NOLIST, NOREF $
$
```

```
$ STORE DTI INPUT IN USER DATABLOCKS
$
ALTER 'CALL IFPL'
TYPE  DB, ZUZR11
TYPE  PARM,NDDL,CHAR8,N, ZNAME $

DMIIN    DMI,DMINDX/loadcomb,,,,,,,,,/S,N,YESPSD $
ZNAME = 'loadcomb' $
EQUIVX   loadcomb/ZUZR11/-1 $
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
COMPILE  SEDRCVR, NOLIST, NOREF $
alter 'PJ1,QMG,UG' $
$
TYPE  PARM,,I,N, NSUBX $
$
$ READ-IN THE PSD MATRIX
$
TYPE  DB, ZUZR11
TYPE PARM,NDDL,CHAR8,N, ZNAME $

ZNAME = 'loadcomb' $
EQUIVX   zuzr11/loadcomb  /-1 $
$
$
$ CONVERT OUTPUT TABLES TO TABLE/MATRIX FORMAT
$
DRMH1    ,,,OES1,/ ,,,,TSTRESS,MSTRESS,,/ $
$
$ Output the matrices to OUTPUT4    RMS OUTPUT BACK TO TABLE FORMAT
$
inputt4  /strsrms,,,,/1/11/-1 $
paraml   mstress //'trailer'/1/s,n,nsubt $ total number of subcases
paraml   strsrms //'trailer'/1/s,n,nrms $  number of rms subcases
paraml   loadcomb//'trailer'/2/s,n,nsub $  number of final subcases

nsubx = nsub - nrms                  $  number of static subcases
matgen   ,/pvec/6/nsubt/nrms/nsubx/nsubt $

partn    mstress,pvec,/,,strs2,/1 $

append   strsrms,strs2/strs/1 $

mpyad    strs,loadcomb,/strs1 $

DRMH3    ,,,,,TSTRESS,STRS1,,,,/,,OES1N,/'STATICS' $

$
EQUIVX OES1N /OES1 /-1 $
$
message //' ' $
message //' response output are rms results' $
message //' ' $
$
```

Appendix C

Methodology for Post Processing Results from MSC/NASTRAN 101

The method begins with the request stress=all in the analysis, and use of param,post,-1 to obtain the stress output file op2 on the computing system. This file is transferred by first converting it on the Cray performing the analysis to convert it from Cray binary form to workstation (Sun or SGI) binary form, and thence to the workstation.

On the workstation, the FEM model is read into MSC/PATRAN by the analysis module to create a working copy of the FEM in a database. (The current version 6 of MSC/PATRAN is assumed, but it is known these procedures will also work with version 5.1 and maybe earlier versions as well.) This model should be complete with material assignments for all elements of interest. The analysis module is also used to read the op2 results into the database. During this process, be sure to open the "Transition Parameters" selection button before entering the op2 data, and select button for "Stress/Strain Invariants" so as to import the MSC/NASTRAN plate Von Mises stresses and the bar Maximum Stresses.

Using the group tool, a group is created for each material to be studied. Then using the list tool, and using material to select elements, all the elements with a particular material are assigned to the appropriate group. Bring up the group post tool, and post the first material group.

The results are processed two times, once to get plate element output and the other time for bar element output. Both outputs are written to files and start in the results menu, with advanced get results option menu, "select all" stress output subcases, "apply" and then "get results." The following procedures may be followed for each material regardless of whether or not there are bars and plates, since a null output file will result if a material only has one element type and is easily discarded.

For the plate elements select "Stress Invariants Von Mises." For Plot Type choose "Text Report" and open "Plot Type Options." Observe the "Select Layer" choices. These should reflect the available stress outputs to be processed, and only the Z1 and Z2 options should be selected. Select "Output to File" so that you can type a file name in the file window, and "Summary Only." Hit "Apply" button, and ignore warning about results only reported in analysis system. You are done in PATRAN for this material for plates.

For the bar elements select "Bar Stresses, Maximum Axial." For Plot Type choose "Text Report" and open "Plot Type Options." Observe the "Select Layer" choice; for bars at this point we should see only the "Center" option selected. The "Summary Only" button should be depressed, and "Output to File" so that you can type a file name in the file window. A file name like mat1.bar.patsrt to show material 1 patran sorted bar output is suggested. Hit "Apply" button, and ignore Warning about results only reported in analysis system. You are done for this material for bars.

Now go to the group post tool, and post the next material, and repeat the procedure. Continue for all materials to be processed, then exit MSC/PATRAN.

The output material files, one for bars and one for plates, should show maximum stresses for each load case. The top of a bar and a plate file for subcase 1 and the start of subcase 2 is given below:

file: mat1.bar.patsrt (gives the Maximum Axial Stress):

```
Load case 1 = SORT W/RANDOM RMS STRESSES, Static Subcase - Lid 5 =   At Center
```

```
Min =    1.203704  at Element  1290 -  Max =  8654.812500 at Element  1166

Load case 2 = SORT W/RANDOM RMS STRESSES, Static Subcase - Lid 5 =  At Center
Min =    0.535614  at Element  1290 -  Max =  3081.775146 at Element   629
```

file: mat1.plt.patsrt (Gives the Von Mises Stress)

```
Load case 1 = SORT W/RANDOM RMS STRESSES, Static Subcase - Lid 6 =  At Z1
Min =   15.075986  at Element  1231 -  Max =  5994.430664 at Element  1919

Load case 1 = SORT W/RANDOM RMS STRESSES, Static Subcase - Lid 7 =  At Z2
Min =    9.421765  at Element  1740 -  Max =  5878.902344 at Element  1919

Load case 2 = SORT W/RANDOM RMS STRESSES, Static Subcase - Lid 6 =  At Z1
Min =   12.237181  at Element  1240 -  Max =  4326.272949 at Element  1933

Load case 2 = SORT W/RANDOM RMS STRESSES, Static Subcase - Lid 7 =  At Z2
Min =   11.609198  at Element  1740 -  Max =  4294.583496 at Element  1933
```

Unix Awk Processing

Next, a unix process is used to finish out getting margins of safely for each material file. A command file, patsrtpost, is fed the file name and the material allowable stress. This can be done separately, or in a file all at once. A listing of the file "post" for the Neurolab biotelemetry FEM model is given below:

File "post" contents:

```
    patsrtpost mat1.patsrt 34000.
    patsrtpost mat21.patsrt 100000.
    patsrtpost mat22.patsrt 7000.
    patsrtpost mat30.patsrt 63300.
```

The command file, patsrtpost listing is:

```
    awk -f $home/sys/patran/awkpatsrtpost -v allow=$2 infil=$1 $1 > "$1.srtms"
    # script to process patran text sorted summary output
    #  by Roy Hampton
```

Note that the patsrtpost and the following awkpatsrtpost files are assumed to be located in a user directory $home/sys/patran which must be defined in the user's path.

The unix awk program file, awkpatsrtpost, listing is:

```
 BEGIN {print "patran summary sort output processing for file = ",infil
      if(allow<=0) print "\***ERROR: must specify allowable stress!***"
      print "Margin of Safety Summary, using Allowable Stress = ",allow
      print "Loadcase","Eid","MaxStress","M.S."
         flag1=0; flag2=1}
#  don't use this, output with spaces instead:       OFS=","
# usage: awk -f awkpatsrtpost -v allow=$2 filename $1 > $1.allow
#  where $1 is the input file, $2 =allowable stress for Margin of Safety calculation
#  script by Roy Hampton

# specify the pattern to get subcase & get it & initialize flag1
# saying we are in a solution step range
        flag2 && /Load case/            {
# zero arrays
```

```
     for (k=1; k<=10; k++) {
          a[k] = 0
          b[k] = 0
          c[k] = 0
          d[k] = 0
          e[k] = 0             }
     flag1 = 1
     flag2 = 0
     cnt = 0
# get first load case & element data
#  a[] is load case, b[] is eleid, c[] is stress
     a[1] = $3
     getline
     b[1] = $13
     c[1] = $10
#   print a[1],b[1],c[1]
                         }

# in range, locate more data and store max stress, etc
 flag1 && /Load case/   {
     while($3==a[1]) {
     getline
     b[2] = $13
     c[2] = $10
     if(c[2]>c[1]) {
          c[1] = c[2]
          b[1] = b[2]  }
#    print a[1],b[1],c[1]
                    } }

# out of range
 flag1 && /Load case/    {
     if($3!=a[1]) {
# get max. stress and MS for printout
   max = c[1]
   if(max!=0.) {ms = allow/max -1.}
   if(max=0.) {ms = 1000000.}
   max = c[1]
# output the data
   if (ms>0) {printf "%8s %8s %4.3e %8.3f \n",
       a[1],b[1],max,ms}
   if (ms<=0) {printf "%8s %8s %4.3e %8.3f ***\n",
       a[1],b[1],max,ms}
# store loadcase, ms for later printout of smallest ms
   cnt = cnt + 1
   d[cnt] = a[1]
   e[cnt] = ms
#  store this new data and iterate some more
   a[1] = $3
     getline
     b[1] = $13
     c[1] = $10
#   print a[1],b[1],c[1]
                  }
```

```
                    }
END {
# get last item max. stress and MS for printout
   max = c[1]
   if(max!=0.) {ms = allow/max -1.}
   if(max=0.) {ms = 1000000.}
   max = c[1]
# output the data
   if (ms>0) {printf "%8s %8s %4.3e %8.3f \n",
       a[1],b[1],max,ms}
   if (ms<=0) {printf "%8s %8s %4.3e %8.3f ***\n",
       a[1],b[1],max,ms}
# now get smallest ms encountered and print load case and ms
# first store this last value, then search all previous cases
   ld = a[1]
   xms = ms
#   print ld,xms
   lct = 1
   while(lct<=cnt)   {
#     print lct,e[lct],xms
     if(e[lct]<xms) {
      xms = e[lct]
      ld = d[lct]   }
     lct = lct + 1    }
#   print lct,cnt
#   print ld,xms
   printf "Minimum M.S. at Load Case %8s is %8.3f \n",
      ld,xms
      }
```

<u>The output from the awk program looks like the following:</u>

```
patran summary sort output processing for file =  mat1.bar.patsrt
Margin of Safety Summary, using Allowable Stress =  34000
Loadcase Eid MaxStress M.S.
     1    1166 8.655e+03   2.928
     2     629 3.082e+03  10.033

skipped lines here towards the bottom:
    42    1787 6.643e+03   4.118
    43    1287 5.130e+03   5.628
Minimum M.S. at Load Case       18 is    1.279
```

The awk utility also works on the plate patran output files.

Appendix D

Buckling Analysis using MSC/NASTRAN 105

A sample analysis deck for quasi-static loads is given below:

EXAMPLE PROBLEM USING SOL 101 QUASI-STATIC LOADS

```
$nastran system(2)=4 $
ID BIOT MESH
SOL 105
DIAG 8,13
TIME 100
CEND
$
TITLE = RAHF SIR 4PU BIOTEL DRAWER VERIFIED FEM MODEL IN-RACK
SUBTITLE = BUCKLING ANALYSIS ON LOAD CASE PRODUCING LARGEST -
STRESSES
ECHO = UNSORT
SEALL = ALL
SUPER = ALL
SPC = 2
SUBCASE 1
 LOAD = 1
 LABEL = +X LIFTOFF +8.0 G, -Y LIFTOFF -6.2 G, +Z LIFTOFF +6.5 G
SUBCASE 2
 METHOD = 10
 DISP(PLOT)=ALL
 STRESS(PLOT)=ALL
$
BEGIN BULK
$
EIGRL,10,-20.,20.
PARAM,POST,-1
PARAM,PATVER,3.0
PARAM,NEWSEQ,-1
PARAM,PRGPST,NO
$
$ G UNIT LOADS
GRAV,111,,1.,1.,0.,0.          $ X-AXIS
GRAV,112,,1.,0.,1.,0.          $ Y-AXIS
GRAV,113,,1.,0.,0.,1.          $ Z-AXIS
$ Spacelab loads
LOAD,1,1.,8.0,111,-6.2,112,6.5,113
$
$*******************************
$ INCLUDE THE MODEL DECK
include 'save/bioinrack3.bdf'
$
ENDDATA
```

EXAMPLE PROBLEM USING POSITIVE QUASI-STATIC LOADS

```
$nastran system(2)=4 $
ID BIOT MESH
SOL 105
DIAG 8,13
TIME 100
CEND
$
TITLE = RAHF SIR 4PU BIOTEL DRAWER VERIFIED FEM MODEL IN-RACK
SUBTITLE = BUCKLING ANALYSIS II
$ USING THE MAX. STRESS COMBINATION LOAD CASE 14, AND WITH
$  AN ACCELERATION LOAD TO CONSERVATIVELY MODEL EFFECT OF
$  RANDOM LOAD INDUCED STRESS IN CASE 1 (RANDOM X WHICH IS IN CASE
14)
$  USING EQUIVALENT G TO GET SAME STRESS BASED ON STATICS CASE 4)
ECHO = UNSORT
SEALL = ALL
SUPER = ALL
SPC = 2
SUBCASE 1
 LOAD = 1
 LABEL = +X RANDOM + LIFTOFF +8.56+8.0 G, -Y LIFTOFF -6.2 G, +Z LIFTOFF
+6.5 G
SUBCASE 2
 METHOD = 10
 DISP(PLOT)=ALL
 STRESS(PLOT)=ALL
$
BEGIN BULK
$
EIGRL,10,-20.,20.
PARAM,POST,-1
PARAM,PATVER,3.0
PARAM,NEWSEQ,-1
PARAM,PRGPST,NO
$
$ G UNIT LOADS
GRAV,111,,1.,1.,0.,0.          $  X-AXIS
GRAV,112,,1.,0.,1.,0.          $  Y-AXIS
GRAV,113,,1.,0.,0.,1.          $  Z-AXIS
$ Spacelab loads
LOAD,1,1.,16.56,111,-6.2,112,6.5,113
$
$******************************
$ INCLUDE THE MODEL DECK
include 'save/bioinrack3.bdf'
ENDDATA
```

EXAMPLE PROBLEM USING NEGATIVE QUASI-STATIC LOADS

```
$nastran system(2)=4 $
ID BIOT MESH
SOL 105
DIAG 8,13
TIME 100
CEND
$
TITLE = RAHF SIR 4PU BIOTEL DRAWER VERIFIED FEM MODEL IN-RACK
SUBTITLE = BUCKLING ANALYSIS II
$ USING THE MAX. STRESS COMBINATION LOAD CASE 14, AND WITH
$  AN ACCELERATION LOAD TO CONSERVATIVELY MODEL EFFECT OF
$  RANDOM LOAD INDUCED STRESS IN CASE 1 (RANDOM X WHICH IS IN CASE
14)
$  USING EQUIVALENT G TO GET SAME STRESS BASED ON STATICS CASE 4)
ECHO = UNSORT
SEALL = ALL
SUPER = ALL
SPC = 2
SUBCASE 1
 LOAD = 1
 LABEL = -X RANDOM - LIFTOFF -8.56-5.0 G, +Y LIFTOFF +6.2 G, -Z LIFTOFF -6.5
G
SUBCASE 2
 METHOD = 10
 DISP(PLOT)=ALL
 STRESS(PLOT)=ALL
$
BEGIN BULK
$
EIGRL,10,-20.,20.
PARAM,POST,-1
PARAM,PATVER,3.0
PARAM,NEWSEQ,-1
PARAM,PRGPST,NO
$
$ G UNIT LOADS
GRAV,111,,1.,1.,0.,0.            $  X-AXIS
GRAV,112,,1.,0.,1.,0.            $  Y-AXIS
GRAV,113,,1.,0.,0.,1.            $  Z-AXIS
$ Spacelab loads
LOAD,1,1.,-13.56,111,6.2,112,-6.5,113
$
$******************************
$ INCLUDE THE MODEL DECK
include 'save/bioinrack3.bdf'
$
ENDDATA
```

EXAMPLE PROBLEM QUASI-STATIC LOADS FOR FORCE, ETC. OUTPUTS

```
$nastran system(2)=4 $
ID BIOT MESH
SOL 101
DIAG 8,13
TIME 100
CEND
$
TITLE = RAHF SIR 4PU BIOTEL DRAWER VERIFIED FEM MODEL IN-RACK
SUBTITLE = FORCE OUTPUT
$ USING THE MAX. STRESS COMBINATION LOAD CASE 14, AND WITH
$  AN ACCELERATION LOAD TO CONSERVATIVELY MODEL EFFECT OF
$  RANDOM LOAD INDUCED STRESS IN CASE 1 (RANDOM X WHICH IS IN CASE 14)
$  USING EQUIVALENT G TO GET SAME STRESS BASED ON STATICS CASE 4)
$   +X RANDOM + LIFTOFF +8.56+8.0 G, -Y LIFTOFF -6.2 G, +Z LIFTOFF +6.5 G
ECHO = UNSORT
SEALL = ALL
SUPER = ALL
SPC = 2
LOAD = 1
ELFORCE = ALL
SPCFORCES = ALL
DISP(PLOT)=ALL
STRESS(PLOT)=ALL
$
BEGIN BULK
$
PARAM,POST,-1
PARAM,PATVER,3.0
PARAM,NEWSEQ,-1
PARAM,PRGPST,NO
$
$ G UNIT LOADS
GRAV,111,,1.,1.,0.,0.          $  X-AXIS
GRAV,112,,1.,0.,1.,0.          $  Y-AXIS
GRAV,113,,1.,0.,0.,1.          $  Z-AXIS
$ Spacelab loads
LOAD,1,1.,16.56,111,-6.2,112,6.5,113
$
$*******************************
$ INCLUDE THE MODEL DECK
include 'save/bioinrack4.bdf'
$
```

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY ***(Leave blank)***

2. REPORT DATE
January 2000

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
MSC/NASTRAN Stress Analysis of Complete Models
Subjected to Random and Quasi-Static Loads

5. FUNDING NUMBERS
297-10-02

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Moffett Field, CA 94035-1000

8. PERFORMING ORGANIZATION REPORT NUMBER
A-00V0007

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/TM–2000-209585

11. SUPPLEMENTARY NOTES
Point of Contact: Roy W. Hampton, Ames Research Center, MS 213-4, Moffett Field, CA 94035-1000
(650) 604-6223

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified — Unlimited
Subject Category 39 Distribution: Standard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Space payloads, such as those which fly on the Space Shuttle in Spacelab, are designed to withstand dynamic loads which consist of combined acoustic random loads and quasi-static acceleration loads. Methods for computing the payload stresses due to these loads are well known and appear in texts and NASA documents, but typically involve approximations such as the Miles' equation, as well as possible adjustments based on "modal participation factors." Alternatively, an existing capability in MSC/NASTRAN may be used to output exact root mean square [rms] stresses due to the random loads for any specified elements in the Finite Element Model. However, it is time consuming to use this methodology to obtain the rms stresses for the complete structural model and then combine them with the quasi-static loading induced stresses. Special processing was developed as described here to perform the stress analysis of all elements in the model using existing MSC/NASTRAN and MSC/PATRAN and UNIX utilities. Fail-safe and buckling analyses applications are also described.

14. SUBJECT TERMS
Dynamics, Stress analysis, Acoustics, Random loads, Modal participation factors, Fail-safe, Space payloads, MSC/NASTRAN, MSC/PATRAN

15. NUMBER OF PAGES
40

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102