SUBSTRUCTURE ANALYSIS TECHNIQUES AND AUTOMATION

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SUMMARY

A basic automated substructure analysis capability for NASTRAN is presented which eliminates most of the logistical data handling and generation chores that are currently associated with the method. Rigid formats are proposed which will accomplish this using three new modules, all of which can be added to Level 16 with a relatively small effort.

INTRODUCTION

Prior to Level 15, no real substructure analysis capability existed in any NASA released version of the NASTRAN program. With the pre-release of Levels 8 and 11, users began expressing the desirability and necessity for a substructure analysis capability. Several user organizations attempted, with limited success, to accomplish substructure analysis by using the checkpoint/restart capability of NASTRAN coupled with the direct matrix abstraction (DMAP) approach. Other organizations utilized user-developed utility modules and Rigid Format DMAP alter packages, thus taking advantage of the Rigid Formats whenever possible.

The latter method with an expansion of user options was adapted by NASA for inclusion in Level 15 and is fully described in Section 4.3 of the Theoretical Manual (reference 1) and Section 1.10 of the User's Manual (reference 2). The casual user may well be quite frustrated with this method since its generality requires the user to design a specific approach for the problem at hand. This involves externally generated partitioning vectors as well as DMAP alter packets which are often unfamiliar to the engineer user. In addition, little assistance is provided in the form of qualitative verification of the hand-generated coupling data or of the resulting coupled matrices. The probability of undetected user-generated errors in this process is therefore rather high. Furthermore, the user must develop customized DMAP packages for any problem that does not match the currently published substructure alter packages.
The currently available Level 15 technique was intended as a general but preliminary capability. The upgrading of this capability with user conveniences and qualitative data checks has been requested by many. As NASTRAN's substructure analysis capabilities are improved, serious users will explore many different approaches. Several techniques and utility module designs developed by necessity will be discussed for use with Levels 15 and 16. Along these lines, several aids are suggested herein. Some take advantage of existing code and capability while others indicate the need for additional user-developed utility modules as well as modifications to several existing modules. The techniques discussed are intended for the casual engineer user and are therefore used somewhat more rigidly than might normally be expected with utility modules. It is hoped, however, that the concepts described will stimulate other serious user teams to develop structurally-oriented and utility modules to ease the difficulties encountered in carrying out an effective substructure analysis.

All new and modified routines and modules are based on the Level 16 version of NASTRAN currently undergoing validation. Many of the techniques described are valid for Level 15, however, and can be installed in that level with slightly more difficulty since many Level 16 features will also have to be installed. It should be possible for a reasonably competent experienced team to install the capability described with a nominal effort.

**SYMBOLS**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Stiffness matrix</td>
</tr>
<tr>
<td>P</td>
<td>Load vector matrix</td>
</tr>
<tr>
<td>u</td>
<td>Displacement vector matrix</td>
</tr>
<tr>
<td>G</td>
<td>Transformation matrix</td>
</tr>
<tr>
<td>M</td>
<td>Mass matrix</td>
</tr>
</tbody>
</table>

**Subscripts:**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>f</td>
<td>Free (unconstrained) set</td>
</tr>
<tr>
<td>a</td>
<td>Analysis (boundary) set</td>
</tr>
<tr>
<td>o</td>
<td>Omitted (interior) set</td>
</tr>
<tr>
<td>g</td>
<td>All degrees of freedom set</td>
</tr>
</tbody>
</table>
Superscripts:

- $T$ Transpose operator
- $-1$ Inverse operator
- $i$ Substructure index
- $o$ Related only to the omitted (interior) set

Other Symbols:

- $-$ Pre-reduction portion of a matrix
- $[,]$ Matrix
- $\{\}$ Matrix of vectors
- $\wedge$ Related to pseudomodel.

Symbols appearing in the appendices are defined in the appropriate appendix as necessary.

OBJECTIVE AND SCOPE

A sample substructure analysis model is shown in figure 1. The grid points on the top surface of this model which are to be coupled are identified by letters. Substructure analysis implicitly assumes that each substructure is analyzed separately and subsequently combined with other previously analyzed substructures to form a pseudostructure as shown in figure 2. Once the pseudostructure is solved, the detailed solutions for each of the substructures may be obtained by a set of data recovery runs. The objective of the techniques and new capability to be presented herein is to define a basic substructure analysis capability which will require a minimum amount of user-generated data and logistics.

With this objective in mind, the scope will be limited to providing a basic capability; therefore, many desired features will be omitted in order to focus attention on the fundamentally important capabilities. In the discussion that follows, the limitations that result from this restricted scope will be identified. It should be kept in mind that most, if not all, of these limitations can be removed by additions to the basic capability once it is implemented.
DISCUSSION

The theory, utilization and programming aspects of NASTRAN's substructure analysis capabilities are discussed in references 1-3. Necessary and desirable features of any substructure analysis capability have been given by many, including papers presented at the first Users' Colloquium (references 4 and 5). For ease of reference, the basic theory is given in the following section as an aid to the interested reader.

The difficulty in carrying out a substructure analysis with NASTRAN lies in the logistical procedures rather than with any inherent deficiency with NASTRAN itself. This logistic problem is illustrated in figures 2 and 3 where the number of runs and retainable data files is seen to be large. The data requirements for substructure analysis in Levels 15 and 16 and for the capability described in this paper, which we shall designate Level 16.X, are tabulated in table 1.

The major disadvantages to the current (Level 15) substructure analysis capability of NASTRAN are:

1. The user must generate partitioning vectors
2. A DMAP alter packet appropriate to the problem being run must be created.

These disadvantages can be overcome relatively easily if a few modest restrictions are imposed. This will be illustrated for the two most commonly used rigid formats, Static Analysis and Normal Modes Analysis which, when upgraded as described herein, will not require the generation of an alter packet to run.

The restrictions that will be imposed are listed in table 2 and are summarized here.

1. Only one (1) level of substructure analysis is supported, consisting of a maximum of twenty (20) substructures.
2. The degrees of freedom at coupled boundary points must agree in number, meaning and direction.
3. The internal sequence of all points on the boundary between any two substructures must be the same.
4. All subcases must be defined in all runs.
5. Output may be obtained during Phase II for any degrees of freedom present as identified by the pseudostructure map printout (see fig. 4).
Advantage features provided are:

1. If the grid points of the substructures are numbered uniquely, the user may request automatic coupling to occur. If exceptions occur, they may be handled by means of bulk data.

2. The minimum required data are the DTI data cards defining the number of substructures present and other logistical control information.

3. If topologically equivalent substructures are present, only one needs to be input; coupling data cards will be required in this case since the grid points are no longer unique.

Level 16.X overcomes the most serious objections by providing an automated capability. This capability is implemented by the addition of new modules, rigid formats, and a user-oriented data table specification. These facets are discussed in the sections which follow the theoretical discussion. As far as the rigid format is concerned, the new modules appear as structural matrix assemblers similar to SMA3 with the substructures appearing internally as arbitrarily defined super elements.

THEORY

The basic theory used as a basis for the implementation of substructure analysis is presented here for the convenience of the reader. Full treatment is given in Section 4.3 of the Theoretical Manual (reference 1). The NASTRAN set notation will be employed.

For static analysis, the free (f) degrees of freedom of the substructure are allocated to the a-set, which contains all boundary degrees of freedom, (i.e., degrees of freedom which are to be coupled to similar degrees of freedom at some grid point in another substructure), and the o-set, which contains the non-boundary degrees of freedom. The equilibrium equations are written as

\[
\begin{bmatrix}
K_{aa} & K_{ao} \\
K_{oa} & K_{oo}
\end{bmatrix}
\begin{bmatrix}
u_a \\
u_o
\end{bmatrix}
= 
\begin{bmatrix}
p_a \\
p_o
\end{bmatrix}
\]  

from which

\[ [K_{aa}]{u_a} = \{p_a\} \]  

\[ \]
where

\[
[k_{aa}] = [\hat{K}_{aa}] + [G_o]^T[K_{oa}]
\]  (3)

\[
\{P_a\} = \{\hat{P}_a\} + [G_o]^T\{P_o\}
\]  (4)

and

\[
[G_o] = -[K_{oo}]^{-1}[K_{oa}]
\]  (5)

Also, the displacements of the interior points are given by

\[
\{u_0\} = \{u_0^0\} + [G_o]\{u_a\}
\]  (6)

where

\[
\{u_0^0\} = [K_{oo}]^{-1}\{P_o\}
\]  (7)

Equations 3, 4, 5 and 7 can be carried out in Phase I. Equation 2 must be deferred to Phase II where the missing contributions to \([K_{aa}]\) from the other substructures are available. Equation 6 consists of two parts, one of which (equation 7) is evaluated in Phase I. The other part depends on the solution generated in Phase II. Equation 6 is therefore done in Phase III.

In Phase II, the substructure boundary matrices \([k_{aa}^i]\) and \([P_a^i]\), which are brought in from User Files generated by the Phase I runs, are expanded to pseudomodel q-size.

\[
[k_{aa}^i] \rightarrow [\hat{K}_{gg}^i]
\]  (8)

\[
\{P_a^i\} \rightarrow \{\hat{P}_g^i\}
\]  (9)

and added to form

\[
[\hat{K}_{gg}] = \sum_i [\hat{K}_{gg}^i]
\]  (10)

\[
\{\hat{P}_g\} = \sum_i \{\hat{P}_g^i\}
\]  (11)

from which a normal solution proceeds.
After the solution $\{\hat{u}_g\}$ is obtained, the boundary displacements are simply
extracted by

$$\{u_a^i\} \rightarrow \{\hat{u}_g\} \quad (12)$$

The merge and partitioning operations defined by equations 8, 9 and 12 require
information identifying degrees of freedom in each substructure with corre-
sponding degrees of freedom of the pseudomodel.

For normal modes analysis, the mass matrix is arbitrarily reduced via
the Guyan reduction

$$[M_{aa}] = [\tilde{M}_{aa}] + [M_{oa}]^T[G_o] + [G_o]^T[M_{oa}] + [G_o]^T[M_{oo}][G_o] \quad (13)$$
described in reference 6 and carried into Phase II in the same way as $[K_{aa}]$.

In dynamics rigid formats, the viscous and structural damping matrices
are similarly treated.

NEW MODULE DESCRIPTIONS

Three new modules are presented in this section which form the basis for
the automation of the basic automatic substructure analysis technique. These
modules can be either added to DMAP alter packets currently being utilized or
to new rigid formats as will be shown in the following section.

The three new modules are:

- SSMA  Substructure Matrix Assembler
- SSVE  Substructure Vector Extractor
- UDBR  User File Data Block Recovery

Descriptions of these modules are presented on the following pages using the
format prescribed for Section 5 of the NASTRAN User's Manual.
I. **NAME:** SSMA (Substructure Matrix Assembler)

II. **PURPOSE:** Generates matrices from substructures -
   1. Obtains substructure matrices and other data from designated User Files.
   2. Assembles g-sized stiffness, mass, viscous damping, structural damping and/or load vector matrices for all substructures designated.
   3. Outputs appropriate diagnostic and information messages and summary information.

III. **DMAP CALLING SEQUENCE:**

```plaintext
SSMA GEOM4, UFTABLE / K, M, B, K4, P, PSD / C, Y, POPT / C, Y, GENSAME / V, N, LUSET $
```

IV. **INPUT DATA BLOCKS:**

**GEOM4** - Contains SAME data

**UFTABLE** - User File information

V. **OUTPUT DATA BLOCKS:**

**K, M, B, K4, P** - Stiffness, mass, viscous damping, structural damping and load vector matrices

**PSD** - Pseudostructure data table

VI. **PARAMETERS:**

**POPT** - Integer-input, default=1.
   *+1*, print pseudostructure map
   *-1*, do not print map

**GENSAME** - Integer-input, default=-1.
   *-1*, coupling data is taken from GEOM4
   *+1*, automatic coupling based on grid point identification numbers will be employed (GEOM4 data is also used if present).

**LUSET** - Integer-output, default=0. Number of degrees of freedom in pseudostructure g-set.
VII. REMARKS:

1. SSMA will read User Files INPT, INP1, INP2, ---, INP9 as specified by the data on UFTABLE.
2. Any or all outputs may be purged.
3. GEØM4 may be purged if GENSAME=+1.
4. UFTABLE may not be purged.

I. NAME: SSVE (Substructure Vector Extractor)

II. PURPOSE: Generates a User File containing substructure boundary displacement vectors.

III. DMAP CALLING SEQUENCE:

SSVE PSD,LA,UGV // $

IV. INPUT DATA BLOCKS:

PSD - Pseudostructure data table (generated by SSMA)
LA - Eigenvalue table
UGV - Displacement vector

V. OUTPUT DATA BLOCKS: None

VI. PARAMETERS: None

VII. REMARKS:

1. Companion module to SSMA, requires pseudostructure data table (PSD) output from SSMA as input.

2. SSVE will write a User File on INFT, INP1, INP2, ---, or INP9 as specified by the data block UFTABLE and passed to the module via PSD.
I. NAME: UDBR (User File Data Block Recovery)

II. PURPOSE: Recovers data blocks from a given User File according to information contained on a directory data block (the first data block on the file).

III. DMAP CALLING SEQUENCE:

```
LIDBR / DB1, DB2, DB3, DB4, DB5 / C, Y, SUBID / C, Y, UNIT / C, Y, USRTPID2 $
```

IV. INPUT DATA BLOCKS: None

V. OUTPUT DATA BLOCKS:

DBi - Data Blocks recovered by module.

VI. PARAMETERS:

- **SUBID** - Integer-input, default=0. Substructure identification number.
- **UNIT** - Integer-input, default=0. Permanent file code as follows:
  
<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>INPT</td>
</tr>
<tr>
<td>1</td>
<td>INP1</td>
</tr>
<tr>
<td>2</td>
<td>INP2</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>8</td>
<td>INP8</td>
</tr>
<tr>
<td>9</td>
<td>INP9</td>
</tr>
</tbody>
</table>

- **USRTPID2** - BCD-input, default=XXXXXXX. User File identification code.

VII. REMARKS:

1. The User File is assumed to have been generated by module SLVE.
2. The number and kind of data blocks recovered depends on the directory data block contents.
NEW RIGID FORMATS

In order to simultaneously use the new utility modules previously defined and to relieve the user of the burdensome chore of preparing DMAP alter packets, new rigid formats have been developed, one for each major analysis capability. Static Substructure Analysis, Rigid Format 16, is given in Appendices B, C and D where the solution subset numbers 1, 2 and 3 are indicative of Phase I, II and III, respectively. If subset 0 (see Appendix A) is used, an ordinary Static Analysis will result. Normal Modes Substructure Analysis, Rigid Format 17, is illustrated for Phase II by Appendix E. These new rigid formats are fully compatible with all existing displacement rigid formats, including restart capability, as defined by Rigid Format Series N which is scheduled for Level 16 of NASTRAN.

Many of the DMAP instruction sequences contained in these rigid formats can be used by current Level 15 users with appropriate caution.

USER DATA REQUIREMENTS

The Phase II coupling process requires that matrices and data tables generated in several Phase I runs be recovered from User Files. Many possible data input configurations are possible, depending on the sequence of Phase I runs and reruns which led up to the Phase II analysis. In order to allow the greatest amount of flexibility in the automated process, a table data block containing user file information will be used to control the Phase II assembly process. This can ultimately be generated from a Case Control packet. For the purposes of the current design, however, this table will be assumed to be input via DTI bulk data cards as illustrated in figure 8 and described in some detail in Appendix F. The UFTABLE data block that results will be required input to module SSMA previously discussed. Future expansion to include control of the load assembly process, as well as features not currently envisioned, is easily accomplished since the records of table data blocks are open-ended.

USAGE

The usage of the capability just presented is shown by the sample data decks in figures 5, 6, 7 and 8. It is to be emphasized that, within the limitations previously described, the burden on the user is minimal. The primary requirement is that the small UFTABLE data block be prepared on DTI cards for input to Phase II. Job control language is still necessary, of course, and will not be discussed here since the subject is not only machine-dependent but usually highly installation-dependent as well.
The user accomplishes substructure matrix generation (Phase I) as presently described in the Level 15 User's Manual without the alter packet. The new modules SSMA and SSVE are used to automate the matrix coupling (Phase II) and thereby eliminate the chore of generating complicated DMAP alter packets. No longer must the user supply the input, merge, add, and equivalence statements for the coupling of each matrix of every substructure. Now one module (SSMA) replaces all of the above-mentioned DMAP statements. The user supplies only substructure names and identification values via bulk data cards to inform SSMA how many substructures are being coupled and to relate the substructures to user-supplied coupling data. The substructure's parameter value is used to indicate the presence of identical substructures. The user may also include user file labels from Phase I, names of matrices to be read from each user file, and, when tapes are used, the installation's tape code when requesting multiple-reel tapes. All tape changes and mount requests are handled similarly to the current NASTRAN user tape modules with the exception that the user is uninvolved once the installation's job control language requirements are met. NASTRAN with one module (SSMA) now requests user tapes, verifies the correct mounting and builds all the coupled matrices, taking full advantage of any identical substructures that exist. Module SSVE is similarly used to request an output tape and uncouple the substructure solution vectors.

As a final indication of the usefulness of the techniques developed, the sample problem used in reference 2 is presented in Appendix G. It is seen that truly little effort is required on the part of the user to prepare data for a substructure analysis using Level 16.X features.

FUTURE IMPROVEMENTS

Once the basic capability becomes implemented, an environment will exist with respect to which improvements can be made. Several of these potentially useful improvements are described in the paragraphs which follow.

One early addition should be to provide data checking capability for points being coupled between substructures. These checks will require that additional geometric information about boundary grid points be carried forward from Phase I. This information can then be automatically recovered in Phase II via SSMA and either used inside that module or passed out of the module in the form of data blocks to be used by other new modules.

Another improvement which can be added relatively easily to the basic capability is the ability to introduce and symbolically manipulate and generate geometrically related loading conditions in Phase II. This also requires the availability of additional geometric information in Phase II. At this point,
it will be possible to introduce direct matrix input as a representation of loading conditions. This capability will complement the existing capability for users who may desire to input loading matrices generated by programs external to NASTRAN.

The ability to relate degrees of freedom of the pseudostructure to externally designated degree of freedom descriptions in Phase II requires only that the correspondence be known. Since this information is contained in the ASET data blocks input from the Phase I runs, it is easy to conceive of a translator module which will accept data referencing external degrees of freedom (e.g., SPC, OMIT, FORCE cards) and generate equivalent data blocks containing internal pseudostructure degree of freedom descriptions. With this capability, analyses of pseudostructure models can be carried out as if they were simple structures.

Non-conforming boundaries can be handled with an extra transformation step. If \([Q]\) is chosen so that the transformed displacement vector

\[
\{u\}^* = [Q]^T\{u\}
\]

has the desired sequence but the same values, then

\[
[Q]^{-1} = [Q]^T
\]

and the conformable matrices and vectors are easily computed as

\[
[K]^* = [Q]^T[K][Q]
\]

and

\[
\{p\}^* = [Q]^T\{p\}.
\]

After solution, the reverse transformation is merely

\[
\{u\} = [Q]\{u\}^*
\]

Since \([Q]\) has an extremely low density, NASTRAN's sparse matrix multiply routines will carry out the indicated computations most efficiently. The essential task is the generation of the \([Q]\) data. With suitable arbitrary conventions, this can be accomplished within the module SSMA and included in the PSD data block for transfer to other modules such as SSVE where the reverse transformation can be made.

Multi-level substructure analysis, while not covered explicitly by the scope of this effort, can be obtained with a small modification to the existing capability herein defined. In this case, the ASET data block output from Phase II will contain both the pseudostructure degrees of freedom and the
equivalent Phase I external degree of freedom designations. Since several Phase I external degree of freedom designations may exist for each Phase II degree of freedom, the data block becomes somewhat more complex but no essential new difficulty is encountered. Once the correspondence recognition feature is accomplished, multi-level substructure analysis capability essentially becomes open-ended with no real limit to the possible number of levels. Since the degree of freedom correspondence is automatically carried forward at each level, it will be possible to return directly to the original substructures in any data recovery phase. In addition, the substructure formed at any level can be analyzed by itself. Figure 9 illustrates this process.

A user convenience improvement would be to replace the DTI form of the input of the table UFTABLE described earlier with a Case Control Deck packet similar to the structure plotter request packet. This will require new code in the Input File Processor (IFP) portion of the preface which will read the data cards, analyze them for correctness and form the UFTABLE data block. When implemented, the present requirement for a dummy UFTABLE input for subset 0 will be eliminated. The language specifications can be made as user-oriented as desired since IFP will interpret the statements and form the UFTABLE data block. At such time as the data block UFTABLE is added to the FIAT as a recognized output from the preface, an EQUIV DMAP instruction will be needed in the rigid formats if DTI input is also to be available.

Another enhancement will be to allow the coupling of individual degrees of freedom at a grid point rather than all unconstrained degrees of freedom as will be done in Level 16. This task is not dependent on anything presented in this paper but can be done at any time since it merely involves the definition of a new data card similar to the present SAME card (see figure 10) and the addition of minor processing logic in the Level 16 module PVEC.

Several other improvements which will either remove restrictions or extend the capability can be envisioned. The important point is that any or all of these improvements can be relatively easily made once the basic capability is operational.

CONCLUSION AND RECOMMENDATIONS

An approach has been presented by which basic automatic substructure analysis can be added to NASTRAN. It is suggested that this technique can be implemented in Level 16 with a relatively small level of effort. While the resulting capability will not completely satisfy all potential users, it is felt that most substructure analyses will be encompassed. Furthermore, reasonable extensions of the techniques presented can be made which will result in any degree of further sophistication, convenience and automation that can be supported by resources that are made available for this purpose.
APPENDIX A

RIGID FORMAT DMAP LISTING FOR S0L 16, (0)

STATIC SUBSTRUCTURE ANALYSIS (ALL PHASES)

Subset 0 of Rigid Format 16 contains all DMAP instructions for Static Substructure Analysis. If run without subsets 1, 2, or 3, a complete static analysis will result which is equivalent to Rigid Format 1. Selection of one of the subsets 1, 2 or 3, however, reduces Rigid Format 16 to a DMAP sequence which will automatically solve Phase I, II or III of Static Substructure Analysis. These subsets are displayed in Appendices B, C and D. The DMAP compilation listing of S0L 16,0 constitutes the remainder of this Appendix, including an explanatory description of the DMAP similar to that found in Section 3 of the NASTRAN User's Manual.
APPENDIX A

RIGID FORMAT XMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET ZERO
NASTRAN SOURCE PROGRAM COMPILATION
DMAP-DMAP INSTRUCTION

1 BEGIN NO.16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N $
2 FILE LLL=TAPE $
3 FILE UG=APPEND/PGG=APPEND/UGV=APPEND/OM=SAVE/KNH=SAVE $
4 JUMP PH2D81 $
5 PARAM //C,N,ADD/V,N,PHASE2/C,N,0/C,N,-1 $
6 ( SMA ) UGH2,C,UFTABLE/KGGPS,PGPS,PSUM1//C,N,PHASE1/C,N,GENSAME/V,N,
   LUSET $
7 SAVE LUSET $
8 CHKPT KGPS,PGPS,PSDATA $
9 LABEL PH2D81 $
10 ( GP1 ) GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPT,SIL/V,N,LUSET/V,N,
   NUGPOT $
11 SAVE LUSET $
12 CHKPT GPL,EQEXIN,GPDT,CSTM,BGPT,SIL $
13 ( GP2 ) UGH2,FQEXIN/ECT $
14 CHKPT ECT $
15 PARAM PCUB//C,N,PRES/C,N,C,N,C,N/V,N,NUGPOT $
16 PURGE PLTSETX,PLTPAR,GPSETS,ELSETS/NPUBLU $
17 CEND FL1,NUGPOT $
18 PLTSET PCUB,FQEXIN/ECT/PLTSETX,PLTPAR,UPSETS,ELSETS,V,N,NSIL/V,N,
   JUMPPLOT+1 $
19 SAVE NSIL,JUMPPLOT $
20 PRMSG PLTSETX/ $
21 PARAM //C,N,MPY/V,N,PLTFLG/C,N,1/C,N,1 $
22 PARAM //C,N,MPY/V,N,PFILC/C,N,0/C,N,U $
23 CEND PI,JUMPPLOT $
24 ( PLUT ) PLTPAR,GPSETS,ELSETS,CASECC,BGPT,EQEXIN,SIL,/,PLUTX1/V,N,
APPENDIX A

RIGID FORMAT DMAP LISTING
SERIES N *** EM3L STATTO SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 16 - SUSTANT E ZERO

NAS TRAN SORCE PRCGRAM LUMPILATION

DMAP-DMAP INSTRUCTION

NO.

25 SAVE JUMPLOT,PLTFLG,PFILE $
26 PRINT PLCWX1// $
27 LABEL P1 $
28 CHKPT PLTPAR,GPSET,ELSET $
29 GP3 UELM3,EDEXIN,GEOMZ/SLT///TT/Vx,N,NGRAV $
30 SAVE NGRAV $
31 PARAM //C,N,AND/Vx,N,NOMGG/Vx,N,NGRAV/Vx,Y,6,UPHT=1 $
32 PUHAGE MUG,MELM,MDICT/NOMGG $
33 CHKPT SLT,GPTT $
34 (1A1) EDT,EPT,CPDPT,STL,GPTT,CSTM/EST,ULI,UPLET/Vx,N,LSET/Vx,N,
NUSIMP/C,N,I/Vx,N,NOGENL/Vx,N,GENCL $
35 SAVE NUSIMP,NOGENL,GENCL $
36 PARAM //C,N,AND/Vx,N,NOELMT/Vx,N,NOSGENL/Vx,N,NUSIMP $
37 COND ERRUR4,NOELMT $
38 PUHAGE KUGX,GPST/NOSIMP/GGPST/GENEL $
39 CHKPT EST,GPECT,GEI,GPST,GGPST $
40 OPTPT1 MPT,EDT,GCT,EST/OPTPI/Vx,N,PRINT/Vx,N,TSTART/Vx,N,LUUNT $
41 SAVE PRINT,TSTART,COUNT $
42 CHKPT OPTPI $
43 JUMP LUOPTOP $
44 LABEL LUOPTOP $
45 COND LBLL,NOSIMP $
46 PARAM //C,N,ADD/Vx,N,NOKGGX/C,N,1/C,N,0 $
47 ESG ESG,CSTM,MPT,DI,T,GEOH2/KELMx,ULLT,HEME,ISUNLIT/Vx,N,NOVGGX/Vx,N,
CPQUAD/C,Y,CPQUAD2/C,Y,CPTFH1/C,Y,CPFH1=2/C,Y,CPFH,B,E/C,Y,
CPQPLT/C,Y,CPTRPLT/C,Y,CPTRBS3C
APPENDIX A

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET ZERO

NASTRAN SOURCE PROGRAM Compilation
UMAP-UMAP Instruction

48 SAVE NOKSWX,NOMGG $
49 CHKPT KELM,KDICT,MELM,MDICT $
50 COND JMPKGG,NOKGUX $
51 EMA GPECT,KDICT,KELM/KGGX,GPST $
52 CHKPT KUGA,GPST $
53 LABEL JMPKUG $
54 COND JMPKGG,NOKMGG $
55 EMA GPECT,MDICT,MELM/MGG,/C,,I,,Y,,wTMass=1.0 $
56 CHKPT MUG $
57 LABEL JMPKUG $
58 COND LBL1,GRPNP $50
59 COND LAVGKZ,NOMGG $
60 GPNU BUPDT,CSTM,EOFXN,MOG/CNN/.OGPT/G,/,Y,,wTMass $
61 DSP OGPWG,,;,,//V,,N,,CARDNO $
62 LABEL LBL1 $
63 EQUIV KUGA,KG/NONE $
64 CHKPT KUG $
65 COND LBL1L,NONE $
66 SMA2 GEI/KGGX/KGGV,NLUSET/V,,N,,NONE/NL/V,,N,,NUSIMP $
67 CHKPT KUG $
68 LABEL LBL1L $
69 JUMP PH2BKX $70 ADD KGG,KGPP/KGGT $
71 EQUIV KGUT,KGG/P14,SE2 $
72 CHKPT KGG $
73 LABEL PH2BKX $

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APPENDIX A

RIGIDU FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGIDU FORMAT 16 - SUBSET ZERO

NAS TRAN SOURCE PROGRAM COMPILATION
UMAP-UMAP INSTRUCTION
INU.

74  PARAM  //Cn,MPLY/Vn,NSKIP/Cn,D/Cn,U $
75  JUMP  LBL11 $
76  Label  LBL11 $
77  GP6  LASEC1/GE1/MA1,EXEXIN,SIL/PBDT/VN,YSET/VN,LSET/VN,MPF1/VN,MPF2/VN,SINGLE/VN,UNIT/VN,REALT/VN,NSKIP/VN,
    REPEAT/VN,NOSET/VN,Y,LVL/VN,NOA/CY,LOCL/DSUCLU $
78  SAVE  MPF1,MPF2,SINGLE,OMIT,REALT,NSKIP,REPEAT,NOSET,NOU,NOA $
79  END  ERRUR3,NOL $
80  PARAM  //Cn,AND/Vn,NSR/Vn,SINGLE/Vn,REALT $
81  PURGE  KRA,KLR,OR,OM/REALT/GH/MPF1/UD,KOU,LOO,PQ,UGV,RUUV/UNIT/PS,
    KFS,KSS/SINGLE/QD/NSR $
82  CHKPT  KRA,KLR,QR,OM,GM,GO,KCO,LOO,PQ,UGV,RUUV,PS,KFS,KSS,UG,USE,RT,GS
    YS,ASET $
83  END  LBL4,CCNCL $
84  GP6  UPL,GPOST,USET,SIL/GPOST/VN,NUPOST $
85  SAVE  NOGPST $
86  END  LBL4,NOGPST $
87  UFP  GPOST,///Vn,CARDNO $
88  Label  LBL4 $
89  EQUIV  KGG,KNF/MPF1 $
90  CHKPT  KNN $
91  END  LBL2,MPF2 $
92  CH61  USET,RC/CM $
93  CHKPT  GM $
94  CH62  USET,GM,KGG,///KNN $,
95  CHKPT  KNN $
96  END  LBL2 $
97  EQUIV  KNN,KFF/SINGLE $
APPENDIX A

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET ZERO

NAS TRAN SOURCE PROGRAM COMPILATION
DMAP-DMP INSTRUCTION

98 CHKPNT KFF $
99 COND LBL3,SINGLE $
100 SEL USEL,KNN,KFF,KFS,KSS,$ $
101 CHKPNT KFS,KSS,KFF $
102 LABEL LBL3 $
103 EQUIV KFF,KAA/OMIT $
104 CHKPNT KAA $
105 COND LBL5,OMIT $
106 CMP1 USEL,KFF,GO,KAA,KOC,LOO,$ $
107 CHKPNT USEL,KAA,KOC,LOO $
108 LABEL LBL5 $
107 EQUIV KAA,KLL/REACT $
110 CHKPNT KLL $
111 PARM //C,N,SUB/V,N,PHASE1/C,N,O/C,O,SUB1=O $  
112 COND LBL7,PHASE1 $
113 COND LBL6,REACT $
114 CMP1 USEL,KAA,KLL,KLR,KRR,$ $
115 CHKPNT KLL,KLR,KRR $
116 LABEL LBL6 $
117 REMO2 KLL/LLL $
118 CHKPNT LLL $
119 COND LBL7,REACT $
120 REMO3 LLL,KLR,KPR/DM $
121 CHKPNT DM $  
122 LABEL LBL7 $
123 SSW1 SMT,EPDT,CDT,EPT,EST,HPT,DPIT,UT,MUG,ACECL,ULT/PG/V,N, 
USEL/V,N,NSKIP $
APPENDIX A

RIGID FORMAT UMAP LISTING

SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 10 - SUBSET ZERO

NASTRAN SOURCE PROGRAM COMPI lATION

UMAP-UMAP INSTRUCTION

NU.

124 JUMP PH2OK3 $
125 ADU PG,PUPS/PCT $
126 EQUIV PUT,PG/PHASE? $
127 LABEL PH2OK3 $
128 CHKPT PG $
129 EQUIV PU,PL/NOSET $
130 CHKPT PL $
131 COND L0L10,NOSET $
132 USUZ USET,G M,YS,KFS,GO,OM,PG,WR,PG,PS,PL $
133 CHKPT LR,FO,PS,PL $
134 LABEL L0L10 $
135 COND P,L0U1,PO,NOSET $
136 USGZ LLL,ULL,PL,LC0,K0U,PO/ULV,UCCV,ULLV,0U0V/V,UNIT/V,Y,URES=-1/V
137 SAVE EPSI $
138 CHKPT ULV,0UGV,RULV,RU0V $
139 COND L0L9,IPES $
140 MATGPR GPL,USET,STL,5ULV/C,AL $
141 MATGPR GPL,USET,STL,RU0V/C,NO $
142 LABEL L0LY $
143 JUMP PH30K1 $
144 LABEL PH1BK1 $
145 COND SKIP,UNIT $
146 FBS LQ0,PO/0UGOV $
147 EQUIV 0UG0,190V/PHASE? $
148 CHKPT U00V $
149 LABEL SKIP
APPENDIX A

RIGI FORMAT UMAP LISTING
Scries N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGI FORMAT IO - SUBSET ZERO

NASTRAN SOURCE PROGRAM COMPILATION
DRAF-UMAP INSTRUCTION
NU.

150  OUTPUT  ASET;KLL;PL;M/C,N;L/O/C,Y;USSTP1U1
151  PARAM  //C,N;ADD/V,N;PHASE3/C,N;O/C,N;L
152  OUTPUT  //ULV,---/C,Y;SUBID/C,Y;UNIT/C,Y;USSTP1U1
153  EQUIV  ULV,ULV;PHASE3
154  CHKPT  ULV
155  LABEL  PH28K1
156  CSW1  USET;PG,ULV;UODIV,Y;G,O;MPS,KPS,KPS,WR/UV,PGW;UV/V,N;N,N/STATICS/C,N;STATICS
157  CHKPT  UGV,PGG
158  COND  LBL8;REPEAT
159  REPT  LBL11;100
160  JUMP  ERROR1
161  PARAM  //C,N;NOT/V,N;TEST/V,N;REPEAT
162  COND  ERROR5;TEST
163  label  LBL8
164  CHKPT  UG
165  JUMP  PH28K4
166  CSVE  PSLATA,UGV//
167  LBL7  PH28K4
168  SDR2  LASECC,CSTM,MPY,DIT,ECEXIN,SIL,OGTT,CUT,OGPUT,UG;UV;EST;PGG/CPG1,UGV1,DES1,OLFL,PUGV1/C,N;STATICS
169  COND  LBL10P,COUNT
170  UPTPR2  UPTP1;DES1;EST/OPTP2,EST1/V,N;PRINT/V,N;START/V,N;COUNT
171  EQUIV  EST1;EST/COUNT/OPTP2,OPTP1/COUNT
172  COND  100;END;PRINT
173  LABEL  LBL24P
174  PARAM  //C,N;MPY/V,N;CARDNO/C,N;O/C,N;O
APPENDIX A

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 10 - SUBSET ZERO

NASTRAN SOURCE PROGRAM COMPIlation
UMAP = UMAP INSTRUCTION

```
175 UFP  UUUU1,0PGI,0PG1,0EFL,DES1,,/V3,N,LARUNO $
176 SAVE  LARUNO $  
177 COND  P2,JUMPLOT $  
178 (PLT)  PLTP,7,GPTS,ELSETS,CASECC,BUFL,E,LAIN,5IL,FUFP,1,0PECT,DES1/ 
           PLTP?,/V3,N,SMFL/V3,N,LUSET/V3,N,JUMPLOT1/V3,N,PLTPLU/V3,N,PLFILE $  
179 SAVE  PLFILE $  
180 PRTPAM  PLUA77/ $  
181 LABEL  F2 $  
182 LABEL  LWPEND $  
183 COND  FINIS,COUNT $  
184 REPT  LOOPTOP,100 $  
185 JUMP  FINIS $  
186 LABEL  ERAR3 $  
187 PRTPAM  //C,N+1/C,N,STATICS $  
188 LABEL  ERRUN8 $  
189 PRTPAM  //C,N+2/C,N,STATICS $  
190 LABEL  ERRUR3 $  
191 PRTPAM  //C,N+3/C,N,STATICS $  
192 LABEL  ERRUR4 $  
193 PRTPAM  //C,N+4/C,N,STATICS $  
194 LABEL  ERRUR5 $  
195 PRTPAM  //C,N+5/C,N,STATICS $  
196 LABEL  FINIS $  
197 EN  $  

**NO ERRAS FOUND - EXECUTE NASTRAN PROGRAM**
```
APPENDIX A

Description of DMAP Operations for Basic Static Substructure Analysis

6. SSMA analyzes and/or generates coupling data and forms coupled substructure matrices \([K_9^S]\) and \([P_9^S]\).

10. GPI generates coordinate system transformation matrices, tables of grid point locations, and tables for relating internal and external grid point numbers.

13. GP2 generates Element Connection Table with internal indices.

17. Go to DMAP No. 27 if no plot package is present.

18. PLTSET transforms user input into a form used to drive structure plotter.

20. PRTEMSG prints error messages associated with structure plotter.

23. Go to DMAP No. 27 if no undeformed structure plot request.

24. PLT generates all requested undeformed structure plots.

26. PRTEMSG prints plotter data and engineering data for each undeformed plot generated.

29. GP3 generates Static Loads Table and Grid Point Temperature Table.

34. TAI generates element tables for use in matrix assembly and stress recovery.

37. Go to DMAP No. 192 and print error message if no elements have been defined.

40. BFTPRI property optimization module for Level 16.

45. Go to DMAP No. 62 if there are no structural elements.

47. EMG generates structural element matrix tables and dictionaries for later assembly.

50. Go to DMAP No. 53 if no stiffness matrix is to be assembled.

51. EMA assembles stiffness matrix \([K_9^S]\) and Grid Point Singularity Table.

54. Go to DMAP No. 57 if no mass matrix is to be assembled.

55. EMA assembles mass matrix \([M_9^S]\).

58. Go to DMAP No. 62 if no weight and balance request.

59. Go to DMAP No. 188 and print error message if no mass matrix exists.

60. GMPW generates weight and balance information.

61. BFP formats weight and balance information and places it on the system output file for printing.

63. Equivalence \([K_9^S]\) to \([K_9^S]\) if no general elements.

65. Go to DMAP No. 68 if no general elements.

66. SNA3 adds general elements to \([K_9^S]\) to obtain stiffness matrix \([K_9^S]\).

70. \(A\) \([K_9^S]\) and \([P_9^S]\) to form \([K_{total}^S]\).
APPENDIX A

71. Equivalence \([k_{\text{total}}] \text{ to } [K_{gg}] \text{ if coupling phase.}\)

75. Go to next DMAP instruction if cold start or modified restart. LBLII will be altered by the Executive System to the proper location inside the loop for unmodified restarts within the loop.

76. Beginning of Loop for additional constraint sets.

77. GP4 generates flags defining members of various displacement sets (USE1), forms multipoint constraint equations \([R_y]u_y = 0 \) and forms enforced displacement vector \(Y_y\).

79. Go to DMAP No. 190 and print error message if no independent degrees of freedom are defined.

83. Go to DMAP No. 88 if general elements present.

84. GPSP determines if possible grid point singularities remain.

86. Go to DMAP No. 88 if no Grid Point Singularity Table.

87. GPFP formats the table of possible grid point singularities and places it on the system output file for printing.

89. Equivalence \([K_{gg}] \text{ to } [K_{nn}] \text{ if no multipoint constraints.}\)

91. Go to DMAP No. 96 if MCE1 and MCE2 have already been executed for current set of multipoint constraints.

92. MCE1 partitions multipoint constraint equations \([R] = [R_m, R_n] \) and solves for multipoint constraint transformation matrix \([G_m] = \pm [R_m][R_n]\).

94. MCE2 partitions stiffness matrix

\[
[k_{gg}] = \begin{bmatrix}
K_{nn} & K_{nm} \\
K_{mn} & K_{mm}
\end{bmatrix}
\]

and performs matrix reduction

\[
[K_{nn}] = [k_{nn}] + [c^T_n][K_{mn}] + [K_{mn}][G_m] + [G_m][K_{mm}][G_m]
\]

97. Equivalence \([K_{nn}] \text{ to } [K_{ff}] \text{ if no single-point constraints.}\)

99. Go to DMAP No. 102 if no single-point constraints.

100. SPL1 partitions out single-point constraints

\[
[k_{nn}] = \begin{bmatrix}
K_{ff} & K_{fr} \\
K_{sf} & K_{ss}
\end{bmatrix}
\]

103. Equivalence \([K_{ff}] \text{ to } [K_{aa}] \text{ if no omitted coordinates.}\)
APPENDIX A

105. Go to DMAP No. 108 if no omitted coordinates.

106. SMP1 partitions constrained stiffness matrix

\[
[K_{ff}] = \begin{bmatrix}
K_{aa} & K_{ao} \\
K_{oa} & K_{oo}
\end{bmatrix}
\]

solves for transformation matrix \( [G_{o}] = [K_{oo}]^{-1}[K_{oa}] \)

and performs matrix reduction \( [K_{aa}] = [K_{aa}] + [K_{oa}]G_{o} \).

109. Equivalence \( [K_{aa}] \) to \( [K_{kk}] \) if no free-body supports.

112. Go to DMAP No. 122 if initial substructure data reduction (Phase I).

113. Go to DMAP No. 116 if no free-body supports.

114. RBMG1 partitions out-free body supports

\[
[K_{aa}] = \begin{bmatrix}
K_{kk} & K_{kr} \\
K_{rk} & K_{rr}
\end{bmatrix}
\]

117. RBMG2 decomposes constrained stiffness matrix \( [K_{kk}] = [U_{kk}]^{T}[L_{kk}] \).

119. Go to DMAP No. 122 if no free-body supports.

120. RBMG3 forms rigid body transformation matrix

\[
[D] = -[K_{kr}]^{-1}[K_{rr}]
\]

calculates rigid body check matrix

\[
[X] = [K_{rr}] + [K_{kr}]^{T}[D]
\]

and calculates rigid body error ratio

\[
e = \frac{\|X\|}{\|K_{rr}\|}
\]

123. SSG1 generates static load vectors \( [P_{g}] \).

125. Add \( [P_{g}] \) and \( [P_{gs}] \) to form \( [P_{g}]^{\text{total}} \).

126. Equivalence \( [P_{g}]^{\text{total}} \) to \( [P_{g}] \) if coupling phase.

129. Equivalence \( [P_{g}] \) to \( [P_{g}] \) if no constraints applied.
APPENDIX A

132. SSG2 applies constraints to static load vectors

\[
\{P_g\} = \begin{pmatrix} \tilde{P}_n \\ \cdots \\ \tilde{P}_m \end{pmatrix}, \quad \{P_n\} = (\tilde{P}_n) + \left[ G_n^T \right] \{P_m\},
\]

\[
\{P_f\} = \begin{pmatrix} \tilde{P}_f \\ \tilde{P}_s \end{pmatrix}, \quad \{P_f\} = (\tilde{P}_f) - \left[ K_{fr} \right] Y_f,
\]

\[
\{P_a\} = \begin{pmatrix} \tilde{P}_a \\ \tilde{P}_o \end{pmatrix}, \quad \{P_a\} = (\tilde{P}_a) + \left[ G_o^T \right] \{P_o\},
\]

and calculates determinate forces of reaction \( \{q_n\} = -\{P_n\} - \left[ D^T \right] \{P_x\} \).

135. Go to DMAP No. 144 if initial substructure data reduction (Phase I).

136. SSG3 solves for displacements of independent coordinates

\[
\{u_x\} = \left[ K_{xx} \right]^{-1} \{P_x\},
\]

solves for displacements of omitted coordinates

\[
\{u_o^D\} = \left[ K_{oo} \right]^{-1} \{P_o\},
\]

calculates residual vector (RULV) and residual vector error ratio for independent coordinates

\[
\{\delta P_x\} = \{P_x\} - \left[ K_{xx} \right] \{u_x\},
\]

\[
\varepsilon_x = \frac{\{u_x^T\} \{\delta P_x\}}{\{P_x^T\} \{u_x\}}
\]

vector (RULV) and residual vector error ratio for omitted coordinates

\[
\{\delta P_o\} = \{P_o\} - \left[ K_{oo} \right] \{u_o^D\}.
\]
APPENDIX A

\[ e_o = \frac{(u_o^T)(e_P^o)}{(p_o^T)(u_o^o)} \]

139. Go to DMAP No. 142 if residual vectors are not to be printed.
140. MATGPR prints the residual vector for independent coordinates (RULV).
141. MATGPR prints the residual vector for omitted coordinates (RUBV).
145. Go to DMAP No. 149 if no omits.
146. FB5 solve for displacements of the omitted coordinates

\[ (u_o^{Ox}) = [K_{OO}]^{-1}(P_o) \]

147. Equivalence \((u_o^{Ox}) = (u_o^o)\) if initial substructure data reduction (Phase I).
150. OUTPUT1 write a user file on INPT containing analysis set information, \([K_{sL}]\) and \([P_x]\)
152. UDBR recover \((u_x^s)\) from coupling phase user file for substructure SUBID (Phase III)
153. Equivalence \((u_x^s)\) to \((u_x)\) for substructure data recovery.
156. SDR1 recovers dependent displacements

\[
\begin{align*}
\begin{pmatrix}
  u_L \\
  u_r
\end{pmatrix} & = (u_a) , \\
\begin{pmatrix}
  u_L \\
  u_o
\end{pmatrix} & = (u_f) , \\
\begin{pmatrix}
  u_r \\
  u_s
\end{pmatrix} & = (u_f) , \\
\begin{pmatrix}
  u_n \\
  u_m
\end{pmatrix} & = (u_g) , \\
\end{align*}
\]

and recovers single-point forces of constraint

\[ (q_s) = -(p_s) + [K_{ss}^T](u_f) + [K_{ss}](Y_s) . \]

158. Go to DMAP No. 163 if all constraint sets have been processed.
159. Go to DMAP No. 76 if additional sets of constraint are to be processed.
160. Go to DMAP No. 186 and print error message if number of loops exceeds 100.
APPENDIX A

162. Go to DMAP No. 194 and print error message if multiple boundary conditions are attempted with improper subset.

166. SSVE partitions \{\text{u}\} into substructure solution vectors and forms user file.

168. SDR2 calculates element forces and stresses (\text{DES1}, \text{DES1}) and prepares load vectors, displacement vectors and single-point forces of constraint for output (\text{BPGI}, \text{BUCVI}, \text{PUGVI}, \text{PQG1}).

170. OPTPR2 property optimization module for Level 16.

172. Go to DMAP No. 182 if no property optimization print control.

175. OPT formats tables prepared by SDR2 and places them on the system output file for printing.

177. Go to DMAP No. 181 if no deformed structure plots are requested.

178. PLOT generates all requested deformed structure plots.

180. PRTMSG prints plotter data and engineering data for each deformed plot generated.

183. Go to DMAP No. 197 if property optimization looping is finished.

184. Go to DMAP No. 44 if property optimization looping is not finished.

185. Go to DMAP No. 197 and make normal exit.

187. STATIC ANALYSIS ERROR MESSAGE NO. 1 - ATTEMPT TO EXECUTE MORE THAN 100 LOOPS.

189. STATIC ANALYSIS ERROR MESSAGE NO. 2 - MASS MATRIX REQUIRED FOR WEIGHT AND BALANCE CALCULATIONS.

191. STATIC ANALYSIS ERROR MESSAGE NO. 3 - NO INDEPENDENT DEGREES OF FREEDOM HAVE BEEN DEFINED.

193. STATIC ANALYSIS ERROR MESSAGE NO. 4 - NO ELEMENTS HAVE BEEN DEFINED.

195. STATIC ANALYSIS ERROR MESSAGE NO. 5 - A LOOPLING PROBLEM RUN ON NON-LOOPING SUBSET.
APPENDIX B

RIGID FORMAT DMAP LISTING FOR SOL 16, (1,7,8,9)

STATIC SUBSTRUCTURE ANALYSIS PHASE I

Subset 1 of Rigid Format 16 reduces the rigid format to a DMAP sequence which solves Phase I of static substructure analysis. No new modules of interest are included. OUTPUT1, DMAP No. 150, is used to transfer the reduced boundary matrices onto User Files from which they are recovered in Phase II. The compilation listing of this DMAP sequence constitutes the remainder of this Appendix. Subsets 7, 8 and 9 remove non-essential capabilities for the purposes of this presentation. These capabilities, which may be utilized if desired, are:

<table>
<thead>
<tr>
<th>Subset</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Structure plotter</td>
</tr>
<tr>
<td>8</td>
<td>Grid Point Weight Generator</td>
</tr>
<tr>
<td>9</td>
<td>Property optimization</td>
</tr>
</tbody>
</table>

Appendix A contains a full listing of Rigid Format 16.
APPENDIX B

RIGID FORMAT UMAP LISTING
SERIES N BASIC STATIC SUBSTRUCTURE ANALYSIS

RIGID FORMAT 16 - SUBSET ONE, SEVEN, EIGHT, NINE

NASTRAN SOURCE PROGRAM COMPILATION

UMAP-UMAP INSTRUCTION

<table>
<thead>
<tr>
<th>No.</th>
<th>Instruction</th>
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<tbody>
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<td>1</td>
<td>BEGIN</td>
</tr>
<tr>
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<td>FILE</td>
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<tr>
<td>10</td>
<td>GP1</td>
</tr>
<tr>
<td>11</td>
<td>SAVE</td>
</tr>
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<td>12</td>
<td>CHKPN1</td>
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<td>13</td>
<td>GP2</td>
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<tr>
<td>14</td>
<td>CHKPN2</td>
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<td>GP3</td>
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<td>SAVE</td>
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<td>51</td>
<td>PARAM</td>
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<td>PARAM</td>
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<td>SAVE</td>
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<tr>
<td>49</td>
<td>CHKPN5</td>
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</tbody>
</table>

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APPENDIX B

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 16 - SUBSET ONE, SEVEN, EIGHT, NINE

NAS TRAN SOURCE PROGRAM COMPIILATION
UMAP-UMAP INSTRUCTION
NUM
50 COND JMPKGG, NOKGGX $
51 LMA GPECT, KDICT, KELM/KGGX, GPST $
52 CHKPT KGGX, GPST $
53 LABEL JMPKGG $
54 COND JMPKGG, NOKGGX $
55 LMA GPECT, MDICT, KELM/KGGX, C2N=1, Y, MAMSS=1.0 $
56 CHKPT MGG $
57 LABEL JMPMGG $
58 LABEL LOLL $
59 EQUIV KGGX, KGG/N0GENL $
60 CHKPT KGG $
61 COND LOLL4, N0GENL $
62 SNA3 GEI, KGGX/KGG/V2N+LUSET/V2N+NOGENL/V2N+NUSET $
63 CHKPT KGG $
64 LABEL LOLL4 $
65 PARAM //C3N, MPY/V2N, NOSKIP/C3N, O/C3N, O $
67 SAVE MFCF1, MFCF2, SINGLE, OMTL, REACT, NOSKIP, REPEAT, NOSET, NDL, NOS $
68 COND EKUR43, NDL $
69 PARAM //C3N, AND/V2N, NOSR/V2N, SINGLE/V2N, KELT $
70 PURGE KAR, KLR, OR, DM, REACT/GM/MPCF1/U6, K00, L00, PU, U00, U00, RU0V/RU0V/OMIT/PS, KFS/KSS/SINGLE/OG/NOSR $
71 CHKPT KAR, KLR, OR, DM, GM, GO, KCC, L00, PU, U00, RU0V, PS, KFS/KSS, LG, USET, FG, YS, ASET $
72 COND LBL4, GENEL $
73 GP5U GP1, GPST, USET, SIL/OGST/V2N, N0GPST $

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APPENDIX B

RIGIU FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGIU FORMAT 16 - SUBSET ONE, SEVEN, EIGHT, NINE

NASTKAN SOURCE PROGRAM LUMPILATION
UMAP-UMAP INSTRUCTION
NO.

  65   SAVE   NUPST $  
  86   COND   LBL4,NOGPST $  
  87   QFP    UGPST,,/V,N,CARDNUM $  
  88   LABEL  LBL4 $  
  89   EQUIV  KGG,KNN/MCEF1 $  
  90   CHKPT   KIN $  
  91   COND   LBL2,MCEF2 $  
  92   MCEF1  USET,GG/G4 $  
  93   CHKPT   G4 $  
  94   MCEF2  USET,GK,KGG,,,/KNN,,, $  
  95   CHKPT   KNN $  
  96   LABEL  LBL2 $  
  97   EQUIV  KNN,KFF/SINGLE $  
  98   CHKPT   KFF $  
  99   COND   LBL3,SINGLE $  
 100  MCEF3  USET,KNN,,,/KFF,KFS,,/S,, $  
 101  CHKPT   KFS,KSS,KFF $  
 102  LABEL  LBL3 $  
 103  EQUIV  KFF,KAA/OMIT $  
 104  CHKPT   KAA $  
 105  COND   LBL3,OMIT $  
 106  SMPI   USET,KFF,,,/GO,KAA,KCC,LOD,,,, $  
 107  CHKPT   GU,KAA,KCC,LOD $  
 108  LABEL  LBL5 $  
 109  EQUIV  KAA,KLL/REACT $  
 110  CHKPT   KLL $  

355
APPENDIX B

RIGID FORMAT 16 - SUBSET ONE, SEVEN, EIGHT, NINE

NASTRAN SOURCE PROGRAM COMPILATION

UHAP-UHAP INSTRUCTION

NUM.

111 PARAM //C,N,SUB/V,N,PHASE1/C,N,O/C,Y,SubI=0 $

112 COND LBL7,PHASE1 $

113 COND LBL6,REACT $

114 RBMG1 USET,KAA/KLL,KLR,KRR,... $

115 CHAPNT KLL,KLR,KRR $

116 LABEL LBL6 $

117 RBMG2 KLL/LLL $

118 CHAPNT LLL $

119 COND LBL7,REACT $

120 RBMG3 LLL,KLR,KRR/DM $

121 CHAPNT GM $

122 LABEL LBL7 $

123 SSG1 SLT,GPDT,CSMT,SIL,EST,MPT,GFTT,CLT,NGH,CASECC,ULT/PG/V/N,

USET/V,N,NSKIF $

124 CHAPNT PU $

128 EQUV PU,PL/NOSET $

130 CHAPNT PL $

131 COND LBL10,NOSET $

132 SSG2 USET,G,M,Y5,KFS,GO,OM,PG/QR,PO,PS,PL $

133 CHAPNT WR,PU,PS,PL $

134 LABEL LBL10 $

145 COND SKIP,OMIT $

146 FBS LOO,PO/UNOVX $

147 EQUV UNOVX,UNOV/PHASE1 $

148 CHAPNT UNOV $ .

149 LABEL SKIP $

150 OUTPUT USET,KLL,PL++,//C,N=-1/C,N,O/C,Y,USBTR101 $
APPENDIX B

RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 10 - SUBSET ONE, SEVEN, EIGHT, NINE

NASTRAN SOURCE PROGRAM COMPIILATION
DMAP-DMAP INSTRUCTION NU.
185 JUMP FI.15 $
188 LABEL ERROR2 $
169 PRTPARM //C,N,-2/C,N,STATICS $
190 LABEL ERROR3 $
191 PRTPARM //C,N,-3/C,N,STATICS $
192 LABEL ERROR4 $
193 PRTPARM //C,N,-4/C,N,STATICS $
196 LABEL FINISH $
197 END $

**NO ERRORS FOUND - EXECUTE NAUTRAN PROGRAM**
APPENDIX C

RIGID FORMAT DMAP LISTING FOR SOL 16, (2,6,7,8,9)

STATIC SUBSTRUCTURE ANALYSIS PHASE II

Subset 2 of Rigid Format 16 reduces the rigid format to a DMAP sequence which solves Phase II of static substructure analysis. The new modules of interest are SSMA, the Substructure Matrix Assembler, DMAP No. 6, and SSVE, the Substructure Vector Extractor, DMAP No. 166. The compilation listing of this DMAP sequence constitutes the remainder of this Appendix. Subsets 6, 7, 8 and 9 remove non-essential capabilities for the purposes of this presentation. These capabilities, which may be utilized if desired, are:

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Appendix A contains a full listing of Rigid Format 16.
APPENDIX C

RIGIU FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGIU FORMAT 10 - SUBSET TWO, SIX, SEVEN, LIGHT, NINE

NAS T R A N S O U R C E P R O G R A M L U M P L A T I O N
UMAP-UMAP INSTRUCTION

1 BEGIN NU16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N &
2 FILE LLL=TAPE $
3 FILE W=APPEND/PGE=APPEND/UV=APPEND/WM=SAVE/KNN=SAVE &
5 PARAM //CN,ADD,V,N,PHASEZ/CN,OG,CN,1 $
6 SAVE //UFTABLE/KGGRS,3,PURS,PQDATA/C,T,RTUPT/CY,USERSAME/V,N/LUSET $
7 SAVE LUSET $
10 GP1 GEOM1,GFDM2;/GPE=EXIN,UPDT,CSTM,BGDP1,.. /V,N,LUSET/V,N,
NUGRP $
11 SAVE LUSET $
12 CKPNT GPL=EXIN,GPDT,CSTM,BGDP1,SIL &
13 GP2 w=UGM2,EOEXIN/ECT $
29 GP3 GEOM3,EOEXIN,GEOM2/SLT,STT/V,N,N-GE1V $
30 SAVE NUGRAV $
31 PARAM //CN,AND/V,N,NCMG/V,N,NOGRAV/V,Y,UFUPNT=1 $
32 PURGE PGM=ELM,M=DOCT/NOMGR $
34 EM1 ECT,EP1,BGDP1,SIL,STT,V,N,LUSET/V,Y,LUSET/V,N,
NUSIMP/CN,1/V,N,NOGENL/V,N,GENEL $
35 SAVE NUSIMP,NOGENL,GENEL $
36 PARAM //CN,AND/V,N,NOELMT/V,N,NOGENL/V,N,NUSIMP $
28 PURGE KGGA,GPST/NOSIMP/DPSTGENEL $
45 UENO LG,1,V,N,SIMP $
46 PARAM //CN,ADD/V,N,NOFGNX/CN,1/CN,1 $
47 EMG LST,CSTM,HPPT,EP1,GEOM2,HELPE=MULT,M=ELM,M=MULT $ /V,N,UGGRX/V,
N,C0/MAG/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/CN,1/
CPWPT/CY,CPRPTPLT/CY,CGTADUL $
48 SAVE UGGRX,NUMGR $
APPENDIX C

RIGID FORMAT UMAP LISTING
SCHEDULES III UMAP STATIC SUB-STRUCTURE ANALYSIS III

RIGID FORMAT II - SUBSET TWO, SIX, SEVEN, EIGHT, NINE

NATURAL SOURCE PROGRAM COMPIlATION

DATA-UMAP INSTRUCTION NUMBER

50 CND U JMPUG,NOOGGX $

51 EMA U PEECT,KDICT,KELM/1KGX,GPST $

53 LABEL JMPKUG $

54 CND U JMAPUG,NOOGG $

55 EMA U PEECT,KDICT,KELM/HUG,UCN-1/UX,IMTH,SOD$

57 LABEL JMPKGG $

62 LABEL LBL1 $

63 EQUIV KUGKX/KGG/KCGENL $

65 CND U LBL11A,NOCEFL $

66 SMAJ U E1,KGX/KGG/VX,NLUSET/VX,NKGENL/VX,NOUSIMP $

68 LABEL LBL11 $

70 ADD KUGKGEPS/KGGE $

71 EQUIV KGGT,KCG/PHASE2 $

74 PARAM //C,N,MY/VX,NSKIP/CN0/CN0 $

75 JUMP LBL11 $

76 LABEL LBL1 $

77 CPA CASECC, GEDM, EQFXIN, SIL, GDPOT/UX, TSUSET/ADLT/VX,NLUSLT/ VX,MPF1/VX,NSMPF2/VX,N SINGLE/VX,NSUNIT/VX,NKHALT/VX,NSKIF/VX, KPLAT/VX, NOSSET/VX, NCL/VX, NUM/LX, SUBLU $

78 SAVE MPF1, MPF2, SINGLE, VUX, REACT, NSKIP, REPLAT, NOSET, NOU, NOA $

79 CND U ERRUS, NOL $

80 PARAM //C,N,AND/VX,NSORKA/VX,N SINGLE/VX,NS REACT $

81 PURGE KRR, RKL, OR, OM, RFAC/TG/MPF1/VU, RLVU, P0, UOUV, NUOV/UNIT/PS, KPS, KSS/SINGLE/OQ/NSK $

82 EQUIV KUG, KN, M/MPF1 $

90 CND U LBL2, MPF2 $

92 ACE1 USEI, PG, TN $

94 ACE2 USET, GM, KGG, KNN, KMM
APPENDIX C

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STIFIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET TWO, SIX, SEVEN, LIGHT, NINE

NASA TRANSVERSE PROGRAM COMPILATION
UMAP-UMAP INSTRUCTION

96 LABEL LBL2 $
97 EQUIV KNN,KFF/SINGLE $
99 CUND LBL3,SINGLE $
100 $102 LABEL LBL5 $
103 EQUIV KFF,KAA/OMIT $
105 CUND LBL5,OMIT $
106 SMPL USET,KFF,G0,KAA,KCC,LOU, $
108 LABEL LBL5 $
109 EQUIV KAA,KLL/REACT $
113 CUND LBL6,PFEAT $
114 $116 LABEL LBL6 $
117 CUND LBL7,REACT $
119 CONJ LBL7,REACT $
120 $$122 LABEL LBL7 $
123 SS41 SLT,GPDT,KSTY,SIL,EST,MPT,GPIT,LUT,MGG,CADLCC,DIT/PG/V,N,
LUSE/VE/N,5KTS $
125 ADD PG,PG/PS/PST $
126 EQUIV PG,PG/PHASE2 $
129 EQUIV PG,PL/NOSET $
131 CONJ LBL10,NOSET $
132 SS42 USET,GY5,KFF,GO,DM,PG/QR,PO,PS,PL $
134 LABEL LBL10 $
136 SS43 LLL,KLL,PL,LCO,KOD,PO/ULV,UCOV,MULV,MUV/V,N,UMIT/V,Y,RES=-1/
V,N,NSKL/V,N,EPSI $

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APPENDIX C

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 10 - SUBSET TWO, SIX, SEVEN, EIGHT, NINE

HAMSTRANSOURCEPROGRAM COMPIRITION
UMAP-UMAP INSTRUCTION
NUM.

137 SAVE EPSI $
139 CUND L59,1RES $
140 MATPR GDL,USE,T,SIL,RULV/C,N,L $
141 MATPR GDL,USE,T,SIL,UDUV/C,N,O $
142 LABEL L59 $
156 SDK1 USET,PG,ULV,UDUV,V5,GO,GM,PS,NFS,KS,WR/UV,PGG,PG/V,N,NSKIP/
CN,STATICS $
158 CUND L59,REPEAT $
159 REPT L59,100 $
160 JUMP ERUR1 $
161 PARAM /C,N,NOT/V,N,TEST/V,N,REPEAT $
162 CUND ERURN-TEST $
163 LABEL L58 $
166 SAVE PSUATA,UUGV/ $
168 SUZ2 LASEC,CSTM,MPT,OT1,EGEX1N,SIL,UV,TI,ULI,UPUT1,ULV1,PGG,EG1,UGV1,ODE1,ODE2,
UPG1,GCG1,UGV1,ODE1,ODE2,PGV1/AN,STATICS $
174 PARAM /C,N,MPY/V,N,CARUMO/C,N/O/C,N,O $
175 OFP UUGV1,PG1,UGG1,ODE1,ODE2)//V,N,CARUMO $
176 SAVE CARUMO $
185 JUMP FINIS $
186 LABEL EIRUR1 $
187 PRIPARM /C,N,-1/C,N,STATICS $
188 LABEL EIRUR2 $
189 PRIPARM /C,N,-2/C,N,STATICS $
190 LABEL EIRUR3 $  
191 PRIPARM /C,N,-3/C,N,STATICS $  
194 LABEL ERRUR $
APPENDIX C

RIGID FORMAT DMAP LISTING

SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET TWO, SIX, SEVEN, EIGHT, NINE

NASTRAN SOURCE PROGRAM LUMPILATION
DMAP-DMAP INSTRUCTION

155 PRTPARM //C,N, -5/C,N,STATICS $
156 LABEL   FINIS $
157 END   $

**NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**
APPENDIX D

RIGID FORMAT DMAP LISTING FOR SOL 16,(3,6,7,8,9)

STATIC SUBSTRUCTURE ANALYSIS PHASE III

Subset 3 of Rigid Format 16 reduces the rigid format to a DMAP sequence which solves Phase III of static substructure analysis. A new module of interest is UDBR, the User File Data Block Recovery, DMAP No. 152. The compilation listing of this DMAP sequence constitutes the remainder of this Appendix. Subsets 6, 7, 8 and 9 remove non-essential capabilities for the purposes of this presentation. These capabilities, which may be utilized if desired, are:

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Appendix A contains a full listing of Rigid Format 16.
APPENDIX D

RIGIU FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGIU FORMAT Lo - SUBSET THREE, SIX, SEVEN, EIGHT, NINE
NAS TRANS SOURCE PROGRAM COMPI LATION
DMAP-UXAP INSTRUCTION

1 BEGIN NO. 16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N $  
2 FILE LLL=TAPE $  
10 GP1 GEOM, GEOM2, GPL, E2EXIN, GPDT, CSTM, DUPUT, SIL/V, N, LUSET/V, N,  
NUGPRT $  
11 SAVE LUSET $  
12 CMKPNT GPL, E2EXIN, GPDT, CSTM, RGPDT, SIL $  
13 GP2 GEUM2, E2EXIN/ECT $  
29 GP3 GEOM3, E2FXIN, GEOM2/SLT, GPTT/V, N, NUGRAV $  
30 SAVE NUGRAV $  
31 PARAM //C, N, AND/V, N, NOMGG/V, N, NUGRAV/V, Y, NUGPNT=-1 $  
32 PURGE MGG, MELM, MDICT/NO MG $  
34 TAI LCT, EPT, RGPDT, SIL, GPTT, CSTM/EST, ULI, GPECT/V, N, LUSET/V, N,  
NUSIMP/C, N, I/V, N, NGEHEL/V, N, NGENEL $  
35 SAVE NOSIMP, NOGENL, GENEL $  
36 PARAM //C, N, AND/V, N, NOELMT/V, N, NGENEL/V, N, NUSIMP $  
37 COND ERROR4, NOELMT $  
38 PURGE KGGX, GPST/NOSIMP/OGPST/GENEL $  
45 COND LBL1, NOSIMP $  
46 PARAM //C, N, ADD/V, N, NOKGGX/C, N, I/C, N, 0 $  
47 GMG LST, CSTM, N, MPT, DIX, GEOM2, KEL, M, AUILT, MELM, AULT, III/V, N, NOKGGX/V,  
N, NOKGGX/C, N, I/C, N, GCG, CF2PMASS/C, Y, CF2BAR/C, Y, CPKD/C, Y,  
CPJUAD1/C, Y, CF2QUAD/C, Y, RTPS/X/CF2TRIA2/C, Y, CFTPUBE/C, Y,  
CPFDPIT/C, Y, CPTRPLT/C, Y, CPTRAVL $  
48 SAVE NOKGGX, NOMGG $  
50 COND JMPKG5, NOKGGX $  
51 EMA GPECT, KDICT, KELM/KGGX, GPST $  
53 LABEL JMPKGG $  
54 COND JMPMUG, NOMGG $  

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APPENDIX D

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT Lo - SUBSET THREE, SIX, SEVEN, EIGHT, NINE

NAS TRA N S O P C E PROGRAM COMPI LATION
UMAP-UMAP INSTRUCTION N U.

55 EMA GPECT,MDICT,HELM/MUG,/C,=1/C,Y,=TMASS=1.0 $
57 LABEL JMPHUG $
62 LABEL LBI1 $
63 EQUIV KUGX,KGG/NOGENL $
55 COND LBL11A,NOGENL $
66 EMA3 GE1,KGGX/KGG/V,N,LUSET/V,N,NOUGENL/V,N,NOSIMP $
68 LABEL LBL11A $
74 PARAM //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $
77 GP4 CASECC,GEOM,DEQEX,K,SIL,GPOT/NU,Y,USET,=SEL/V,N,LUSET/V,N,
MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,HEMT/V,N,NSKIP/V,N,
REPEAT/V,N,NOSE//V,N,NOL/V,N,NOA/L,V,SUBIU $
78 SAVE MPF1,MPF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,LUSET,NUL,NOA $
79 COND ERR0A3,NUL $
80 PARAM //C,N,AND/V,N,NOSR/V,N,SINGLE/V,N,REACT $
81 PURGE KAR,ALR,07,DM/REACT/GK/MPF1/NU,KU,LU,PU,UCV,UCV/KU/V,OMIT/PS,
KFS,KSS,SINGLE/OG/NOSR $
83 COND LBL4,GENEL $
84 GPSP GPL,GPST,LUSET,SIL/OGPST/V,N,NUGPST $
85 SAVE NUGPST $
86 COND LBL4,NUGPST $
87 OGP OGPST,......//V,N,CARDNC $
88 LABEL LBL4 $
89 EQUIV KGG,KNN/MPF1 $
91 COND LBL2,MPF2 $
92 MCE1 USET,AG/CH $
94 MCE2 USET,GM,KGG,///KNN, $
96 LABEL LBL2 $
97 EQUIV KNN,KFF/SINGLE $

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APPENDIX D

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 16 - SUBSET THREE, SIX, SEVEN, EIGHT, NINE

NASTRAN SOURCE PROGRAM COMPIIATION
UMAP-UMAP INSTRUCTION

NO.

99 COND LBL3,SINGLE $

100 SCGL USET,KNN,+/KFF,KFS,KSS,± $

102 LABEL LBL3 $

103 EQUIV KFF,KAA/OMIT $

105 COND LBL5/OMIT $

106 OMPI USET,KFF,+/GO,KAA,KGC,LOU,±± $

108 LABEL LBL5 $

109 EQUIV KAA,KLL/REACT $

113 COND LBL6/REACT $

114 RBMG1 USET,KAA,+/KLL,KLP,KRR,± $

116 LABEL LBL6 $

117 RBMG2 KLL/LLI $

119 COND LBL7/REACT $

120 RBMG3 LLL,KLR,KRR/DM $

122 LABEL LBL7 $

123 SSG1 SLT,GOPT,CSTM,STL,EST,MPG,GPP,T,LUT,MCU,CASECC,DIR/PG/V,N,
        LUSET/V,N,N,SKIP $

129 EQUIV PG,PL/NOSET $

131 COND LBL10,NOSET $

132 SSG2 USET,GM,YS,KFS,GO,OM,PG/QR,PG,PS,PL $

134 LABEL LBL10 $

136 SSG3 LLL,KLL,PL,LCG,COO,PG/ULV,UCCV,ULV,UVUV,V,N,UNIT/V,Y,INES=-1/
        V,N,SKIP/V,K,EPSI $

137 SAVE EPSI $

139 COND LBL9,INES $

140 MATGR GPL,USET,STL,RULV/CM,N,L $

141 MATGPA GPL,USET,STL,RULV/CM,N,0 $

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APPENDIX D

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 16 - SUBSET THREE, SIX, SEVEN, EIGHT, NINE

NASTRAN SOURCE PROGRAM COMPIILATION
DAAP-UMAP INSTRUCTION

142 LABEL LBL9 $
151 PARAM //C\_N\_ADD/Vn,PHASE3/C\_N\_O/C\_N\_I
152 ULVR /ULVX++,C\_Y,SURIO/C\_Y,UNIT/C\_Y,USRTPID2 $
153 EWU1V ULVX,ULV/PHASE3 $
156 SUR1 USER1,PG,ULV,UGDV,YS,GC,GM,PS,AFS,KS,S,UK/UUV,PGU,UG/Vn,NSKIP/
C\_N\_STATICS $
161 PARAM //C\_N\_NOT/Vn,TEST/Vn,REPEAT $
162 CUNO ERROR5,TEST $
168 SUR2 CASECC,CSTM,MPT,DIT,EGEXIN,SIL,UPIT,LUT,UGPUT++,UG,+UUV,EST,,PGG/
UPG1,OGG1,OGGV1,GE1,CEF1,PUGV1/L\_N\_STATICS $
174 PARAM //C\_N\_MPY/Vn,CARDNO/C\_N\_O/C\_N\_U $
175 DFP UGV1,OGG1,OGGV1,GE1,CEF1//Vn,CARDNO $
176 SAVE CARUNO $
185 JUMP FINISH $
188 LABEL ERROR2 $
189 PTRPAM //C\_N\_2/C\_N\_STATICS $
190 LABEL ERROR3 $
191 PTRPAM //C\_N\_3/C\_N\_STATICS $
192 LABEL ERROR4 $
193 PTRPAM //C\_N\_4/C\_N\_STATICS $
194 LABEL ERROR5 $
195 PTRPAM //C\_N\_5/C\_N\_STATICS $
196 LABEL FINISH $
197 END $

**NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**

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APPENDIX E

RIGID FORMAT DMAP LISTING FOR SØL 17,(2,6,7,8)
NORMAL MODES SUBSTRUCTURE ANALYSIS PHASE II

Subset 2 of Rigid Format 17 reduces the rigid format to a DMAP sequence which solves Phase II of normal modes substructure analysis. The new modules of interest are SSMA, the Substructure Matrix Assembler, DMAP No. 5, and SSVE, the Substructure Vector Extractor, DMAP No. 127. The compilation listing of this DMAP sequence constitutes the remainder of this Appendix. Subsets 6, 7 and 8 remove non-essential capabilities for the purposes of this presentation. These capabilities, which may be utilized if desired, are:

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APPENDIX E

RIIGI FORMAT DMAP LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURAL ANALYSIS ***

RIIGI FORMAT 17 - SUMSET TWO, SIX, SEVEN, EIGHT

N A S T R A N S O U R C E P R O G R A M L I N K I L A T I O N

DMAP-DMAP INSTRUCTION NO.

1 BEGIN RIGI17 BASIC NORMAL MODES SUBSTRUCTURAL ANALYSIS - SERIES N $
2 FILE LLL=TOP $ 
5 UEMH, UTABLE/KGGPS, MGGPS, MGGP, PSUATA/C, Y, PKTUPT/C, Y, GENSAKE/V, N, 
   LUSET $ 
6 SAVE LUSET $ 
7 CHKPT KGGPS, MGGPS, PSUATA $ 
9 GP1 UEMH, GEOH2/GPL, EQEIX, GPDT, CSTH, BGPDT, SIL/V, N, LUSET/ V, N, 
   NUGP $ 
10 SAVE LUSET $ 
12 GP2 UEMH, EQEIX/ECT $ 
29 GP3 CEUM3, EQEIX, GEOH2, GPDT/V, N, NUGP $ 
30 ITI ECT, EPT, BGPDT, SIL, GPDT, CSTH/EST, BPT, OPECT/V, N, LUSET/ V, N, 
   NUSIMP/C, N, 1/V, N, NOGENL/V, N, GENEL $ 
31 SAVE NOGENL, NOSIMP, GENEL $ 
32 PARAM //C, N, ADD/V, N, NOELTS/V, N, PHASE2/V, N, NUSIMP $ 
33 CUND ERR1, NOELTS $ 
34 PURGE KGGX, GOST, MGG/MOSIMP/CGPST/GENEL $ 
36 CUND LBL1, NCSIMP $ 
37 PARAM //C, N, ADD/V, N, NOGGX/C, N, 1/C, N, 2 $ 
38 PARAM //C, N, ADD/V, N, NOGGX/C, N, 1/C, N, 2 $ 
39 EMU ECT, CSTH, BPT, DIT, GEOM2/KELM, KULT, HCLM, MDULT, V, N, 1/V, N, UGGX/V, 
   CPQADIC/C, Y, CPQADIC/C, Y, CPTRIML/C, Y, CPDKIA2/C, Y, CPDFUNE/C, Y, 
   CPDFUNL/C, Y, CPTRPLT/C, Y, CPTRUBL $ 
40 SAVE NOGGX, NOUXX $ 
42 CUND JMPGOOD, NOUGGX $ 
43 ENA GPCT, KDICT, XELM/KGGX, GPST $ 

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APPENDIX E

RIGID FORMAT UMAI LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 17 = SUBSET TWO, SIX, SEVEN, EIGHT

NASTRAN SOURCE PROGRAM Compilation
UMAP=UMAP Instruction

45 LABEL JMPKG $ 46 COND ERROR1, '0'MG $ 47 CMA UPEC1, MCIC, ELEM/HMG, /C, N, -1/4, Y, *TRAS=1.0 $ 52 LABEL LBL1 $ 53 EQUIV KUGA, KGG/KOGEN $ 54 CHKPT KGG $ 55 COND LBL11, KOGENL $ 56 SMA GE1, KGG/KG/KNL/VN, LUS/VTN, NOGENL/VN, NOSIMP $ 58 LABEL LBL11 $ 60 ADU KGG, KGP/KG $ 61 EQUIV KGFT, KGG/PHASE2 $ 62 ADU MUG, MGG/KG $ 63 EQUIV MUGT, MGG/PHASE2 $ 65 CHKPT KGG $ 67 PARAM /C, N, MPY/VN, NSkip/C, N, 0/C, N, 0 $ 68 GP4 CASECG, GCOM, GKKIN, SIT, GPDT/KV, USF, USET/ASSET/VN, LUS/VN, VN, MCS=V, VN, MPFC2/VN, SINGLE/VN, UNIT/VN, NE/VT, VN, NSkip/VN, REPS/VN, NOSET/VN, NGA/VN, NUA/VN, SUBDU $ 69 SAVE MPFC1, MPFC2, SINGLE, ORIT, REACT, NSkip, MREPS, TNOSET, NOL, NOA $ 70 COND ERRUR3, NOL $ 71 PURGE KAR, KLP, DM, MLR, MR/REAC/GM/MPCF2/AD/UNIT/KFS/SINGLE/UG/NUSE $ 79 EQUIV KGG, KNN/MPCF1/MGG, MNN/MPCF1 $ 81 COND LBL2, MPFC2 $ 82 MCEL USF, RG/ON $ 84 MCEL LUS, GM, KGG, MGG, KNN, MNN $ 86 LABEL LBL2 $ 87 EQUIV KNN, KF/F/SINGLE, MAN, MFF/SINGLE 6

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APPENDIX E

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC NORMAL MASSES SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 17 - SUBSET TWO, SIX, SEVEN, EIGHT

NA STR ANS C U R E P R O G R A M  C O M P I L A T I O N
DRAF-UMAP INSTRUCTION

89 COND LBL3,SINGLE $
90 $CC1 USET,KNM,MMN,/,KFF,KFS,,KFF,, $
92 LABEL LBL3 $
93 EQUIV KFF,KAA,OMIT $
94 EQUIV KFF,MA8,OMIT $
96 COND LBL5,OMIT $
97 $MP1 USET,KFF,,,GO,KAA,KOC,LOG,++++, $
99 $MP2 USET,GO,KFF,MAA $
101 LABEL LBL5 $
106 CCNU LDO,REACT $
107 $BP1 USET,KAA,MAA/KLL,..LR,..KL,..MLA,..MAH $
109 $BP2 KLL/LLL $
111 $BP3 LLL,KLP,KRR/CM $
113 $BP4 UM,MLL,MLR,MPS,MHR $
115 LABEL LDO $
117 SAVE NUEEU $
118 COND EKRUZ,NGEED $
120 $KAA KAA,MAA,MROM,EE0,USET,CASECC/LAM,PHIA,MLI0,SL/C,Modes/Vh, NEIGV $
121 SAVE NEIGV $
123 $FAM //Vh,NMPY/Vh,NCARNO/C,M0/C,M0 $
124 $FPP LAM,DEIGS,++++//Vh,NCARNO $
125 SAVE CAAUH0 $ 127 SAVE $PSDALL,L3MA,PHIA/ $
133 $END FINIS,NEIGV $
APPENDIX E

RIGID FORMAT UMAP LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS ***
RIGID FORMAT 17 - SUBSET TWO, SIX, SEVEN, EIGHT

NASTRAN SOURCE PROGRAM COMPIATION
OMAP-OMAP INSTRUCTION

134  @L1=  USET++P14,,,GO+G4G+XFS++/PHI++/-home/CnN+AC16 &
136  PARAM /CnN,SAU/VnN,SCALAR/VnN,SIL/VnN,LUSET &
137  EQUIV SIL,SIP/SCALAR/BGPD,BGPD/SCALAR &
139  CUND LBL7,SCALAR &
140  QLTRAN BUPT,VnN,BGPD,BGPD,SIP/VnN,LUSET/VnN,LUSEP &
141  SAVE LUSEP &
143  LABEL LBL7 &
148  QUA2 CASELC,CSTM,MPT,DIT,E2XIN,SIL,...GPDP,LMAN++,PHI++EST+/ &
    UPHG=OPHG,DES1,DEF1,OPHG/CnN,AC16 &
149  OFF UPHG=OPHG,DEF1,DES1,++/VnN,CMUWH &
150  SAVE CMUWH &
156  JUMP FINIS &
157  LABEL ERROR1 &
158  PRTPARM /CnN,-1/CnN,MODES &
159  LABEL ERROR2 &
160  PRTPARM /CnN,-2/CnN,MODES &
161  LABEL ERROR3 &
162  PRTPARM /CnN,-3/CnN,MODES &
163  LABEL FINIS &
164  END &

**NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**
APPENDIX F
UTABLE USAGE WITH RIGID FORMATS 16 AND 17

Subset 0 requires a dummy form of the direct input table UFTABLE as shown:

<table>
<thead>
<tr>
<th>Card</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DTI UFTABLE 0</td>
<td>4</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DTI UFTABLE 1</td>
<td>2</td>
<td></td>
<td>INP1 WIDGET02</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DTI UFTABLE 2</td>
<td>4</td>
<td></td>
<td>INP2 WIDGET04</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DTI UFTABLE 3</td>
<td>6</td>
<td></td>
<td>INP3 WIDGET06</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DTI UFTABLE 4</td>
<td>9</td>
<td></td>
<td>INP4 WIDGET09</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DTI UFTABLE 5</td>
<td>0</td>
<td></td>
<td>INPT WGTPh2</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subsets 1 and 3 do not need or use UFTABLE.

Subset 2 requires UFTABLE for information about the Phase I user files, identification of identical substructures, and, if desired, a user defined label for the coupling phase output user file. The content of the table will vary depending on where the Phase I materials were generated (e.g., Rigid Format 16 subset 1 or Rigid Format 1 with alters). The minimum data requirements are illustrated in example a. below with example b. showing the form for identifying items generated by rigid formats other than the coupling phase rigid format.

EXAMPLE a. (four substructures, N=4)

<table>
<thead>
<tr>
<th>Card</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DTI UFTABLE 0</td>
<td>4</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DTI UFTABLE 1</td>
<td>2</td>
<td></td>
<td>INP1 WIDGET02</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DTI UFTABLE 2</td>
<td>4</td>
<td></td>
<td>INP2 WIDGET04</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DTI UFTABLE 3</td>
<td>6</td>
<td></td>
<td>INP3 WIDGET06</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DTI UFTABLE 4</td>
<td>9</td>
<td></td>
<td>INP4 WIDGET09</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXAMPLE b. (five substructures, N=5)

<table>
<thead>
<tr>
<th>Card</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DTI UFTABLE 0</td>
<td>5</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DTI UFTABLE 1</td>
<td>10</td>
<td></td>
<td>INP1 GROUP4</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3a</td>
<td>DTI UFTABLE 2</td>
<td>13</td>
<td></td>
<td>INP4 PLT4 104823</td>
<td>HAMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3b</td>
<td>+AO2 A AS13B K</td>
<td></td>
<td>KLL13 M M13EF</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>DTI UFTABLE 3</td>
<td>23</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DTI UFTABLE 4</td>
<td>16</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6a</td>
<td>DTI UFTABLE 5</td>
<td>237</td>
<td></td>
<td>INP3</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6b</td>
<td>+AO6 A 3 K</td>
<td></td>
<td>1 M 2</td>
<td>ENDREC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Remarks:

1. Card 1 defines the trailer for UFTABLE. Field 4 specifies that the table has N substructures. SSMA will use the information in field 5 to recognize that the tables were prepared for use with Rigid Format 16 and 17 for examples a and b respectively.

2. Cards starting with card 2 define records 1 thru N of UFTABLE, where N is the number of substructures. Field 4 gives the substructure identification number for use with the Phase II SAME bulk data cards and the Phase III data recovery module UDBR. Field 6 gives the GINØ file name for the User File containing the data for each substructure. Field 7 contains the User File Label for SSMA verification. Field 8 contains an optional tape reel identification number.

3. Optional data (shown in example b on card 3) is input whenever the data blocks required are not in the expected order on the User File as defined by the convention established for the Rigid Format being utilized. In the example, the ASET data block has the name AS13B, the stiffness matrix has the name KLL13 and the mass matrix has the name M134F.

4. In example a, card 6 defines the User File Label and GINØ file name to be used by SSVE when writing the Phase II output onto a User File. In example b, since five substructures are present and no card 7 is input, default values will be automatically implied.
APPENDIX G
SAMPLE PROBLEM DATA DECK LISTING

As an illustration of the automation that is introduced as a result of this new capability, the example used in the NASTRAN User's Manual (reference 2, p. 1.10-2 (6/1/72)) will be presented here. The sketch below shows the model for the problem being solved.

Substructure 1

Substructure 2

1. Grid point numbers
2. Element numbers
3. \( b = 6.096 \text{ m} \) (240 in)
4. \( E = 207 \text{ GPa} \) \((30 \times 10^6 \text{ psi})\)
5. \( I = 2.08 \times 10^{-4} \text{ m}^4 \) \((500 \text{ in}^4)\)
6. \( P = 4,448 \text{ kN} \) \((1000 \text{ lb})\)
APPENDIX G

The following data deck is used for Phase I of substructure 1:

ID PHASE ONE $
TIME 2
CHKPNT YES
APP DISP
SØL 16,1
CEND
TITLE = PHASE ONE - SUBSTRUCTURE 1 - RIGID FORMAT 16
SPC = 101
BEGIN BULK
ASET 3 126
CBAR 1 10 1 2 1.0 1
CBAR 2 10 2 3 1.0 1
GRID 1 345
GRID 2 240. 345
GRID 3 480. 345
MAT1 II 30.+6
PARAM SUBID 10
PARAM USRTP1I BEAMS1
PBAR 10 11 60. 500.
SPC 101 1 12
ENDDATA
APPENDIX G

The following data deck is used for Phase 1 of substructure 2:

```
ID      PHASE ONE
TIME    2
CHKPNT  YES
APP     DISP
SOL     16,1
CEND
TITLE = PHASE ONE - SUBSTRUCTURE 2 - RIGID FORMAT 16
SPC = 201
LOAD = 202
BEGIN BULK
ASET 3 126
CBAR 3 10 3 4 1.0 1
CBAR 4 10 4 5 1.0 1
CBAR 5 10 5 6 1.0 1
FORCE 202 3 1000. -1.0
FORCE 202 4 1000. -1.0
GRID 3 480. 345
GRID 4 720. 345
GRID 5 960. 345
GRID 6 1200. 345
MAT1 11 30. +6
PARAM SUBID 20
PARAM USRTPID BEAMS2
PBAR 10 11 60. 500.
SPC 201 6 2
ENDDATA
```
APPENDIX G

The following data deck is used for Phase II.

ID       PHASE TWO
TIME     2
APP      DISP
SØL     16,2
CEND
TITLE = PHASE TWO - RIGID FORMAT 16
BEGIN BULK
DTI UFTABLE 0 2 16
DTI UFTABLE 1 10 INP3 BEAMS1 ENDREC
DTI UFTABLE 2 20 INP7 BEAMS2 ENDREC
DTI UFTABLE 3 0 INPT BEAMPH2 ENDREC
PARAM GENSAME 1
ENDDATA

The NASTRAN Data Deck for the Phase III analysis of substructure 1 is given as follows:

ID       PHASE THREE $
TIME     2
APP      DISP
SØL     16,3
READ CARDS FROM 3 $ RESTART DICTIONARY FROM UNIT 3
CEND
TITLE = PHASE THREE - SUBSTRUCTURE 1 - RIGID FORMAT 16
DISP = ALL
ELFØRCE = ALL
ØLØAD = ALL
SPCFØRCE = ALL
BEGIN BULK
PARAM USRIPID2 BEAMPH2
ENDDATA

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APPENDIX G

The NASTRAN Data Deck for the Phase III analysis of substructure 2 is given below:

ID PHASE THREE $
TIME 2
APP DISP
SØL 16,3
READ CARDS FROM 92 $ RESTART DICTIONARY FROM UNIT 92
CEND
TITLE = PHASE THREE - SUBSTRUCTURE 2 - RIGID FORMAT 16
DISP = ALL
ELFORCE = ALL
ØLOAD = ALL
SPCFORCE = ALL
BEGIN BULK
PARAM USRTPID2 BEAMPH2
ENDDATA
REFERENCES


<table>
<thead>
<tr>
<th>ITEM</th>
<th>LEVEL 15</th>
<th>LEVEL 16</th>
<th>LEVEL 16.X</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMAP Alter Packet</td>
<td>Required</td>
<td>Required</td>
<td>None</td>
</tr>
<tr>
<td>CHKPNT File</td>
<td>Tape</td>
<td>Tape (or Disk)</td>
<td>Disk (or Tape)</td>
</tr>
<tr>
<td>Output User File</td>
<td>Tape for Module INPUT1</td>
<td>Tape (or Disk) for Module OUTPUT1</td>
<td>Disk (or Tape) for Module OUTPUT1</td>
</tr>
<tr>
<td>DMAP (or Alter Packet)</td>
<td>Required</td>
<td>Required</td>
<td>None</td>
</tr>
<tr>
<td>Input User Files</td>
<td>Tape(s) for Module INPUT1</td>
<td>Tape (or Disk) for Module INPUT1</td>
<td>Disk (or Tape) Automatically Processed by Module SSMA</td>
</tr>
<tr>
<td>Treatment of Identical Subroutines</td>
<td>Possible by DMAP</td>
<td>Handled by Module PVEC Parameters and DMAP Alters</td>
<td>Automatic via Simple User Data</td>
</tr>
<tr>
<td>Coupling Information</td>
<td>USER CREATED (GOOD LUCK!)</td>
<td>Generated by Modules PVEC/VEC</td>
<td>Automatically Generated</td>
</tr>
<tr>
<td>Pseudomodel Description</td>
<td>User Supplied</td>
<td>Can be Obtained from PVEC on Extra Run</td>
<td>Automatic</td>
</tr>
<tr>
<td>Output User File</td>
<td>Tape for Module OUTPUT1</td>
<td>Tape (or Disk) for Module OUTPUT1</td>
<td>Disk (or Tape) Automatically Processed by Module SSVE</td>
</tr>
<tr>
<td>DMAP Alter Packet</td>
<td>Required</td>
<td>Required</td>
<td>None</td>
</tr>
<tr>
<td>Restart File</td>
<td>Tape</td>
<td>Tape (or Disk)</td>
<td>Disk (or Tape)</td>
</tr>
<tr>
<td>Restart Dictionary</td>
<td>Cards Required from Phase I</td>
<td>Cards Required from Phase I</td>
<td>Can be Requested from Ext. File</td>
</tr>
<tr>
<td>Input User File</td>
<td>Tape for Module INPUT1</td>
<td>Tape (or Disk) for Module INPUT1</td>
<td>Disk (or Tape) for Module UDBR</td>
</tr>
</tbody>
</table>
**TABLE 2**

**ASSUMPTIONS AND RESTRICTIONS**

- Only one (1) level of substructures is allowed.
- The Number of substructures may not exceed twenty (20).
- Coordinate systems of points to be coupled are parallel. This is not verified by program.
- Degrees of freedom at two points to be coupled are the same. Exceptions can be handled via multipoint constraints in Phase II.
- The sequence (internal) of points along the boundary between any two substructures is the same.
- All subcases must be defined in the Case Control Decks for all runs.
- Static loads applied geometrically must be defined in Phase I. Loads may be applied to the pseudostructure degrees of freedom in Phase II in the usual way.
- Output obtained in Phase II must be requested using pseudostructure degree of freedom identifiers.
- Only a single boundary condition is considered; geometrically specified boundary conditions must be defined in Phase I.
(For clarity, only connected points on the top surface are shown.)

FIGURE 1. SAMPLE STATIC SUBSTRUCTURE ANALYSIS PROBLEM MODEL
The pseudomodel map shown below was generated by module PVEC for the structure shown in figure 1.

<table>
<thead>
<tr>
<th>Internal DOF</th>
<th>Substructure Identification Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4001-3</td>
</tr>
<tr>
<td>15</td>
<td>4002-3</td>
</tr>
<tr>
<td>18</td>
<td>4004-3</td>
</tr>
<tr>
<td>21</td>
<td>4005-3</td>
</tr>
<tr>
<td>24</td>
<td>4006-3</td>
</tr>
<tr>
<td>27</td>
<td>4007-3</td>
</tr>
<tr>
<td>30</td>
<td>4008-3</td>
</tr>
<tr>
<td>33</td>
<td>4009-3</td>
</tr>
<tr>
<td>36</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>2002-3</td>
</tr>
<tr>
<td>48</td>
<td>2003-3</td>
</tr>
<tr>
<td>51</td>
<td>2004-3</td>
</tr>
<tr>
<td>54</td>
<td>2005-3</td>
</tr>
<tr>
<td>57</td>
<td>2006-3</td>
</tr>
<tr>
<td>60</td>
<td>2007-3</td>
</tr>
<tr>
<td>63</td>
<td>2008-3</td>
</tr>
<tr>
<td>66</td>
<td>2009-3</td>
</tr>
</tbody>
</table>

**Notes:**

1. For clarity, only the "3" degree of freedom is shown.

2. Single-point constraints have been applied to point 1 in substructure 2 and point 3 in substructure 4.

**FIGURE 4. PSEUDOMODEL MAP**
ID PHASE ONE
TIME 10
CHKPNT YES,DISK
APP DISP
(1) SOL 16.1 $ BASIC STATIC SUBSTRUCTURE ANALYSIS
CEND

{Case Control Deck}
BEGIN BULK
{Structural Data for Substructure}

(2) PARAM SUBID 10
(3) PARAM USRTPID1 ABC
ENDDATA

Notes:
1. Solution subset 1 is used for Phase I runs.
2. User-specified substructure identification number.

FIGURE 5
LEVEL 16.X PHASE I DATA DECK
ID PHASE TWO
TIME 10
APP DISP
(1) SOL 16,2 $ BASIC STATIC SUBSTRUCTURE ANALYSIS
CEND

\{Case Control Deck\}
BEGIN BULK
(2) \{DTI definition of User File Data\}
(3a) PARAM GENSAME -1
(4) PARAM PRTOPT 1
(3b) \{Coupling Data (can be optional)\}
ENDDATA

Notes:

1. Solution subset 2 is used for Phase II runs.

2. User-specified data providing
   a. Number of substructures
   b. Identification numbers for both real and identical substructures
   c. User File Data Location Information and Identification Codes

3a and b. Coupling Information
   (a) GENSAME=+1 means coupling data automatically generated
       GENSAME=-1 means coupling data supplied by user via SAME cards (fig. 10).
   (b) See figure 8.

4. Pseudostructure map print option.

FIGURE 6
LEVEL 16.X PHASE II DATA DECK
ID PHASE THREE
TIME 10
APP DISP
(1) S0L 16.3 $ BASIC STATIC SUBSTRUCTURE ANALYSIS
(2) READCARDS FROM 3 $ RESTART DICTIONARY FROM UNIT 3
CEND

Case Control Deck

BEGIN BULK
(3) PARAM USRTPIDZ XYZ
ENDDATA

Notes:

1. Solution subset 3 is used for Phase III runs.
2. The Problem Tape Dictionary is recovered from Unit 3.
3. User-specified User File Identification Code from Phase II.

FIGURE 7
LEVEL 16.X PHASE III DATA DECK
FIGURE 8. USER FILE COUPLING DATA
Figure 9. Multi-level Substructure Analysis
Input Data Card   SAME   Joining Data

Description: Defines grid or scalar points which are to be coupled in a substructure analysis.

Format and Example:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAME</td>
<td>S</td>
<td>G</td>
<td>S</td>
<td>G</td>
<td>S</td>
<td>G</td>
<td>S</td>
<td>G</td>
<td>abc</td>
</tr>
<tr>
<td>SAME</td>
<td>3</td>
<td>79</td>
<td>4</td>
<td>216</td>
<td>6</td>
<td>93</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+bc</td>
<td>S</td>
<td>G</td>
<td>S</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>etc.</td>
</tr>
<tr>
<td>+BC</td>
<td>7</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>etc.</td>
</tr>
</tbody>
</table>

Alternate Form

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAME</td>
<td>S</td>
<td>G1</td>
<td>&quot;THRU&quot;</td>
<td>G2</td>
<td>S</td>
<td>G1</td>
<td>&quot;THRU&quot;</td>
<td>G2</td>
<td>+abc</td>
</tr>
<tr>
<td>SAME</td>
<td>10</td>
<td>1</td>
<td>THRU</td>
<td>60</td>
<td>20</td>
<td>101</td>
<td>THRU</td>
<td>160</td>
<td>ABC</td>
</tr>
<tr>
<td>+abc</td>
<td>S</td>
<td>G1</td>
<td>&quot;THRU&quot;</td>
<td>G2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>etc.</td>
</tr>
<tr>
<td>+BC</td>
<td>30</td>
<td>526</td>
<td>THRU</td>
<td>585</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>etc.</td>
</tr>
</tbody>
</table>

Field      Contents
S          Substructure identification number (Integer > 0)
G, G1, G2  Grid or Scalar point identification number (Integer > 0; G1 < G2)

Remarks:
1. Up to four grid or scalar points (in four different substructures) may be coupled by a single card. As many continuation cards as required may be used.
2. No degrees of freedom of coupled points may be members of the o-set.
3. The substructure identification numbers should be written in ascending order.
4. If two SAME cards are to be joined, the highest numbered substructure entry on the first one should be repeated on the second one.
5. If the alternate form is used, all of the grid and scalar points G1 thru G2 are assumed. Each G1 THRU G2 sequence must define the same number of points.

FIGURE 10. SAME CARD DESCRIPTION