NASTRAN MAINTENANCE AND

ENHANCEMENT EXPERIENCES

Ronald P. Schmitz

Sperry Rand Corporation

ABSTRACT

This paper describes Sperry Support Services' recent experiences in maintaining and enhancing the NASTRAN Program. The Sperry Version of NASTRAN started with the adoption of Level 15.1.2 (NSRDC) in 1972 and has evolved through a series of program improvements and error corrections. The current capability, which has been added to Level 15.5, includes isoparametric elements, optimization of grid point sequencing and new eigenvalue routine. Overlay and coding errors were corrected for cyclic symmetry, transient response and differential stiffness rigid formats.

In addition to maintaining a Sperry version of NASTRAN, we are also publishing a newsletter quarterly, providing user training to world wide UNIVAC users and maintaining and developing a set of NASTRAN pre and post processors which include mesh generators and interactive graphics.

The enhancement of NASTRAN is a continuing effort with a primary motivation of providing state-of-the-art analytical capability to in-house analysts, and to offer Sperry UNIVAC and its customers a source for error corrections and program enhancements in a continuous and timely manner. Developments scheduled for the current year are described in the paper as well as a brief description of analyses being performed using the program.

INTRODUCTION

Although Sperry has been a user of finite element programs dating back to early versions of SAMIS (reference 1) and the initial release of NASTRAN, our interest in maintaining and enhancing a local version is of more recent origin. The Sperry version of NASTRAN started with the adoption of Level 15.1.2 (reference 2) in 1972 and has evolved since that time through a series of program improvements and error corrections. Our early work was performed on both UNIVAC and CDC versions. In recent years, a natural emphasis upon developments for the UNIVAC computer systems has occurred through our association and cooperation with other divisions of the Sperry Rand Corporation.

The enhancement of NASTRAN is a continuing effort with a primary motivation of providing state-of-the-art analytical capability to in-house analysts, and to offer Sperry UNIVAC and its customers a source of error corrections and program enhancements in a continuous and timely manner. In addition to maintaining a Sperry Version of NASTRAN, we are also publishing a Newsletter quarterly, (reference 3, 4, and 5), providing user training to world wide UNIVAC users and maintaining and developing NASTRAN pre and post processors which include mesh generators and interactive graphics.

The association and cooperation with Sperry UNIVAC has resulted in a two way exchange of new routines and error corrections; and Sperry Support Services has acted as a focal point for the Corporation, bringing together the experiences of many domestic divisions and foreign subsidiaries.

ERROR CORRECTION EXPERIENCES

Any in-house programming effort with NASTRAN invariably begins with error corrections. Error corrections account for 25 percent of all NASTRAN programming efforts at Sperry. These involve:

- Implementing corrections obtained from NSMO via the SPR LOG and Newsletters.

- Independently locating and correcting errors existing in Level 15.5.

- Locating and correcting errors in the Sperry enhanced Level 15.6.

In the period January to May 1975, Sperry has made 17 error corrections. Five of these errors were found in the original Level 15.5 and the remaining errors were found in new code implemented in the Sperry Version 15.6.

These errors are briefly described in Table I, and do not include corrections obtained from NSMO SPR LOG or Newsletters, since these sources of corrections were implemented prior to January 1975.

Our experience with Level 15.5 error corrections shows that overlay errors account for most of the remaining errors and since many of the overlay errors do not exist in CDC or IBM versions, it is our conclusion that past NSMO maintenance of NASTRAN has not done a thorough job in checking the UNIVAC version overlay structure. On the other hand, the inclusion of a reverse trace of subroutine calls has been a significant help in locating many of the overlay problems.

CURRENT CAPABILITIES

The current capabilities of Sperry Version NASTRAN, structured around the standard COSMIC release Level 15.5, are summarized as follows:

- Isoparametric Elements - Four isoparametric elements, two surface elements and an independent thermal analysis capability (Rigid Format 14) originally developed by NSRDC (reference 6), have been installed. These elements have been utilized extensively since 1972 for the analyses of high energy laser and large space telescope mirrors, shown in Figures 1 and 2. The thermal analysis capabilities were compared with the CINDA thermal analyzer (reference 7) and published at the 5th Navy NASTRAN Colloquium (reference 8). Figure 1 also illustrates a comparison of CINDA and Sperry NASTRAN Thermal Analyzers.

  The implementation of this capability into Level 15.5 required the addition of 103 new subroutines, and 113 modified subroutines requiring over 4000 Fortran update cards. Since the basic capability already existed in Level 15.1, the major programming effort required updating data block tables and correcting any conflicts between the isoparametric elements and the improvements implemented by NSMO between 15.1 and 15.5.

- LINK0 - Many users operate at computer installations where the cost algorithms include the number of input card images read. The conventional "CONTRL" file can introduce many hundreds of data cards during the execution of a rigid format. LINK0 was developed to eliminate the large number of input cards and automatically generate the necessary @XQT instruction for each succeeding link. A typical NASTRAN run stream becomes:

```
@XQT *NASTRAN.LINK1
ID A,B
   .
   .
   .
ENDDATA
@XQT *NASTRAN.LINK0
```

- Improved LINK1 - The BANDIT and WAVEFRONT procedures (references 9 and 10) were added to LINK1 overlay to permit automatic grid point resequencing to minimize the stiffness matrix decomposition time. Resequencing is requested through the NASTRAN card. Either method may be selected separately or both may be used. The sequencing resulting in the minimum decomposition time is automatically inserted into the data deck. All of the normal options of BANDIT and WAVEFRONT have been retained through the use of control cards containing a $ in column 1.

- Plot Tape Parity Option - Many UNIVAC users, especially those operating on 1110 systems, often find it necessary to generate plot tapes, PLT1 or PLT2, in odd or even parity. A program change was made in SGINO, and a new data card added to the case control deck to permit the selection of tape parity from within the NASTRAN plot data deck (case control) e.g.,

```
@AST,T PLT2,20N
    .
    .
PLOTID = NAME, LOCATION
OUTPUT (PLOT)
PLOTTER CALCOMP
PLT2 EVEN
```

This run stream will mount a 9 track tape for the CALCOMP plot tape. All plot commands will be written in odd parity.

• Rayleigh-Ritz with Stadola Iteration Eigenvalue Routine - A new eigenvalue routine was added to NASTRAN. The formulation was based on work performed by J. R. Admire, reference 11. The procedure had previously been implemented in the FORMA (reference 12) and SPAR (reference 13) programs and is, therefore, well established as a fast and accurate technique. Figure 3 illustrates the basic equations used in the formulation. Capability to solve symmetric and unsymmetric matrices has been included, and the Input Data Card EIGR was modified for use with the procedure and is illustrated in Figure 4.

The size of the analysis set (A-set) is limited only by the core required for matrix decomposition. Several test problems have shown the technique to be at least three times faster than the Inverse Power method.

Some statistics on the changes required for the Rayleigh-Ritz routines are:

- Seven new subroutines added

- Special logic for selecting FBS or INVFBS routines

- A new incore inversion routine added

- Stadola and Jacobi incore eigenvalue routines were added

- Programming effort was approximately 3 months

- Subroutines were modified to accept the changes to the EIGR cards.

OTHER ACTIVITIES

Sperry has gone beyond normal program maintenance and improvements by publishing a NASTRAN newsletter, providing user training, and developing pre and post processors. The newsletters are similar to the NSMO newsletter. Publication started in September 1974 and we plan to continue publishing one every 3 or 4 months. The objective of the newsletter is to provide Sperry UNIVAC customers with timely information on the development of new capabilities, current developments, error corrections and user's experiences.

The user's contributions published in the newsletters are chosen to illustrate new capabilities incorporated in the Sperry version or to illustrate a solution to a UNIVAC users' problem which Sperry feels may be of general interest to the user community. Past papers have included examples in the use of the thermostructural rigid format 14, cyclic symmetry, and buckling analyses using conical shell elements.

NASTRAN short courses have been taught in the United States and in Europe for users of the Sperry version of NASTRAN. This writer has found the European NASTRAN user to be very competent. In general they are analyzing large structures (e.g., automobile bodies, off shore oil rigs and ship structures) utilizing substructuring, cyclic symmetry, DMAP alters and DMAP programs. Their major limitations are the high cost of computer time and the failure of management to recognize the value of finite element analyses or to allow sufficient budgeting for large scale problem solution.

The development of pre and post processors is also being undertaken at Sperry. The current trend in the development of these programs is to include the capability to work with more than one finite element program. The GEOMPLT program (reference 14) is an interactive graphics program which was initially developed to graphically display and edit NASTRAN Bulk Data. It has since been modified to work with SPAR and ICES/STRUDL (reference 15) data as well. The ICES/TOPOLOGY mesh generation subsystem (reference 16) is currently being modified to output NASTRAN data. This approach has been taken to give the Sperry analysts additional flexibility in problem solution.

FUTURE DEVELOPMENT

The list of current development priorities for the Sperry Version of NASTRAN are:

• Automated Substructuring

• Contour Plotting added to the PLOT module

• Improved I/O

• Improved matrix decomposition

• Improved matrix multiplication

• New modal shock response rigid format

• Non-linear shell analysis

• Post-buckling rigid format

• New elements including pipe bends, and rigid elements.

Due to the leasing policy and export restrictions placed on post 15.5 NSMO improvements, all of the future development improvements will be added to the 15.5 program structure. Further, it will be necessary to duplicate existing capabilities such as automated substructuring instead of investing our resources

in new enhancements of mutual benefit to NASA and Sperry. It is recommended that NASA consider alternatives to the current policies. In the past, the NASTRAN program has gained a reputation for being a low cost general purpose structures program with excellent documentation and on-going maintenance. For this reason a large number of companies large and small have adopted the program. The return on the tax payers investment should not be measured only by the monetary return or even the direct benefit derived by NASA projects, but by the greater productivity derived from its use by commercial companies, the excellent information exchange obtained from its common use, and finally the positive effect on the export sale of large scale computer systems.

REFERENCES

1. Melosh, R. J., et al, "Structural Analysis and Matrix Interpretive System (SAMIS) Program Report," NASA JPL Report TM 33-307, Rev. 1, December 1966.

2. McCormick, C. W., Editor, "The NASTRAN USER'S Manual (Level 15.0)," NASA SP-222(01), May 1973.

3. "Sperry NASTRAN Newsletter," Number 1 Sperry Support Services, Huntsville, Alabama, October 10, 1974.

4. "Sperry NASTRAN Newsletter," Vol. 2, No. 1, Sperry Support Services, Huntsville, Alabama, February 1, 1975.

5. "Sperry NASTRAN Newsletter," Vol. 2, No. 2, Sperry Support Services, Huntsville, Alabama, June 6, 1975.

6. Hurwitz, M. M., "Additions to the NASTRAN User's Manual and Theoretical Manual for a Thermostructural Capability for NASTRAN using Isoparametric Finite Elements," NSRDC Report 4134, Bethesda, Maryland, May 1973.

7. Gaski, J. D., Lewis, D. R. and Thompson, L. R., "Chrysler Improved Numerical Differencing Analyzer for Third Generation Computers," TN-AP-67-287, October 20, 1967.

8. Proceedings of the Fifth NAVY-NASTRAN Colloquium," NSRDC Report CMD-32-74, September 1974.

9. Everstine, G. C., "The Bandit Computer Program for the Reduction of Matrix Bandwidth for NASTRAN," NSRDC Report 3827, March 1972.

10. Levy, R., "Structural Stiffness Matrix Wavefront Resequencing Program (WAVEFRONT), JPL, Pasadena, California. (Cosmic Report NPO-13322).

11. Admire, J. R., "Modal Analysis of Substructures by an Iterative Rayleigh-Ritz Technique," NASA TMX-64528, MSFC, 1970.

12. Wohlen, R. L., "Synthesis of Dynamic Systems using FORMA - Fortran Matrix Analysis," Martin Marietta Corp. Report MCR-71-75, NASA Contract NAS8-25922, May 1971.

13. Whetstone, W. D., "SPAR Reference Manual," Lockheed Missiles and Space Co. Report LMSC D403168, NASA Contract NAS8-26352, June 1974.

14. Schmitz, R. P., "GEOMPLT, Interactive Graphics Program for Finite Element and Thermal Network Models," Sperry Support Services, Huntsville, Alabama, November 30, 1974.

15. Logcher, R. D., et al, "ICES STRUDL-II, The Structural Design Language Engineering User's Manual," MIT Report R70-77, 2nd Edition, Cambridge, Mass., December 1973.

16. Bjaaland, H. K., et al, "ICES TOPOLOGY, Engineering User's Manual," MIT Report R72-65, Cambridge Mass., October 1972.

Table I. Sperry NASTRAN Error Corrections.

LEVEL 15.6.2

SPR NO.   DESCRIPTION

S-110   An infinite loop in plot module.

S-111*   Problem stops during gravitation load evaluation in SSG1.

S-112   No element forces printed.

S-114   Format error when printing solid isoparametric element
            stresses.

S-115   Problem max times in GP3 when using PLOAD2, SURF4, SURF8,
            IS3D8 or IS3D20 Bulk Data cards.

S-116*   COSMIC source code error in KQDMM1.

LEVEL 15.6.3

SPR NO.   DESCRIPTION

S-113   Restart error when restart with altered case control deck.

S-117   Plot error in IS3D8, IS3D20 and IS2D8 elements.

S-118   Mis-spelled word PQEMEM2.

S-119   NTRAN error, Unit 44/45 not available.

S-121*   Format error in Grid Point Singularity Table.

S-122   Force print error for CQDMEM2 element.

LEVEL 15.6.4

SPR NO.   DESCRIPTION

S-123, 128* Error in NASTRAN General Plotter.

S-124*   Multiple time step error in Transient Analysis.

S-126   Incorrect time printed for RF 14 temperature output.

S-127   Permit plot tape parity change in Case Control Deck.

S-129   Add TAPEFLAG keyword to NASTRAN card of directing user tape
            files to DISK.

*Correction to original Level 15.5 code.
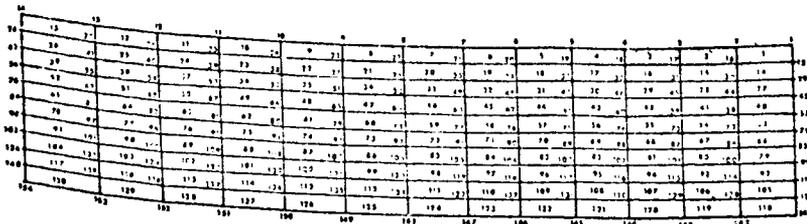
NTU PRIMARY MIRROR
FINITE ELEMENT MODEL
TOP 0.2 IN. THICKNESS

— TOP SURFACE

NTU PRIMARY MIRROR
FINITE ELEMENT MODEL

END OF 5TH LASER CYCLE
(CINDA 3G)

END OF 5TH LASER CYCLE
(NASTRAN)

END OF 1ST LASER CYCLE (NASTRAN)

END OF 1ST LASER CYCLE (CINDA 3G)

TEMPERATURE °F

RADIAL DISTANCE (CM)
SURFACE TEMPERATURE DISTRIBUTION OF PRIMARY MIRROR
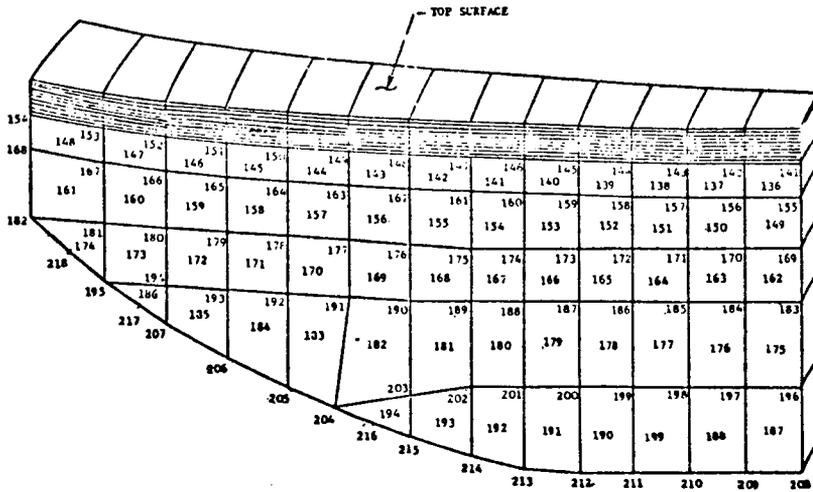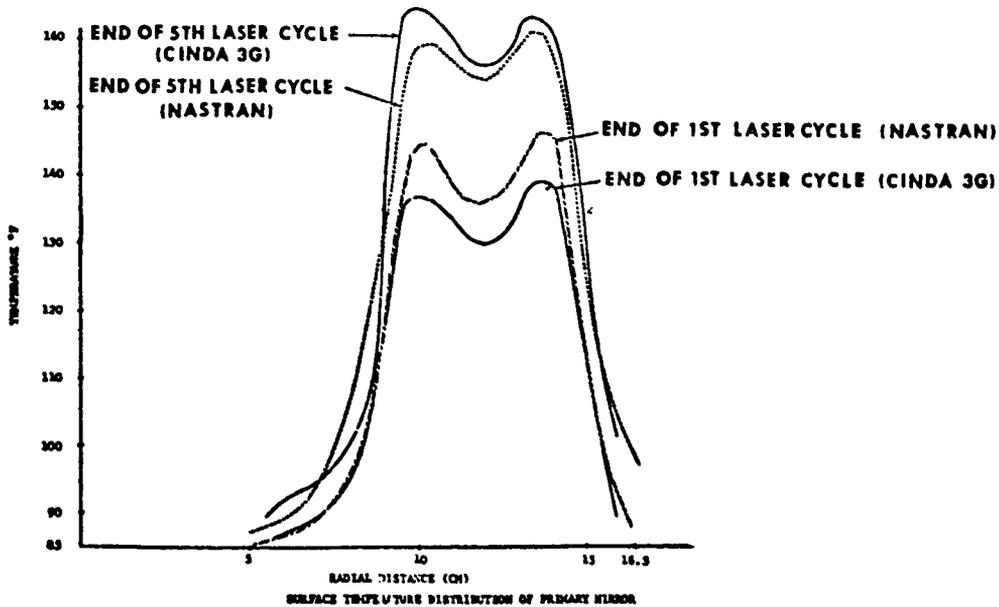
FIGURE 1. PRIMARY MIRROR, FINITE ELEMENT MODEL (648 DOF)

31
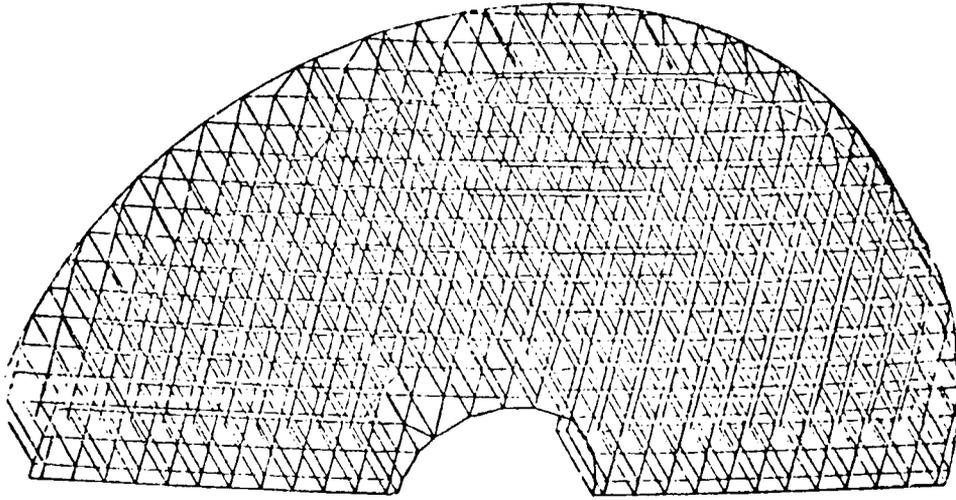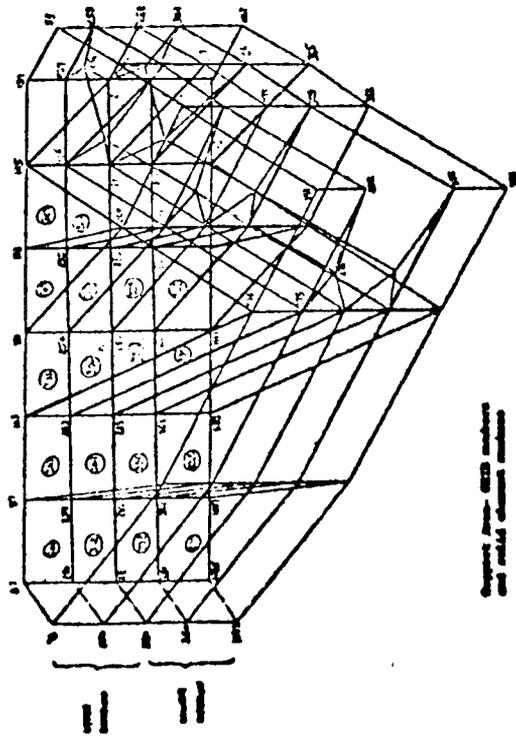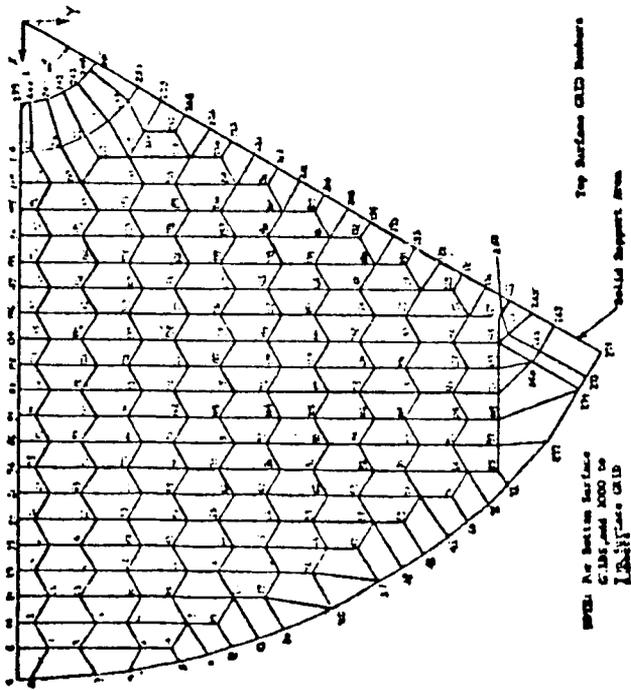
(5220 DOF)

(2932 DOF)

FIGURE 2. LST PRIMARY MIRROR, CERVIT AND ULE FINITE ELEMENT MODELS

1) Subtract $[K] - \lambda_s [M] = [\hat{K}]$;

2) Decompose $[\hat{K}] = [U]^T [D] [U]$;

3) Select initial modes $[Z]_o$;

4) Multiply $[M] [Z_o] = [G]$;

5) Repress higher modes $[U]^T [\hat{K}] [Z] = [G]$;

6) Triple matrix product $[Z]^T [\hat{K}] [Z] = [\overline{K}]$, for 1st iteration only;

7) Multiply $[Z]^T [G] = [\overline{K}]$, skip this step for 1st iteration;

8) Multiply $[M] [Z] = [MZ]$;

9) Multiply $[Z]^T [MZ] = [\overline{M}]$;

10) Solve the eigenvalue/eigenvector problem

$$([\overline{K}] - \Omega^2 [\overline{M}]) \{q\} = \{0\}$$

for eigenvalues $[\Omega^2]$ and eigenvector $[Y*]$;

11) Calculate structural eigenvalues, $\omega_i^2 = \Omega_i^2 + \lambda_s$. Test ω_i^2 for convergence with previous iteration values. If converged, go to Step 13;

12) Multiply $[MZ] [Y*] = [G]$, go to Step 5;

13) Multiply $[Z] [Y*] = [Z]_{final}$;

14) End.

Figure 3. Rayleigh-Ritz Iterative Eigenvalue Formulation Used for Sperry Version NASTRAN.

Input Data Card <u>EIGR</u> (continued)   Real Eigenvalue Extraction Data

Description: Defines data needed to perform real eigenvalue analysis using the Rayleigh-Ritz
with Stadola or Jacobi iteration method.

Format and Example:

EIGR	SID	METHØD	F1	F2	NE	ND	NZ	E	+abc
EIGR	13	RRTZ	0.0	50.0	20	10	-4	1.-3	+ER13

+abc	NORM	G	C						
+ER13	MASS								

<u>Field</u>

SID   Set identification number (unique integer > 0)

METHOD   Method of eigenvalue extraction, one of the BCD values "RRTZ" or "URRZ."

             RRTZ - Rayleigh-Ritz method, symmetric matrix operations.

             URRZ - Rayleigh-Ritz method, unsymmetric matrix operations.

F1,F2   Frequency range of interest, F1 is the shift frequency, F2 is the upper limit
             of frequency of output eigenvectors. ($0.0 \leq$ F1 < F2, Real)

NE   Maximum number of iterations used (integer $\geq$ 3)

ND   Number of roots desired, $2 \leq$ ND $\leq$ 90 (integer)

NZ   Convergence criteria for accuracy of eigenvalues, IF < 0 EPS1 = 10^{-NZ}
             IF $\geq$ 0 EPS1 = .0001
             (integer)

E   Mass orthogonality test parameter (Default is 0.0 which means no test
             will be made (Real $\geq$ 0.0)).

NORM   Method for normalizing eigenvectors, one of the BCD values "MASS", "MAX" or
             "POINT."

             MASS   - Normalize to unit value of the generalized mass

             MAX   - Normalize to unit value of the largest component in the analysis set.

             POINT - Normalize to unit value of the component defined in fields 3 and 4 -
                       defaults to "MAX" if defined component is zero.

             G   - Grid or Scalar point identification number (required if and only if
                       "NORM" = "POINT") (integer $\geq$ 0)

             C   - Component number (one of the integers 1-6) (required if and only if
                       "NORM" = "POINT" and G is a geometric grid point.

34

Figure 4. EIGR Bulk Data Input Card.

Remarks:

1. Real eigenvalue extraction data set must be selected in the Case Control Deck (METHØD = SID) to be used by NASTRAN.

2. The units of F1 and F2 are cycles per unit of time.

3. The continuation card is required.

4. If NE is omitted, NE is set equal to 1/3 the size of the A set or a maximum of 30, whichever is smaller.

5. The number of eigenvectors used for the iteration procedure is 1.3 times the number of roots desired (ND).

6. DIAG 16 may be used to obtain intermediate printout of the iteration procedure. Eigenvalues printed by this method have been shifted by F1. The final eigenvalue summary table has been corrected for the shift frequency.

Figure 4. EIGR Bulk Data Input Card. (Continued)