EVALUATING MODAL CONTRIBUTORS IN A NASTRAN FREQUENCY RESPONSE ANALYSIS

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ABSTRACT

A special purpose (alter) program has been added to the MSC/NASTRAN modal frequency response rigid format (Solution 30), via the direct matrix abstraction program (DMAP) capability.

The DMAP program allows an in-depth analysis of the frequency response on a per-mode basis.

An example of how the program was applied to the modal frequency response analysis of Hughes Advanced Attack Helicopter is presented along with some unexpected results.

INTRODUCTION

The topic "Evaluating Modal Contributors in a NASTRAN Frequency Response Analysis" covers the follow-on work from that which was presented in the paper of Reference 1 at last year's conference. By way of introduction, a modal analysis was performed on Hughes' Advanced Attack Helicopter (AAH) (see Figures 1 and 2). At this time, the AAH is in the production phase of a contract with the U.S. Army where it is designated the AH-64A Apache. The AAH is a relatively large helicopter - 50 feet long, 12 feet high, and having a 12-foot wing span. It can carry up to a maximum of four pylons which contain a variety of missiles and rockets. In addition, it has a 30mm chain gun under its nose. Its weight is approximately 15,000 pounds.

The analysis was performed on the NASTRAN dynamic model shown in Figure 3. This relatively large model had 1632 grid points, 4357 structural elements, and 9792 dynamic degrees of freedom (DOF). The detail of this model, which is the same size as the structural model after a compatible mass representation was added, was maintained by solving for the modes and frequencies using Generalized Dynamic Reduction (GDR).

Modes and frequencies were then calculated up to 25 Hz using GDR. A partial NASTRAN frequency summary table is shown in Table 1. Fifty modes are shown up to 12.82 Hz. A total of 87 modes were calculated up to 25 Hz and all were used during the frequency response analyses.

Models containing this detail give rise to the term "high modal density," i.e., many modes within a given frequency range. This detail in the mode shapes allows a more thorough analysis of the modes. Figures 4 through 6 are but a few examples of typical mode shapes that illustrate the detail provided by large DOF dynamic models.

Table 2 is a summary of the major structural modes which were identified from the analysis along with a few major test modes that correlated with the analytical modes. The identification of the major structural modes from models with high modal density using the kinetic energy approach was the topic of last year's paper. This paper, which uses updated modal data for frequency response analysis in solution 30 of MSC/NASTRAN, presents a special direct matrix abstraction program (DMAP) which permits identification of primary contributing modes to a particular response and enhanced the understanding of the vibration characteristics.

In the helicopter industry, the comfort of the pilot is very important. Our goal is to give him the same smooth ride enjoyed by the airline pilot, but unfortunately the technology will not yet allow it.

It is common, in an attempt to give the pilot as smooth a ride as possible, to add vibration control devices; therefore, the response work presented here was performed to evaluate the vibration response at the pilot's seat in the vertical (Z) direction in the event that such a control device was deemed necessary.

In addition, helicopters generally have certain discrete forcing functions which cause the maximum structural response. In the case of the AAH, a major structural input force from the rotor occurs at the 4/rev or 18.85 Hz circular frequency, where 4/rev is defined as 4 times the main rotor speed.

Initial analyses calculated response at the pilot's seat for 6 independent orthogonal 4/rev forcing functions at the main rotor hub. These results did not compare favorably with the results of a previously run modal test performed on the AAH. The responses were too low. However, during the modal test the helicopter was suspended from the main rotor hub and the shaker inputs (forcing functions) were applied at the aircraft's nose and tail - not at the main rotor hub. When the analysis was repeated for these conditions, i.e., the forcing was applied at the nose and tail, a much better correlation to the test results was achieved. In order to gain more insight into the response, a DMAP was written to obtain the frequency response on a per-mode basis. The DMAP was written for solution 30, Version 61B of MSC/NASTRAN. Figure 7 shows the standard frequency response equations which are solved in solution 30. Equation (1) is the standard modal summation equation for calculating physical, or discrete, displacements.

Equation (2) is an important variation of Equation (1). Using a special element by element

$$\begin{pmatrix} E \\ x \\ E \end{pmatrix}$$

multiply, Equation (2) solves for the frequency response on a per-mode basis by multiplying but not summing as in the standard matrix multiply of Equation (1). The summation of the individual X_i's in Equation (2) is then equal to the total X in Equation (1).

The DMAP solves for the response on the per-mode basis as shown in Equation (2) and contains a check that solves Equation (3) and allows the user to compare with the results of Equation (1) which is standard NASTRAN frequency response output.

DMAP PROGRAM

The DMAP written for Version 61B is shown in Figures 8 and 9. The program is automated, but requires certain user inputs that are outlined in the bulk data of Figure 9.

Execution of the program does not require an understanding of the DMAP (although it would increase the user's flexibility to further modify the program). Therefore the detailed steps will not be explained. However, a few features will be mentioned (see Note on Figure 8). Comment cards have been inserted to document major sections. The first output from the DMAP is the frequency summary table from solution 3. Upon restarting into solution 30 from solution 3, this table is not reprinted. The authors feel this information is important, and is printed by the "OFP LAMA//$" statement.

Next the modal matrix is normalized (ZPSN) in order to quickly isolate the larger displacement values. Note "ZPSN" is a transposed single row matrix which represents the degree of freedom and all 87 modes of the pilot's seat in the "Z" direction.

Next, the modal displacement (TETAM) and physical displacement (TOTM) on a per-mode basis are calculated. This is followed by the acceleration (TOTMA) on a per-mode basis. Additional matrix outputs ending in letter "N" have normalized the preceding matrix to a maximum value of unity to assist the analyst in determining the largest contributors.

Figure 9 notes the required user input in the case control deck. Set 1 selects all six DOF of the grid point corresponding to the pilot's seat, i.e., 10013. The user must input his desired grid point at which the response will be determined.

Figure 9 also notes the user input required in the bulk data section. Matrix C6, see DM1 card 2, selects the user's desired response direction, which in this example is 3. The "PARAM, NCASE, 2," selects the number of subcases to be run. And finally, the frequency of the forcing function is input as $-\omega^2$ in complex form, where ω^2 is in $(rad/sec)^2$.

APPLICATION

The 4/rev forcing function at 18.85 Hz is very close to some of the major structural modes as shown in Figure 10. Any shift in the frequency of these modes toward 18.85 Hz could greatly affect the response.

The forcing function (a 1000 pound vertical oscillating load) was then applied at the main rotor hub and aircraft tail, and the response at the pilot seat in the vertical direction was calculated for these independently applied loads.

Table 3 is the complex modal acceleration for all 87 modes, i.e., "$\ddot{q}$". This is normal NASTRAN output in the complex form of Real and Imaginary parts. In reviewing Table 3, large values such as those for modes 73 through 75 are of interest. If one can match up large values of "$\ddot{q}$" with large values of "ϕ", the resulting response ($\ddot{X}_i$) for that particular mode will be large.

The next output of interest is shown in Table 4. This again is normal solution 30 NASTRAN output. Here we have the total modal acceleration response, all 6 DOF, for selected grid points on the aircraft. Again our interest is the pilot's seat at point ID 10013. The third column represents the response in the "Z" direction. Later in the program, the individual modal responses are added, the sum of which should be equal to column 3 of Table 4. If this is the case, the calculation is verified.

Table 5 is the first calculated matrix output from the DMAP. This is the transposed row of the modal matrix which corresponds with the vertical response of the pilot's seat. This column has been normalized to "unity" such that the largest values may be easily established. Again a large modal value which matches with a large acceleration "$\ddot{q}$" will produce a large acceleration for that particular mode.

And finally, Table 6 is the output data of the response on a per-mode basis. Case 1 represents the 4/rev forcing function applied at the main rotor hub and Case 2 applied at the tail.

In order to gain a better understanding of the two cases, attention is turned to Equation (4). Equation (4) is similar to

$$\left\{ \ddot{X}_{i_1} \;\middle|\; \ddot{X}_{i_2} \right\}_{87\times2} = \left\{ \underset{\text{CASE 1}}{\phi^T_{PS}} \;\middle|\; \underset{\text{CASE 2}}{\phi^T_{PS}} \right\}_{87\times2} \; E \times E \; \left\{ \underset{\text{CASE 1}}{\ddot{q}_{i_1}} \;\middle|\; \underset{\text{CASE 2}}{\ddot{q}_{i_2}} \right\}_{87\times2} \tag{4}$$

Equation (2) except two cases have been formulated. The values of columns 1 and 2 of the "phi" (ϕ^T) matrix are identical. However, the columns of the "$\ddot{q}$" matrix are different, since the forcing function was applied at a different location for each case. "$\ddot{X}_{i_1}$" and "$\ddot{X}_{i_2}$" are the responses per mode for the two cases.

Table 7 summarizes the check matrix, i.e., the summation of the response per-mode matrix. This summation is a check on the method presented and should be equal to the normal frequency response output shown in Column 3 of Table 4. This check is a part of the DMAP.

The results of the root of the sum of the squares (RSS) magnitudes in g's for cases 1 and 2 are summarized in Table 8 from the results of Table 6. Column 1 is the number of the largest contributors on a per-mode basis. Column 2 is RSS response at the pilot's seat due to a force at the hub. Column 3 is mode number at which the response occurs, and column 4 is the corresponding frequency at which it occurs. Columns 5 through 7 are identical to 2 through 4 for a force applied at the tail.

Note, the largest contributor when the force was applied at the tail was the 75 mode at 18.97 Hz, but when the force was applied at the hub, this was only the third largest contributor.

The results of Table 8 were plotted as shown in Figure 11. As expected, the two largest responses when the forcing function was applied at the tail are very close to the forcing function. However, when the forcing function was applied at the main rotor hub, the largest response occurred at 14.56 Hz, the 60th mode. The 18.97 Hz mode was but the third largest contributor. What these unexpected results indicate is that if we wanted to add a vibration control device, we should work on the mode at 14.56 Hz - not 18.97 Hz, which is the mode closest to the forcing function.

Without these data, we could have spent a lot of time, money, and energy working on the more logical 18.97 Hz mode with little effect.

CONCLUSIONS

The identification of modal contribution to local response is very valuable in identifying the primary contributing modes of the total response. It provides the analyst with a far better understanding of the vibration characteristics of the system and points to areas where structural improvements may be beneficial. The application as presented to the AAH provides a good example. If a vibration control device had been designed to isolate the modes close to the frequency of the forcing function, little if any benefit would have been realized. The mode at 14.56 Hz was the one to isolate.

Although the DMAP presented was written for a specific application in the helicopter industry, the authors believe that it perhaps can be applied to the constant speed rotary machinery field as well.

ACKNOWLEDGMENT

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REFERENCE

1. Parker, G.R. and J.J. Brown, "Kinetic Energy DMAP for Mode Identification," MSC/NASTRAN User's Conference Proceedings, Paper 8, March 1982.

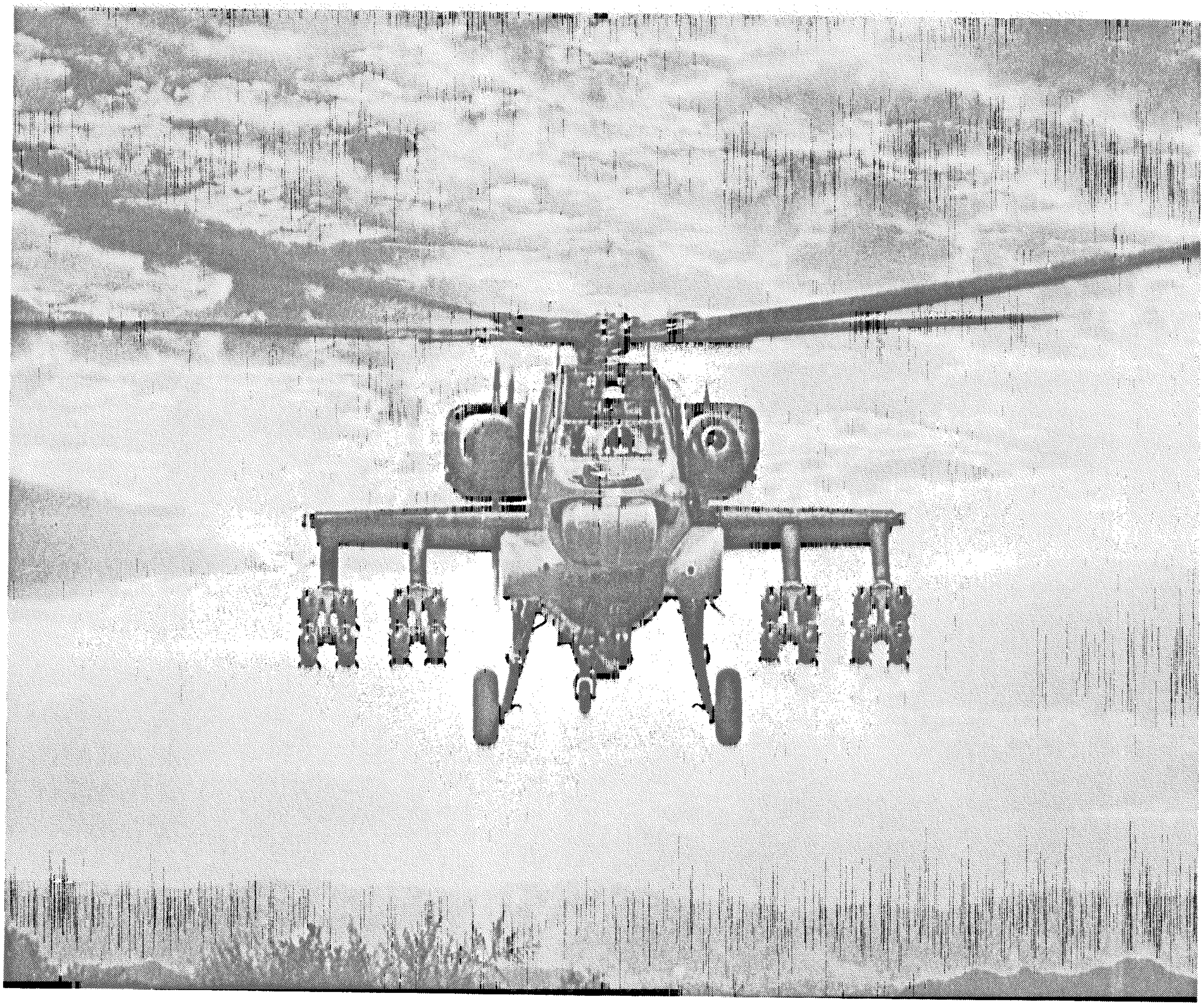

Figure [illegible]: Hughes Advanced Attack Helicopter

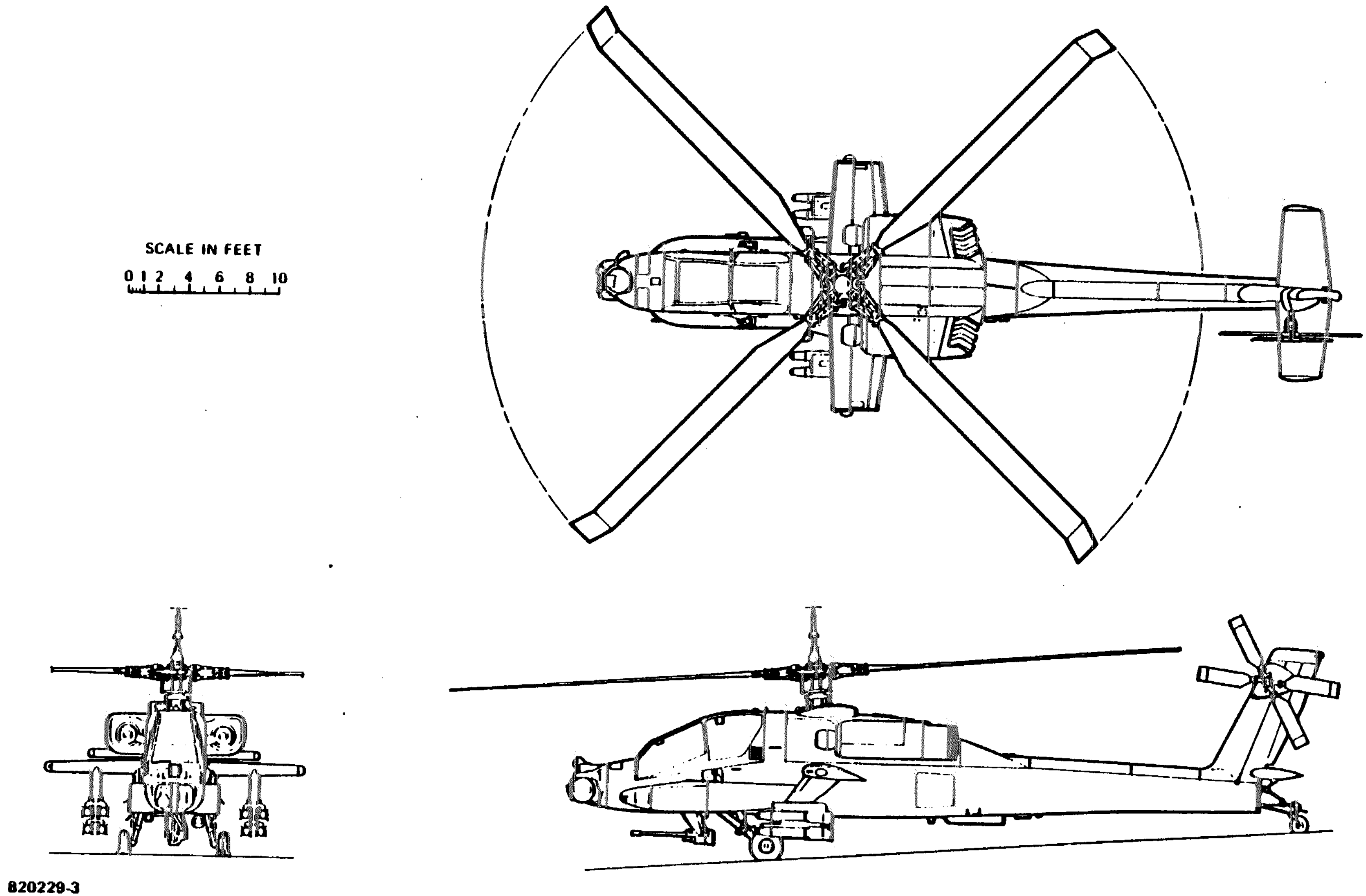

Figure 2. Hughes Advanced Helicopter

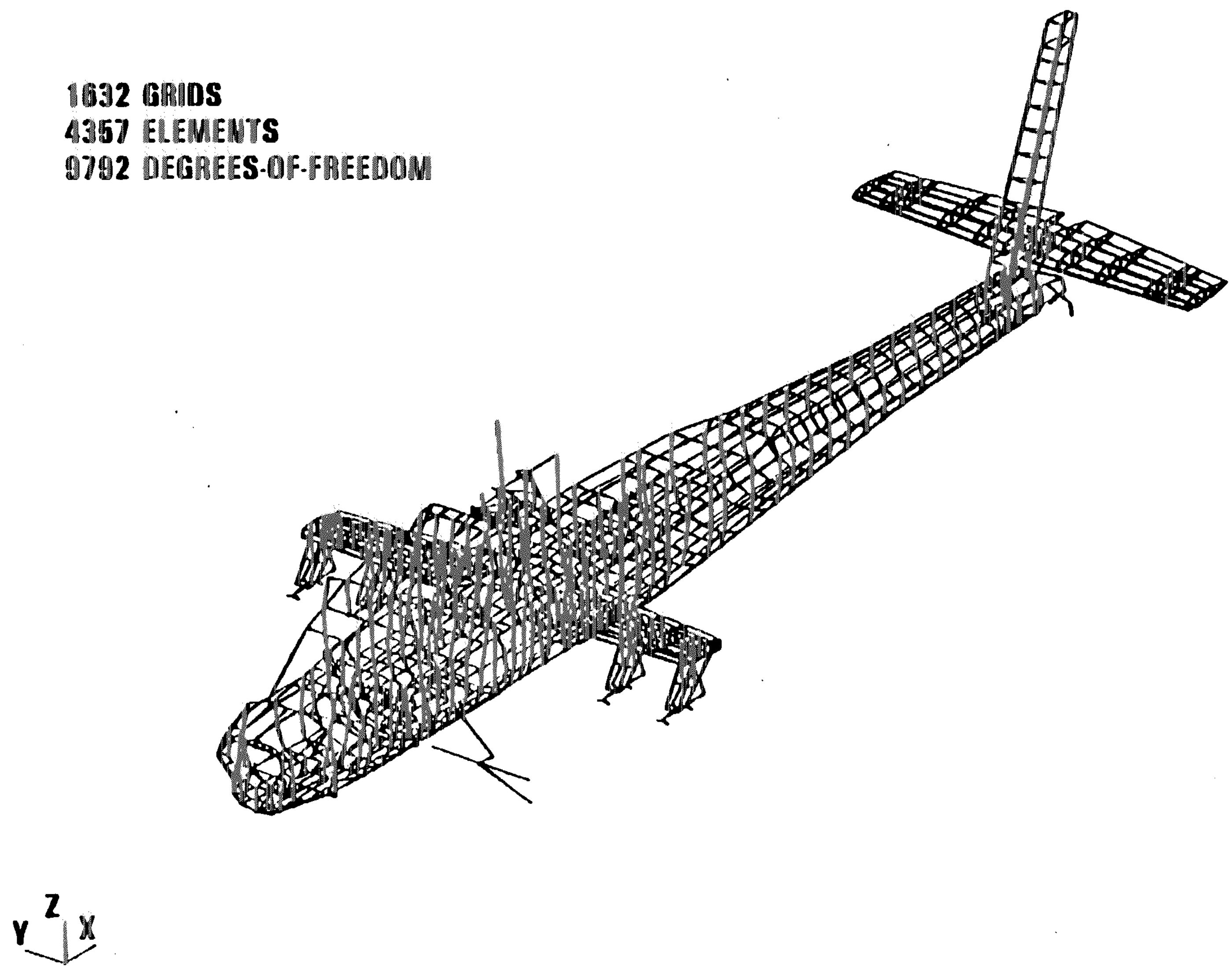

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Figure 3. AAH Dynamic NASTRAN Model

TABLE 1. DYNAMIC NASTRAN

• NASTRAN CAN IDENTIFY MANY MODES IN SMALL FREQUENCY RANGE

MODE NO.	EXTRACTION ORDER	EIGENVALUE	REAL EIGENVALUES RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	154	1.503159E-06	1.226034E-03	1.951294E-04	1.000000E+00	1.503159E-06
2	153	2.877826E-06	1.696415E-03	2.699929E-04	1.000000E+00	2.877826E-06
3	152	-4.397833E-06	2.097101E-03	3.337640E-04	1.000000E+00	-4.397833E-06
4	151	-1.635350E-05	4.043946E-03	6.436140E-04	1.000000E+00	-1.635350E-05
5	150	-1.042269E-04	1.020916E-02	1.624838E-03	1.000000E+00	-1.042269E-04
6	149	-1.124452E-04	1.060402E-02	1.687682E-03	1.000000E+00	-1.124452E-04
7	134	2.516975E+02	1.586498E+01	2.524990E+00	1.000000E+00	2.516975E+02
8	144	3.394329E+02	1.842370E+01	2.932226E+00	1.000000E+00	3.394329E+02
9	146	3.671488E+02	1.916113E+01	3.049588E+00	1.000000E+00	3.671488E+02
10	145	3.744222E+02	1.934999E+01	3.079647E+00	1.000000E+00	3.744222E+02
11	147	4.154079E+02	2.038156E+01	3.243826E+00	1.000000E+00	4.154079E+02
12	148	4.154104E+02	2.038162E+01	3.243836E+00	1.000000E+00	4.154104E+02
13	135	6.591513E+02	2.567394E+01	4.086135E+00	1.000000E+00	6.591513E+02
14	137	8.739556E+02	2.956274E+01	4.705056E+00	1.000000E+00	8.739556E+02
15	138	8.995762E+02	2.999294E+01	4.773524E+00	1.000000E+00	8.995762E+02
16	141	1.036563E+03	3.219570E+01	5.124105E+00	1.000000E+00	1.036563E+03
17	142	1.054847E+03	3.247840E+01	5.169098E+00	1.000000E+00	1.054847E+03
18	143	1.070243E+03	3.271457E+01	5.206686E+00	1.000000E+00	1.070243E+03
19	140	1.092594E+03	3.305440E+01	5.260772E+00	1.000000E+00	1.092594E+03
20	139	1.152540E+03	3.394909E+01	5.403165E+00	1.000000E+00	1.152540E+03
21	136	1.217770E+03	3.489657E+01	5.553961E+00	1.000000E+00	1.217770E+03
22	133	1.445545E+03	3.802032E+01	6.051122E+00	1.000000E+00	1.445545E+03
23	132	1.675495E+03	4.093281E+01	6.514660E+00	1.000000E+00	1.675495E+03
24	131	1.814305E+03	4.259466E+01	6.779151E+00	1.000000E+00	1.814305E+03
25	130	1.842669E+03	4.292632E+01	6.831937E+00	1.000000E+00	1.842669E+03
26	128	1.962254E+03	4.429734E+01	7.050141E+00	1.000000E+00	1.962254E+03
27	129	1.973041E+03	4.441892E+01	7.069491E+00	1.000000E+00	1.973041E+03
28	127	2.279396E+03	4.774302E+01	7.598537E+00	1.000000E+00	2.279396E+03
29	126	2.352183E+03	4.849931E+01	7.718905E+00	1.000000E+00	2.352183E+03
30	125	2.410746E+03	4.909935E+01	7.814405E+00	1.000000E+00	2.410746E+03
31	124	2.472794E+03	4.972719E+01	7.914329E+00	1.000000E+00	2.472794E+03
32	123	2.538250E+03	5.038105E+01	8.018393E+00	1.000000E+00	2.538250E+03
33	122	3.096273E+03	5.564416E+01	8.856044E+00	1.000000E+00	3.096273E+03
34	121	3.201632E+03	5.658297E+01	9.005459E+00	1.000000E+00	3.201632E+03
35	120	3.412053E+03	5.841278E+01	9.296682E+00	1.000000E+00	3.412053E+03
36	119	3.780534E+03	6.148605E+01	9.785809E+00	1.000000E+00	3.780534E+03
37	118	4.000472E+03	6.324929E+01	1.006644E+01	1.000000E+00	4.000472E+03
38	117	4.090191E+03	6.395460E+01	1.017869E+01	1.000000E+00	4.090191E+03
39	115	4.512305E+03	6.717370E+01	1.069103E+01	1.000000E+00	4.512305E+03
40	114	4.687153E+03	6.846278E+01	1.089619E+01	1.000000E+00	4.687153E+03
41	116	4.762547E+03	6.901121E+01	1.098347E+01	1.000000E+00	4.762547E+03
42	113	4.872559E+03	6.980372E+01	1.110961E+01	1.000000E+00	4.872559E+03
43	112	5.081446E+03	7.128426E+01	1.134524E+01	1.000000E+00	5.081446E+03
44	111	5.276135E+03	7.263701E+01	1.156054E+01	1.000000E+00	5.276135E+03
45	109	5.653276E+03	7.518827E+01	1.196658E+01	1.000000E+00	5.653276E+03
46	110	5.825881E+03	7.632746E+01	1.214789E+01	1.000000E+00	5.825881E+03
47	108	5.874899E+03	7.664789E+01	1.219889E+01	1.000000E+00	5.874899E+03
48	107	6.092215E+03	7.805264E+01	1.242246E+01	1.000000E+00	6.092215E+03
49	106	6.184311E+03	7.864039E+01	1.251601E+01	1.000000E+00	6.184311E+03
50	105	6.497409E+03	8.060651E+01	1.282892E+01	1.000000E+00	6.497409E+03

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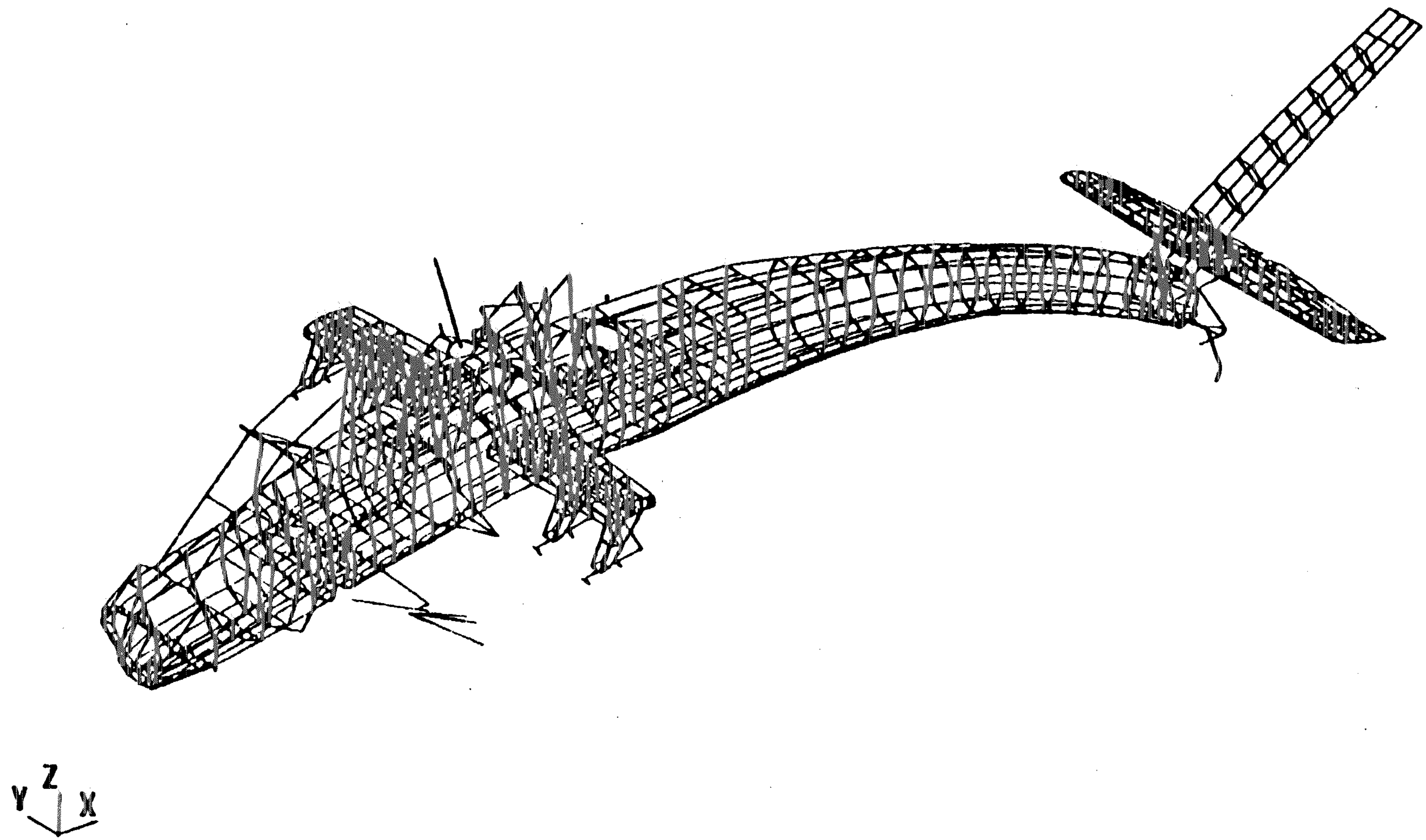

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Figure 4. AAH Dynamic NASTRAN Model First Vertical Bending Mode (5.55 Hz)

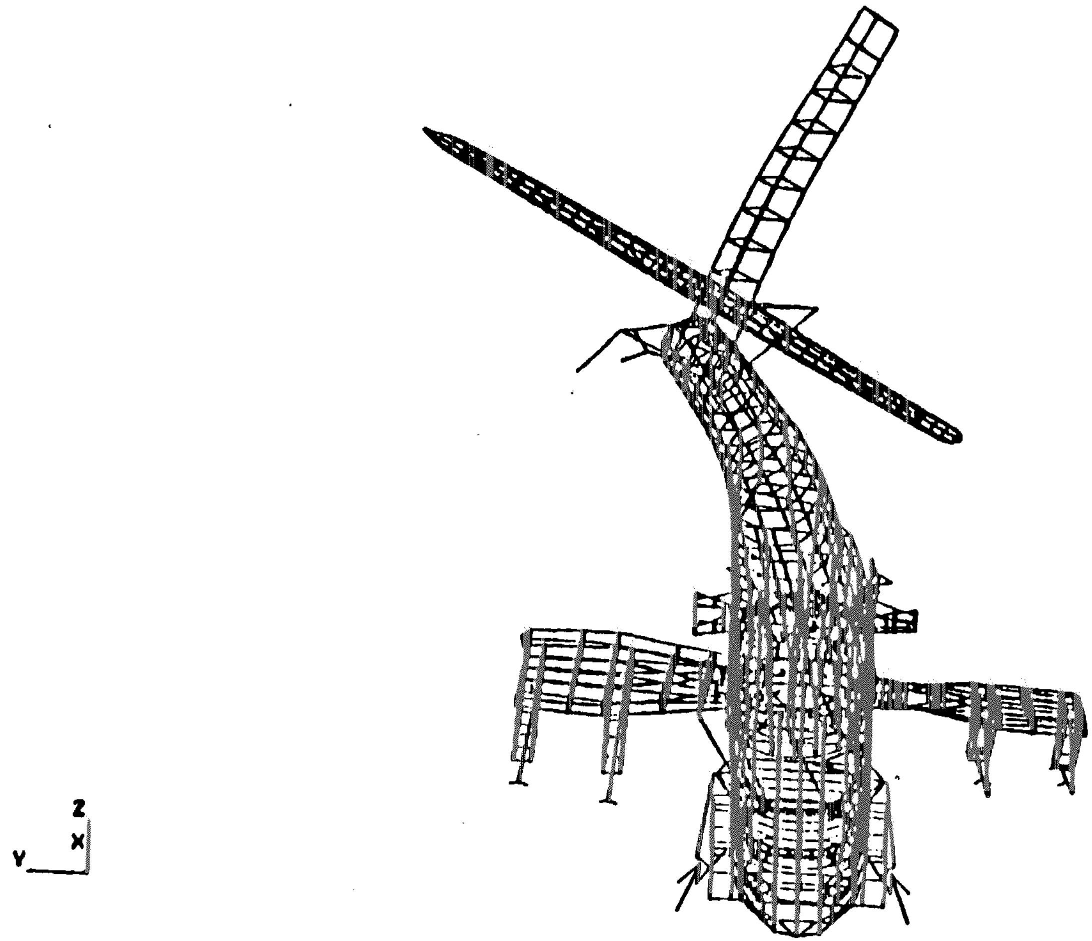

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Figure 5. AAH Dynamic NASTRAN Model First Antisymmetric Wing/Pylon Torsion Mode (7.59 Hz)

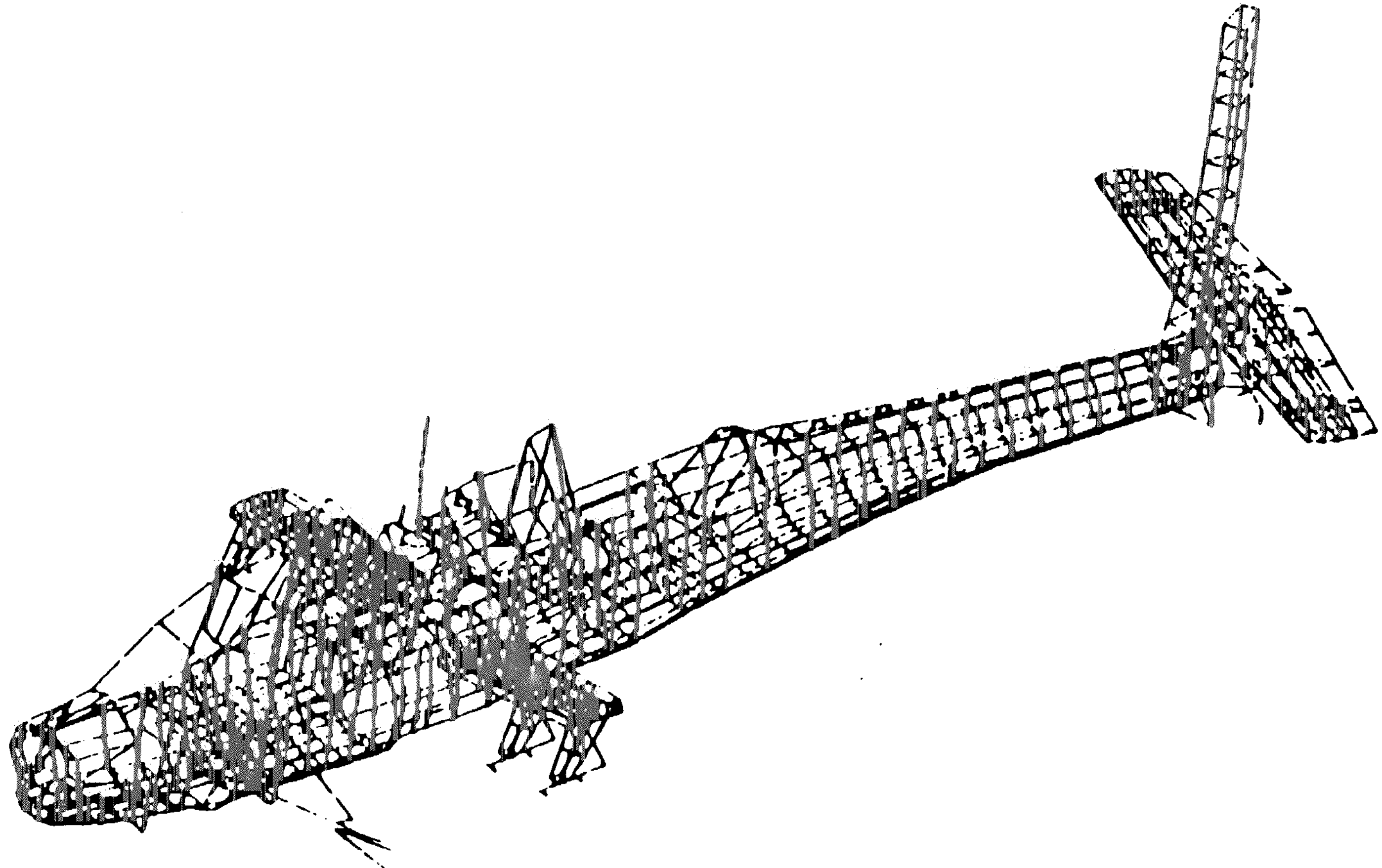

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Figure 6. AAH Dynamic NASTRAN Model Second Vertical Bending Mode (22.3 Hz)

TABLE 2. AAH DYNAMIC NASTRAN MODEL MODE IDENTIFICATION SHOWING COMPARISON WITH TEST DATA

NASTRAN MODE NO.	NASTRAN FREQUENCY	DESCRIPTION	TEST MODE, FREQUENCY
13	4.08	LAT/TORSION	LAT/TOR 4.59
14	4.70	SYM WING BEND	
17	5.17	VERT + ENG	
20	5.40	ANTI/SYM WING BEND	
21	5.55	1ST VERT	VERT 5.76
25	6.83	WING/TOR	
28	7.59	ANTI/SYM WING/PYLON TOR	
30	7.81	SYM WING TOR	
31	7.91	SYM WING/PYLON TOR	
33	8.85	1ST LAT BEND	1ST LAT BEND 9.37
35	9.30	VERT + TAIL	
47	12.2	STAB YAW	
49	12.5	STAB YAW	
53	13.5	WING RIGID BODY	
57	14.2	WING TOR ROLL	
59	14.3	WING TOR ROLL	
60	14.5	WING SYM	
63	15.7	STAB ROLL	
64	15.8	STAB/WING ROLL	
66	16.4	STAB YAW	
69	17.3	TAIL/STAB MODE	
74	18.7	VERTICAL	
75	18.97	2ND VERT	2ND VERT 19.39
78	20.2	LAT/TOR WING/STAB	
81	21.2	2ND LAT/TOR	2ND LAT/TOR 20.6
85	22.3	VERT + STAB	
86	22.7	TAIL/STAB	

820056-1A

DISCRETE

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{f(t)\} = \{F_e^{i\omega t}\}$$

$$\text{LET} \quad \{X\} = [\phi]\{q\} \; ,$$

$$\{\dot{X}\} = [\phi]\{\dot{q}\} \; , \quad \dot{q} = i\omega q$$

$$\{\ddot{X}\} = [\phi]\{\ddot{q}\} \; , \quad \ddot{q} = -\omega^2 q$$

MODAL (GENERALIZED COORDINATES)

$$\{q_o\} = \underbrace{\left[\lceil 1 \rfloor - \left[\left(\frac{\omega}{\omega_N} \right)^2 \right] + i \left[\left(\frac{\omega}{Q\omega_N} \right) \right] \right]^{-1}}_{[T_P]} \left[\omega_N^2 \right]^{-1} \lceil M \rfloor^{-1} [\phi]^T \{F_o\}$$

$$\underset{87 \times 1}{\{q_o\}} = \underset{87 \times 87}{\lceil T_P \rfloor} \; \underset{87 \times 87}{\lceil \omega_N^2 \rfloor^{-1}} \; \underset{87 \times 87}{\lceil M \rfloor^{-1}} \; \underset{87 \times 1}{[\phi]^T} \; \underset{1 \times 1}{\{F_o\}}$$

COMPLEX MODAL RESPONSE

COMPLEX DISCRETE RESPONSE

$$\underset{1 \times 1}{\{X\}} = \underset{1 \times 87}{[\phi]} \; \underset{87 \times 1}{\{q\}} \qquad \text{MODAL SUMMATION} \qquad (1)$$

$$\left\{ X \right\}_{87 \times 1} = \left\{ \phi^T \right\}_{87 \times 1} \; \text{EXE} \; \left\{ q \right\}_{87 \times 1} \qquad (2)$$

$$X_{TOTAL} = \sum_{i=1}^{m} X_i = \sum_{i=1}^{m} \phi_i \, q_i \qquad (3)$$

Figure 7. Dynamic NASTRAN Dynamic Equations

```
NASTRAN(P10,MR01400,CM250000,L020)
ACCOUNT(C1556A,RANDD)
CID(G PARKER)
BANNERS(OP-SDT)*AAH FREQ*RESPONSE*MSC83R*
FORMATL.DEST-PR453,SYS-A,RECIP-'G PARKER K20-2'
*****************************************
*  NASTRAN INPUT FILE - MSC83R
*  DEF OUT FILE - OMSC83R
*  DAYFILE FILE - DMSC83R
*  RESTART TFN - MSC1
*****************************************
BANNERS.*INPUT*
REWIND,INPUT.
COPYSBF,INPUT.
REWIND,INPUT.
SKIPR,INPUT.
BANNERS.*END OF INPUT*
*********************************************
SYSCALL(MNASTRN/NONOTES,VERSION-61B,NOSCAN,CTM,RESTART-TAPE,
RTFN-AD25,RLABEL-AD25,RID-AD25,RFILES-$OPTP,PUNCH$)
GOTO(1HOST)
EXIT.
 1HOST,*
SYSCALL(ROUTE/SAVE,PFN-OMSC83R)
DAYFILE(DMSC83R)
REPLACE(DMSC83R)
RETURN,PUNCH.
/EOR
NASTRAN FILES-(OPTP)
ID FREQ DYNAMIC
TIME 20
DIAG 8,19,22
SOL 30
$READ DICT
$********************************************
$     DMAP ALTER TO CALCULATE FREQUENCY RESPONSE
$     CONTRIBUTION PER MODE
$
$     INPUTS
$     SEE BULK DATA SECTION FOR
$     PROGRAM INPUTS
$********************************************
ALTER 572
$
$  PRINT FREQUENCY TABLE
$
OFP     LAMA// $                                      <- NOTE
$
$ EXTRACT PILOT SEAT MODESHAPES (6 DOF G-SET)
$
PRTPARM // $
MATMOD     EQEXIN,USET,SIL,CASECC,,/VECX,/17/0/1/S,N,NOVEC $
PARTN     PHIGH,,VECX/,PHIP,,/1/0/ $
MPYAD     C6,PHIP,/ZPS/1 $
TRNSP     ZPS/ZPST $
MATPRN    ZPST//$
$
$  PRINT NORMALIZED MODESHAPE
$
NORM      ZPST/ZPSN $
MATPRN    ZPSN//$                                     <- NOTE
$
```

```
$  EXPAND MODE TO NUMBER OF CASES
$
MATGEN    ,/IC/1/C,Y,NCASE $
MATMOD     IC,,,,,/R3,/7 $
TRNSP      R3/C3 $
MPYAD     ZPST,C3,/ZPST3 $
$
$  FORM COMPLEX CONJUGATE OF ETA
$
MATMOD  UHV1,,,,,/ETAM,/10 $
ADD     UHV1,ETAM/TETA///1  $
DIAGONAL    TETA/TETAM/UHOLE/0.5 $
MATPRN  TETAM//$
$
NORM     TETAM/TETAMN $
MATPRN   TETAMN//$                                    <- NOTE
$
$  FORM PHI X ETA
$
ADD    ZPST3,UHV1/TOT///1 $
MATPRN    TOT//$
$  FORM COMPLEX CONJUGATE
MATMOD TOT,,,,,/TOTC,/10 $
ADD     TOT,TOTC/TOTMD///1 $
$
$  SQUARE ROOT
$
DIAGONAL    TOTMD/TOTM/UHOLE/0.5 $
MATPRN    TOTM//$                                     <- NOTE
NORM    TOTM/TOTMN $
MATPRN    TOTMN// $
$
$  SUM MODES
$
MATGEN    ,/IDENT/1/C,Y,LMODES $
MATMOD     IDENT,,,,,/COL,/7 $
MPYAD    COL,TOT,/SUM/1 $
MATPRN    SUM//$
$
$  FORM  PHI X ETADD
$
ADD       ZPST3,UHV1/TOTA/C,Y,U2//1 $
MATPRN    TOTA// $
$
$  FORM COMPLEX CONJUGATE
$
MATMOD TOTA,,,,,/TOTAC,/10 $
ADD     TOTA,TOTAC/TOTMDA///1 $
$
$  SQUARE ROOT
$
DIAGONAL    TOTMDA/TOTMA/UHOLE/0.5 $
MATPRN    TOTMA//$                                    <- NOTE
NORM    TOTMA/TOTMAN $
MATPRN    TOTMAN// $
$
$  SUM MODES
$
MPYAD    COL,TOTA,/SUMA/1 $
MATPRN   SUMA//$
EXIT $
CEND
TITLE - AAH FREQUENCY RESPONSE / MODE CHECK
```

Figure 8. Modal Frequency Response Contribution Per Mode DMAP

```
         SUBTITLE = RESTART FROM AD25 TAPE
         ECHO = NOSORT
         $  **********************************
         $   SET 1 VALUE EXTRACTS 6 DOF FOR
         $   GRID POINT LISTED
INPUT -> SET 1 = 10013
         $  **********************************
         PARTN = 1
         SET 90 = 54,10013,54712
         METHOD=100
         DYNRED=200
         MPC = 10
         SDAMP1=10
         FREQ = 100
         $
         SET 30 = 54
         SET 50 = 54712
         $
         DISPL   = 90
         ACCEL   = 90
         SACCEL   = ALL
         SDISPL   = ALL
         $
         SUBCASE 3000
         LABEL = FOR 4P FZ = 1000 LBS. AT HUB NODE 54
         DLOAD = 3000
         OLOAD = 30
         $
         SUBCASE 5000
         LABEL = FOR 4P FZ = 1000 LBS. AT TAIL NODE 54712
         DLOAD = 5000
         OLOAD = 50
         $
         BEGIN BULK
         $  ********************************
         $  NOTE- CARDS IN THIS SECTION ARE INPUTS TO
         $        THE DMAP, AND MUST BE SET FOR EACH
         $        PROBLEM
         $
         $ SECOND DMI CARD WITH VALUE OF 3
         $ INDICATES RESPONSE BE CALCULATED
         $ FOR THE Z-DIRECTION.  THIS VALUE
         $ CAN BE 1-6 FOR X,Y,Z,TX,TY,,TZ
         $ RESPECTIVELY
         DMI,C6,0,2,1,1,,6,1
INPUT -> DMI,C6,1,3,1.0
         $
         $ NCASE = NUMBER OF SUBCASES
INPUT -> PARAM,NCASE,2
         $
         $ W2 VALUE= - W2(FORCING FREQUENCY, RAD/SEC2)
         $ NOTE W2 VALUE IS A COMPLEX NUMBER
INPUT -> PARAM,W2,-14027.57,0.0
         $
         $ NOTE- SET 1 CARD IN CASE CONTROL
         $ IS SET TO DESIRED GRID POINT WHERE
         $ RESPONSE IS TO BE CALCULATED
         $  **********************************
         $
         $ THE FOLLOWING BULK DATA ARE STANDARD
         $ CARD INPUTS FOR MODAL FORCED RESPONSE
         PARAM,DDRMM,0
         PARAM,LMODES,87
         FREQ,100,18.85
         TABDMP1,10,,,,,,,,+TBD10
         +TBD10,0.5,.04,30.0,.04,ENDT
         $
         TABLED1,111,,,,,,,,+T111
         +T111,0.0,0.0,10.65,0.,10.66,1.,19.04,1.,+T112
         +T112,19.05,0.0,ENDT
         $
         DLOAD,3000,1.0,1000.0,3
         RLOAD1,3,33,,,111
         DAREA,33,54,3,.2588-2
         $
         DLOAD,5000,1.0,1000.0,5
         RLOAD1,5,55,,,111
         DAREA,55,54712,3,.2588-2
         $
         ENDDATA
         $
```

Figure 9. Modal Frequency Response Contribution Per Mode DMAP

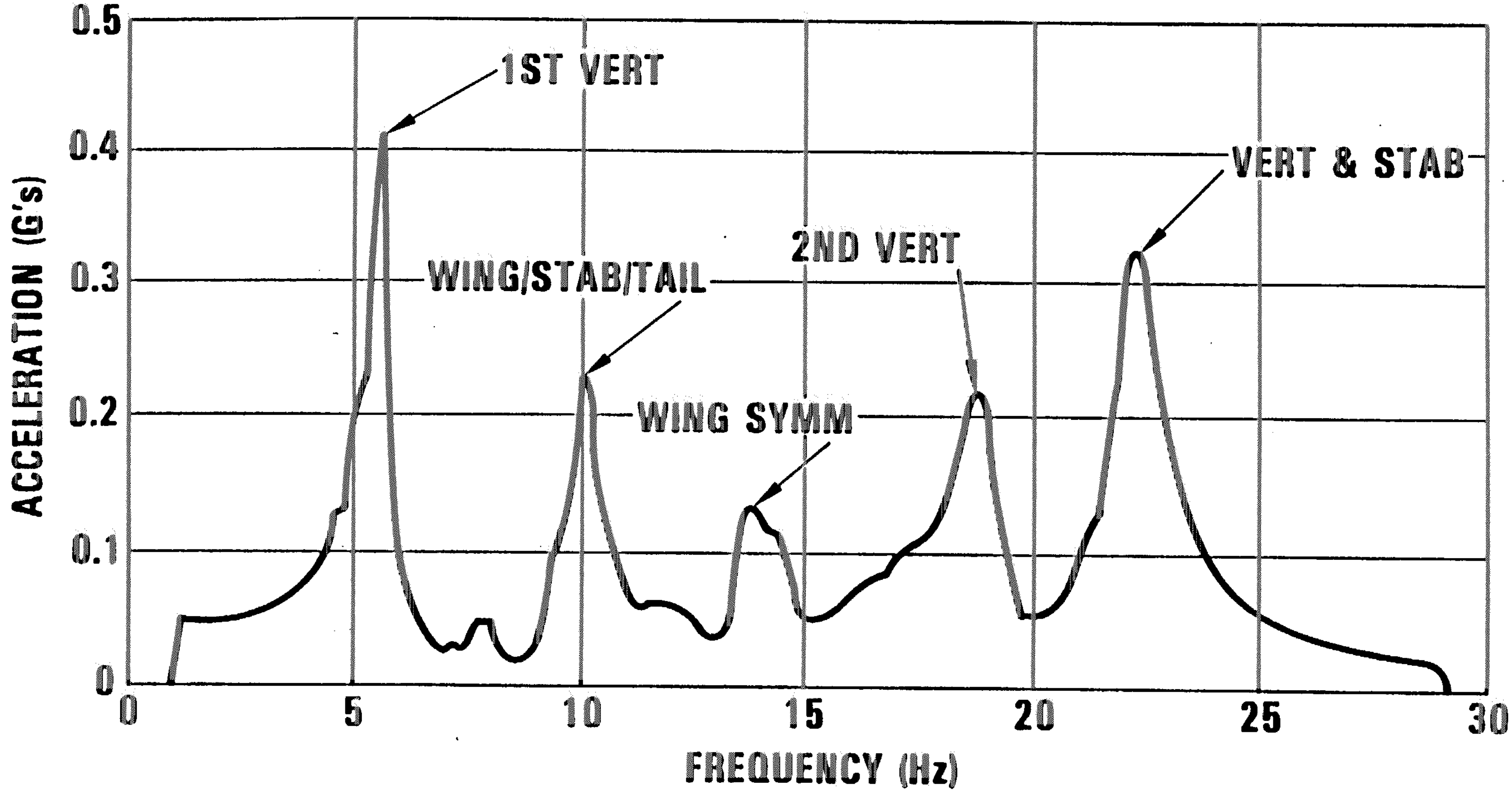

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Figure 10. AAH Dynamic NASTRAN Model Frequency Sweep Showing Response at Pilot's Seat Due to Excitation at Tail

TABLE 3. DYNAMIC NASTRAN MODAL FREQUENCY RESPONSE ANALYSIS

C O M P L E X   A C C E L E R A T I O N   V E C T O R   (SOLUTION SET)
(REAL/IMAGINARY)

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	M	1.408802E-04	3.206251E-02	-1.266728E-02	-1.584343E-02	-1.318453E+00	-5.407066E-01
		5.833394E-11	1.836955E-08	-8.971534E-09	-2.163830E-08	-4.545936E-06	-1.936426E-06
7	M	-5.096182E-05	-1.170967E-03	1.972044E-03	1.132520E-03	-6.949435E-05	-6.267619E-07
		-2.780459E-07	-7.466693E-06	1.310463E-05	7.604055E-06	-4.929592E-07	-4.445960E-09
13	M	2.668100E-03	-9.711008E-02	-4.117037E-03	1.785697E-01	-4.009815E-01	5.495019E-02
		2.427537E-05	-1.033987E-03	-4.456117E-05	2.096593E-03	-4.755020E-03	6.572737E-04
19	M	-2.169022E-01	1.248664E-02	-8.372275E-01	3.812314E-03	1.905385E-02	1.114313E-02
		-2.625904E-03	1.559828E-04	-1.080526E-02	5.457644E-05	2.991339E-04	1.641119E-04
25	M	2.117021E-04	-8.409160E-03	-2.163489E-02	3.695763E-04	5.332581E-03	2.388587E-02
		3.533281E-06	-1.462658E-04	-3.776798E-04	7.115326E-06	1.049429E-04	4.782782E-04
31	M	-1.267217E-01	-3.037973E-02	1.734037E-02	9.629617E-02	6.357238E-01	-5.227338E-02
		-2.583655E-03	-6.311142E-04	4.151743E-04	2.384407E-03	1.657244E-02	-1.485970E-03
37	M	-7.633489E-01	2.347115E-01	2.526677E-02	-1.187755E-01	-2.116510E-03	-1.369042E-02
		-2.281154E-02	7.156248E-03	6.450440E-04	-4.124452E-03	-7.468695E-05	-4.945242E-04
43	M	3.555234E-02	-3.738940E-02	-5.362630E-02	9.124712E-04	-4.205567E-03	6.041088E-02
		1.342079E-03	-1.470207E-03	-2.281030E-03	4.022980E-05	-1.873165E-04	2.815060E-03
49	M	3.053847E-03	-2.033576E-02	-1.738341E-01	1.065681E-01	-5.657314E-01	3.491734E-02
		1.452975E-04	-1.031282E-03	-1.004981E-02	6.237596E-03	-3.323980E-02	2.196170E-03
55	M	6.817407E-02	1.564360E-01	-1.341251E-01	1.236751E-01	-7.257126E-02	-1.050251E-01
		4.397839E-03	1.078465E-02	-9.412735E-03	8.728679E-03	-5.274594E-03	-8.034523E-03
61	M	2.875370E-02	-9.902904E-02	-1.778723E-01	1.849171E-03	7.563513E-03	-6.349685E-03
		2.689651E-03	-9.506251E-03	-1.991099E-02	2.152962E-04	9.681246E-04	-9.251840E-04
67	M	7.654929E-02	-6.306015E-03	-4.365845E-03	-1.018355E-01	2.212055E-01	1.812456E-01
		1.208314E-02	-1.372581E-03	-1.083911E-03	-2.670757E-02	5.977332E-02	1.041907E-01
73	M	7.726559E-01	-8.909719E-01	-1.535315E+00	-4.381344E-02	-1.820643E-01	3.263200E-01
		9.005753E-01	-3.790209E+00	4.704655E+00	2.221796E-02	6.056388E-02	-9.262296E-02
79	M	1.635985E-02	1.020797E-01	7.307423E-02	1.850494E-02	6.095145E-02	-6.082948E-02
		-3.186105E-03	-1.769188E-02	-1.224010E-02	-2.912429E-03	-8.708437E-03	7.835138E-03
85	M	3.528446E-01	4.298734E-02	1.233908E-02			
		-4.179560E-02	-4.556823E-03	-1.207814E-03			

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TABLE 4. DYNAMIC NASTRAN MODAL FREQUENCY RESPONSE ANALYSIS

AAH FREQUENCY RESPONSE / MODE CHECK
RESTART FROM AD25 TAPE

MARCH 28, 1983 NASTRAN 12/14/81

FOR 4P FZ = 1000 LBS. AT TAIL NODE 54712
FREQUENCY = 1.885000E+01

SUBCASE 5000

C O M P L E X A C C E L E R A T I O N V E C T O R
(REAL/IMAGINARY)

	POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
	54	G	1.512239E-01	2.081894E-02	-5.219275E-02	-4.189949E-04	5.968174E-03	2.127246E-04
			-1.392614E-02	4.958088E-02	5.757180E-02	-2.414039E-03	4.399776E-03	-6.687746E-04
PILOT SEAT →	10013	G	-1.459833E-02	-1.213395E-03	-8.540148E-02	3.323403E-05	-4.750295E-04	1.896063E-04
			-2.991421E-01	6.477760E-03	2.053571E-01	-4.953487E-05	4.305886E-03	-6.682004E-04
	54712	G	3.280976E-02	1.907732E-02	1.442403E+00	0.0	0.0	0.0
			-3.133969E-01	1.481826E-02	6.611448E-01	0.0	0.0	0.0

TABLE 5. DYNAMIC NASTRAN MODAL FREQUENCY RESPONSE ANALYSIS

AAH FREQUENCY RESPONSE / MODE CHECK
RESTART FROM AD25 TAPE

MATRIX ZPSN (GINO NAME 101) IS A REAL 1 COLUMN X 87 ROW RECTANG MATRIX.

COLUMN 1 ROWS 1 THRU 87

ROW										
1)	8.6473E-01	1.0000E+00	4.6657E-01	-7.8704E-02	2.7189E-01	7.2408E-02	2.7964E-05	6.3521E-04	-8.8450E-04	-1.0639E-03
11)	-8.0171E-05	6.4390E-05	-1.0238E-02	-1.0017E-01	1.8669E-03	8.3999E-02	-1.0485E-01	1.2218E-02	-2.9061E-02	-1.5111E-02
21)	-1.7139E-01	4.0826E-03	9.9303E-03	3.6915E-06	-2.5443E-03	-4.3860E-02	-6.1289E-02	8.1181E-03	1.0122E-02	-1.5383E-02
31)	1.7124E-01	2.7404E-02	-2.4163E-02	5.6960E-03	5.7975E-02	1.0784E-01	1.4685E-01	8.5533E-03	-3.7397E-02	-4.9452E-02
41)	-1.4179E-05	8.9547E-03	-6.8971E-02	7.1415E-02	-4.4750E-02	7.4259E-03	6.6571E-02	6.5602E-02	9.4345E-03	-3.2040E-02
51)	-6.4236E-02	-1.8154E-01	8.4719E-02	2.8998E-02	9.6125E-02	1.6542E-01	9.9032E-02	-3.0783E-02	-6.4009E-02	-4.3443E-01
61)	6.7608E-03	-3.7126E-02	8.2515E-03	3.1683E-02	2.3827E-02	-1.5499E-02	1.6231E-01	4.7628E-03	1.4119E-02	-2.2733E-02
71)	1.4435E-01	4.3671E-02	8.5817E-02	-1.0931E-01	2.1629E-01	1.8624E-02	8.2138E-02	-6.5891E-02	-1.2998E-01	-1.1300E-01
81)	-3.4094E-02	-3.9672E-02	-7.7608E-02	1.3541E-01	-6.7059E-01	-9.7823E-02	1.1194E-01			

TABLE 6. DYNAMIC NASTRAN MODAL FREQUENCY RESPONSE ANALYSIS

AAH FREQUENCY RESPONSE / MODE CHECK
RESTART FROM AD25 TAPE

MARCH 28, 1983 NASTRAN 12/14/81

MATRIX TOTMA (GINO NAME 101) IS A REAL 2 COLUMN X 87 ROW RECTANG MATRIX.

COLUMN 1 ROWS 1 THRU 87 --

ROW										
1)	2.8980E-02	3.8878E-02	8.9772E-03	2.5680E-04	2.7092E-03	4.2804E-04	2.4139E-12	1.3090E-09	1.4973E-09	7.3784E-08
11)	2.1029E-10	9.4429E-12	3.6310E-07	2.5043E-04	7.5217E-08	5.8839E-05	4.8410E-04	7.7571E-06	1.3721E-04	5.6809E-06
21)	2.6225E-03	1.5372E-07	3.9637E-06	1.6264E-09	5.0390E-07	5.8924E-06	1.0929E-04	2.0389E-06	3.4397E-06	1.2870E-05
31)	7.7815E-04	3.8496E-05	1.8209E-05	1.0398E-05	2.6591E-04	6.9841E-04	3.2545E-03	2.3822E-06	3.4443E-05	4.7217E-04
41)	4.4516E-10	5.7943E-06	4.5553E-04	5.0311E-04	1.2251E-04	5.1710E-06	3.5673E-04	4.2485E-05	9.0904E-06	1.9053E-04
51)	5.6110E-04	3.6021E-03	1.7931E-03	8.7041E-05	6.4623E-05	7.1542E-03	1.4725E-03	2.4355E-04	1.4355E-03	2.5238E-02
61)	6.0842E-06	4.3076E-04	5.2052E-06	1.8347E-04	6.8290E-05	4.4592E-05	2.1963E-04	3.7934E-06	9.7132E-05	1.1619E-04
71)	4.9196E-03	4.8484E-04	1.4970E-03	6.6275E-03	1.0609E-02	1.9530E-04	5.4395E-05	7.3527E-05	2.0574E-03	2.4573E-04
81)	2.2585E-05	2.9275E-05	1.7793E-04	9.9003E-04	1.6387E-02	4.6831E-04	1.2509E-03			

COLUMN 2 ROWS 1 THRU 87 --

ROW										
1)	1.5921E-05	4.1902E-03	7.7239E-04	1.6296E-04	4.6849E-02	5.1167E-03	1.8624E-10	9.7209E-08	2.2796E-07	1.5747E-07
11)	7.2814E-10	5.2744E-12	3.5699E-06	1.2713E-03	1.0045E-06	1.9604E-03	5.4940E-03	8.7748E-05	8.2384E-04	2.4660E-05
21)	1.8754E-02	2.0343E-06	2.4731E-05	5.3766E-09	7.0403E-08	4.8208E-05	1.7332E-04	3.9217E-07	7.0555E-06	4.8030E-05
31)	2.8365E-03	1.0882E-04	5.4774E-05	7.1704E-05	4.8183E-03	7.3699E-04	1.4656E-02	2.6249E-04	1.2356E-04	7.6809E-04
41)	3.9244E-09	1.6032E-05	3.2069E-04	3.4923E-04	3.1390E-04	8.8640E-07	3.6625E-05	5.1849E-04	3.7758E-06	8.5261E-05
51)	1.4618E-03	2.5327E-03	6.2745E-03	1.3259E-04	8.5821E-04	3.3899E-03	1.7402E-03	4.9879E-04	6.0867E-04	5.9802E-03
61)	2.5516E-05	4.8270E-04	1.9301E-04	7.7085E-06	2.3744E-05	1.2997E-05	1.6439E-03	4.0171E-06	8.3024E-06	3.1278E-04
71)	4.3227E-03	1.1932E-03	1.3308E-02	5.5622E-02	1.3989E-01	1.1956E-04	2.0597E-03	2.9210E-03	2.8313E-04	1.5299E-03
81)	3.3013E-04	9.7123E-05	6.2448E-04	1.0854E-03	3.1139E-02	5.5264E-04	1.8938E-04			

THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN = 87

THE DENSITY OF THIS MATRIX IS 100.00 PERCENT.
*8** MODULE NORM - DNAP 572 - MATRIX TOTMAN - COLS= 2, ROWS= 87, FORM= 2, TYPE=1, NZWDS= 87, DEN=1.0000, BLKS= 1 *

TABLE 7. DYNAMIC NASTRAN MODAL FREQUENCY RESPONSE ANALYSIS

```
AAH FREQUENCY RESPONSE / MODE CHECK                                   MARCH  28, 1983   NASTRAN 12/14/81
RESTART FROM AD25 TAPE

    MATRIX SUMA      (GINO NAME 101 ) IS A COMPLEX        2 COLUMN X       1 ROW RECTANG  MATRIX.

COLUMN       1       ROWS       1 THRU       1       --------------------------------------------------
   ROW
    1)  9.6061E-02, 2.1326E-02

COLUMN       2       ROWS       1 THRU       1       --------------------------------------------------
   ROW
    1) -8.5401E-02, 2.0536E-01

THE NUMBER OF NON-ZERO TERMS IN THE DENSEST COLUMN =        1

THE DENSITY OF THIS MATRIX IS 100.00 PERCENT.
```

TABLE 8. DYNAMIC NASTRAN MODAL FREQUENCY RESPONSE ANALYSIS

RSS MAGNITUDE (Gs)

	Fz AT HUB	MODE #	FREQ Hz	Fz AT TAIL	MODE #	FREQ Hz
1	2.52 E-02	60	14.56	1.40 E-01	75	18.97
2	1.64 E-02	85	22.30	5.56 E-02	74	18.76
3	1.06 E-02	75	18.97	3.11 E-02	85	22.30
4	7.15 E-03	56	14.16	1.87 E-02	21	5.55
5	6.63 E-03	74	18.76	1.47 E-02	37	10.07
6	4.92 E-03	71	17.51	1.33 E-02	73	18.53

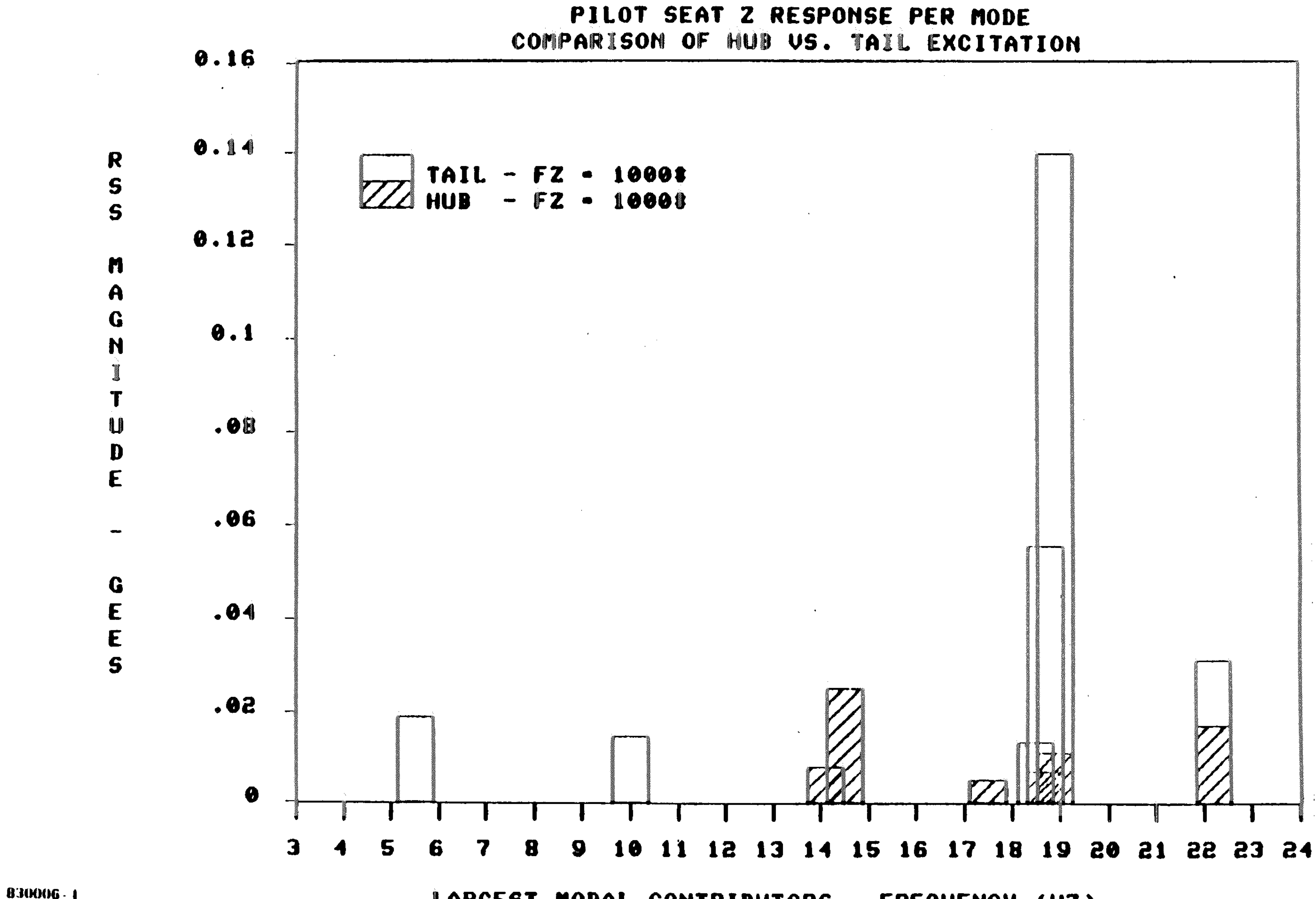

Figure 11. Dynamic NASTRAN Modal Frequency Response Analysis