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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

K	Stiffness matrix
P	Load vector matrix
u	Displacement vector matrix
G	Transformation matrix
M	Mass matrix

Subscripts:

f	Free (unconstrained) set
a	Analysis (boundary) set
o	Omitted (interior) set
g	All degrees of freedom set

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
^	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

$$\left[\begin{array}{c|c} \bar{K}_{aa} & K_{ao} \\ \hline K_{oa} & K_{oo} \end{array}\right] \left\{\begin{array}{c} u_a \\ \hline u_o \end{array}\right\} = \left\{\begin{array}{c} \bar{P}_a \\ \hline P_o \end{array}\right\} \quad (1)$$

from which

$$[K_{aa}]\{u_a\} = \{P_a\} \quad (2)$$

where

$$[K_{aa}] = [\bar{K}_{aa}] + [G_o]^T[K_{oa}] \tag{3}$$

$$\{P_a\} = \{\bar{P}_a\} + [G_o]^T\{P_o\} \tag{4}$$

and

$$[G_o] = -[K_{oo}]^{-1}[K_{oa}] \quad . \tag{5}$$

Also, the displacements of the interior points are given by

$$\{u_o\} = \{u_o^o\} + [G_o]\{u_a\} \tag{6}$$

where

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} \quad . \tag{7}$$

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 $[K^i_{aa}]$ and $\{P^i_a\}$, which are brought in from User Files generated by the Phase I runs, are expanded to pseudomodel g-size.

$$[K^i_{aa}] \rightarrow [\hat{K}^i_{gg}] \tag{8}$$

$$\{P^i_a\} \rightarrow \{\hat{P}^i_g\} \tag{9}$$

and added to form

$$[\hat{K}_{gg}] = \sum_i [\hat{K}^i_{gg}] \tag{10}$$

$$\{\hat{P}_g\} \quad \sum_i \{\hat{P}^i_g\} \tag{11}$$

from which a normal solution proceeds.

After the solution $\{\hat{u}_g\}$ is obtained, the boundary displacements are simply extracted by

$$\{u_a^i\} \leftarrow \{\hat{u}_g\} \quad . \tag{12}$$

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

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

$$[M_{aa}] = [\bar{M}_{aa}] + [M_{oa}]^T[G_o] + [G_o]^T[M_{oa}] + [G_o]^T[M_{oo}][G_o] \tag{13}$$

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:

```
SSMA     GEØM4,UFTABLE / K,M,B,K4,P,PSD / C,Y,PØPT / C,Y,GENSAME /
         V,N,LUSET $
```

IV. INPUT DATA BLOCKS:

GEØM4 - 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:

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

GENSAME - Integer-input, default =-1.
=-1, coupling data is taken from GEØM4
=+1, automatic coupling based on grid point identification numbers will be employed (GEØM4 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 INPT, 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:

UDBR / 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:

0	INPT
1	INP1
2	INP2
.	.
.	.
.	.
9	INP9

USRTPID2 - BCD-input, default=XXXXXXXX. 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, ØMIT, FØRCE 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

$$\{u\}^* = [Q]^T\{u\} \tag{14}$$

has the desired sequence but the same values, then

$$[Q]^{-1} = [Q]^T \tag{15}$$

and the conformable matrices and vectors are easily computed as

$$[K]^* = [Q]^T[K][Q] \tag{16}$$

and

$$\{P\}^* = [Q]^T\{P\} \quad . \tag{17}$$

After solution, the reverse transformation is merely

$$\{u\} = [Q]\{u\}^* \tag{18}$$

Since [Q] has an extremely low density, NASTRAN's sparce 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 SØL 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 SØL 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

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

RIGID FORMAT 16 - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

  1  BEGIN     NO.16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N $

  2  FILE      LLL=TAPE $

  3  FILE      UG=APPEND/PGG=APPEND/UGV=APPEND/UM=SAVE/KNN=SAVE $

  4  JUMP      PH2BK1 $

  5  PARAM     //C,N,ADD/V,N,PHASE2/C,N,0/C,N,-1 $

  6  SSMA      GEOM4,UFTABLE/KGGPS,,,,PGPS,PSDATA/C,Y,PRTOPT/C,Y,GENSAME/ V,N,
               LUSET $

  7  SAVE      LUSET $

  8  CHKPNT    KGGPS,PGPS,PSDATA $

  9  LABEL     PH2BK1 $

 10  GP1       GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/  V,N,
               NOGPDT $

 11  SAVE      LUSET $

 12  CHKPNT    GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL $

 13  GP2       GEOM2,EQEXIN/ECT $

 14  CHKPNT    ECT $

 15  PARAML    PCDB//C,N,PRES/C,N,/C,N,/C,N,/V,N,NOPCDB $

 16  PURGE     PLTSETX,PLTPAR,GPSETS,ELSETS/NOPCDB $

 17  COND      P1,NOPCDB $

 18  PLTSET    PCDB,EQEXIN,ECT/PLTSETX,PLTPAR,GPSETS,ELSETS/V,N,NSIL/   V,N,
               JUMPPLOT=-1 $

 19  SAVE      NSIL,JUMPPLOT $

 20  PRTMSG    PLTSETX// $

 21  PARAM     //C,N,MPY/V,N,PLTFLG/C,N,1/C,N,1 $

 22  PARAM     //C,N,MPY/V,N,PFILE/C,N,0/C,N,0 $

 23  COND      P1,JUMPPLOT $

 24  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,,,,/PLOTX1/   V,N,
```

APPENDIX A

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

RIGID FORMAT 16 - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.
                NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $

 25  SAVE       JUMPPLOT,PLTFLG,PFILE $

 26  PRTMSG     PLOTX1// $

 27  LABEL      P1 $

 28  CHKPNT     PLTPAR,GPSETS,ELSETS $

 29  GP3        GEOM3,EQEXIN,GEOM2/SLT,GPTT/V,N,NOGRAV $

 30  SAVE       NOGRAV $

 31  PARAM      //C,N,AND/V,N,NOMGG/V,N,NOGRAV/V,Y,GRDPNT=-1 $

 32  PURGE      MGG,MELM,MDICT/NOMGG $

 33  CHKPNT     SLT,GPTT $

 34  TA1        ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,/V,N,LUSET/   V,N,
                NOSIMP/C,N,1/V,N,NOGENL/V,N,GENEL $

 35  SAVE       NOSIMP,NOGENL,GENEL $

 36  PARAM      //C,N,AND/V,N,NOELMT/V,N,NOGENL/V,N,NOSIMP $

 37  COND       ERROR4,NOELMT $

 38  PURGE      KGGX,GPST/NOSIMP/OGPST/GENEL $

 39  CHKPNT     EST,GPECT,GEI,GPST,OGPST $

 40  OPTPR1     MPT,EPT,ECT,DIT,EST/OPTP1/V,N,PRINT/V,N,TSTART/V,N,COUNT $

 41  SAVE       PRINT,TSTART,COUNT $

 42  CHKPNT     OPTP1 $

 43  JUMP       LOOPTOP $

 44  LABEL      LOOPTOP $

 45  COND       LBL1,NOSIMP $

 46  PARAM      //C,N,ADD/V,N,NOKGGX/C,N,1/C,N,0 $

 47  EMG        EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
                N,NOMGG/C,N,/C,N,/C,N,/C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
                CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,
                CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $
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RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 48  SAVE      NOKGGX,NOMGG $

 49  CHKPNT    KELM,KDICT,MELM,MDICT $

 50  COND      JMPKGG,NOKGGX $

 51  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 52  CHKPNT    KGGX,GPST $

 53  LABEL     JMPKGG $

 54  COND      JMPMGG,NOMGG $

 55  EMA       GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $

 56  CHKPNT    MGG $

 57  LABEL     JMPMGG $

 58  COND      LBL1,GRDPNT $

 59  COND      ERROR2,NOMGG $

 60  GPWG      BGPDT,CSTM,EQEXIN,MGG/OGPWG/V,Y,GRDPNT/C,Y,WTMASS $

 61  OFP       OGPWG,,,,,//V,N,CARDNO $

 62  LABEL     LBL1 $

 63  EQUIV     KGGX,KGG/NOGENL $

 64  CHKPNT    KGG $

 65  COND      LBL11A,NOGENL $

 66  SMA3      GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $

 67  CHKPNT    KGG $

 68  LABEL     LBL11A $

 69  JUMP      PH2BK2 $

 70  ADD       KGG,KGGPS/KGGT $

 71  EQUIV     KGGT,KGG/PHASE2 $

 72  CHKPNT    KGG $

 73  LABEL     PH2BK2 $
```

APPENDIX A

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

RIGID FORMAT 16 - SUBSET ZERO

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 74  PARAM    //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $

 75  JUMP     LBL11 $

 76  LABEL    LBL11 $

 77  GP4      CASECC,GEOM4,EQEXIN,SIL,GPDT/RG,YS,USET,ASET/V,N,LUSET/ V,N,
              MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/V,N,NSKIP/V,N,
              REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $

 78  SAVE     MPCF1,MPCF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,NOSET,NOL,NOA $

 79  COND     ERROR3,NOL $

 80  PARAM    //C,N,AND/V,N,NOSR/V,N,SINGLE/V,N,REACT $

 81  PURGE    KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
              KFS,KSS/SINGLE/QG/NOSR $

 82  CHKPNT   KRR,KLR,QR,DM,GM,GO,KOO,LOO,PO,UOOV,RUOV,PS,KFS,KSS,QG,USET,RG,
              YS,ASET $

 83  COND     LBL4,GENEL $

 84  GPSP     GPL,GPST,USET,SIL/OGPST/V,N,NOGPST $

 85  SAVE     NOGPST $

 86  COND     LBL4,NOGPST $

 87  OFP      OGPST,,,,,//V,N,CARDNO $

 88  LABEL    LBL4 $

 89  EQUIV    KGG,KNN/MPCF1 $

 90  CHKPNT   KNN $

 91  COND     LBL2,MPCF2 $

 92  MCE1     USET,RG/GM $

 93  CHKPNT   GM $

 94  MCE2     USET,GM,KGG,,,/KNN,,, $

 95  CHKPNT   KNN $

 96  LABEL    LBL2 $

 97  EQUIV    KNN,KFF/SINGLE $
```

APPENDIX A

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 98  CHKPNT    KFF $

 99  COND      LBL3,SINGLE $

100  SCE1      USET,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  SMP1      USET,KFF,,,/GO,KAA,KOC,LOO,,,,, $

107  CHKPNT    GO,KAA,KOO,LOO $

108  LABEL     LBL5 $

109  EQUIV     KAA,KLL/REACT $

110  CHKPNT    KLL $

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

112  COND      LBL7,PHASE1 $

113  COND      LBL6,REACT $

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

115  CHKPNT    KLL,KLR,KRR $

116  LABEL     LBL6 $

117  RBMG2     KLL/LLL $

118  CHKPNT    LLL $

119  COND      LBL7,REACT $

120  RBMG3     LLL,KLR,KRR/DM $

121  CHKPNT    DM $

122  LABEL     LBL7 $

123  SSG1      SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/V,N,
               LUSET/V,N,NSKIP $
```

APPENDIX A

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 16 - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

124  JUMP      PH2BK3 $

125  ADD       PG,PGPS/PGT $

126  EQUIV     PGT,PG/PHASE2 $

127  LABEL     PH2BK3 $

128  CHKPNT    PG $

129  EQUIV     PG,PL/NOSET $

130  CHKPNT    PL $

131  COND      LBL10,NOSET $

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

133  CHKPNT    QR,PO,PS,PL $

134  LABEL     LBL10 $

135  COND      PH1BK1,PHASE1 $

136  SSG3      LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/V,N,OMIT/V,Y,IRES=-1/
               V,N,NSKIP/V,N,EPSI $

137  SAVE      EPSI $

138  CHKPNT    ULV,UOOV,RULV,RUOV $

139  COND      LBL9,IRES $

140  MATGPR    GPL,USET,SIL,RULV//C,N,L $

141  MATGPR    GPL,USET,SIL,RUOV//C,N,O $

142  LABEL     LBL9 $

143  JUMP      PH3BK1 $

144  LABEL     PH1BK1 $

145  COND      SKIP,OMIT $

146  FBS       LOO,,PO/UOOVX $

147  EQUIV     UOOVX,UOOV/PHASE1 $

148  CHKPNT    UOOV $

149  LABEL     SKIP $
```

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 1b - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

150  OUTPUT1  ASET,KLL,PL,,//C,N,-1/C,N,0/C,Y,USRTPID1 $

151  PARAM    //C,N,ADD/V,N,PHASE3/C,N,0/C,N,-1 $

152  UDBR     /ULVX,,,,/C,Y,SUBID/C,Y,UNIT/C,Y,USRTPID2 $

153  EQUIV    ULVX,ULV/PHASE3 $

154  CHKPNT   ULV $

155  LABEL    PH3BK1 $

156  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/V,N,NSKIP/
              C,N,STATICS $

157  CHKPNT   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  CHKPNT   QG $

165  JUMP     PH2BK4 $

166  SSVE     PSDATA,,UGV// $

167  LABEL    PH2BK4 $

168  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/C,N,STATICS $

169  COND     LBLOFP,COUNT $

170  OPTPR2   OPTP1,OES1,EST/OPTP2,EST1/V,N,PRINT/V,N,TSTART/V,N,COUNT $

171  EQUIV    EST1,EST/COUNT/OPTP2,OPTP1/COUNT $

172  COND     LOOPEND,PRINT $

173  LABEL    LBLOFP $

174  PARAM    //C,N,MPY/V,N,CARDNO/C,N,0/C,N,0 $
```

APPENDIX A

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

RIGID FORMAT 1o - SUBSET ZERO

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

175  OFP       OUGV1,OPG1,OQG1,OEF1,OES1,//V,N,CARDNO $

176  SAVE      CARDNO $

177  COND      P2,JUMPPLOT $

178  PLOT      PLTPAR,GPSETS,ELSETS,CASECC,BGPDT,EQEXIN,SIL,PUGV1,,GPECT,OES1/
               PLOTX2/V,N,NSIL/V,N,LUSET/V,N,JUMPPLOT/V,N,PLTFLG/V,N,PFILE $

179  SAVE      PFILE $

180  PRTMSG    PLOTX2// $

181  LABEL     P2 $

182  LABEL     LOOPEND $

183  COND      FINIS,COUNT $

184  REPT      LOOPTOP,100 $

185  JUMP      FINIS $

186  LABEL     ERROR1 $

187  PRTPARM   //C,N,-1/C,N,STATICS $

188  LABEL     ERROR2 $

189  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 $

194  LABEL     ERROR5 $

195  PRTPARM   //C,N,-5/C,N,STATICS $

196  LABEL     FINIS $

197  END       $

     **NO ERRORS 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 $[K_{gg}^{ps}]$ and $\{P_g^{ps}\}$.

10. GP1 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. PRTMSG prints error messages associated with structure plotter.

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

24. PLØT generates all requested undeformed structure plots.

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

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

34. TA1 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. ØPTPR1 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 $[K_{gg}^{x}]$ and Grid Point Singularity Table.

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

55. EMA assembles mass matrix $[M_{gg}]$.

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. GPWG generates weight and balance information.

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

63. Equivalence $[K_{gg}^{x}]$ to $[K_{gg}]$ if no general elements.

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

66. SMA3 adds general elements to $[K_{gg}^{x}]$ to obtain stiffness matrix $[K_{gg}]$.

70. Add $[K_{gg}]$ and $[K_{gg}^{ps}]$ to form $[K_{gg}^{total}]$.

APPENDIX A

71. Equivalence $[K_{gg}^{total}]$ to $[K_{gg}]$ if coupling phase.

75. Go to next DMAP instruction if cold start or modified restart. LBL11 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 (USET), forms multipoint constraint equations $[R_g]\{u_g\} = 0$ and forms enforced displacement vector $\{Y_s\}$.

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

89. Equivalence $[K_{gg}]$ to $[K_{nn}]$ 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 $[R_g] = [R_m \mid R_n]$ and solves for multipoint constraint transformation matrix $[G_m] = -[R_m]^{-1}[R_n]$.

94. MCE2 partitions stiffness matrix

$$[K_{gg}] = \left[\begin{array}{c|c} \bar{K}_{nn} & K_{nm} \\ \hline K_{mn} & K_{mm} \end{array}\right]$$

and performs matrix reduction

$$[K_{nn}] = [\bar{K}_{nn}] + [G_m^T][K_{mn}] + [K_{mn}^T][G_m] + [G_m^T][K_{mm}][G_m] .$$

97. Equivalence $[K_{nn}]$ to $[K_{ff}]$ if no single-point constraints.

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

100. SCE1 partitions out single-point constraints

$$[K_{nn}] = \left[\begin{array}{c|c} K_{ff} & K_{fs} \\ \hline K_{sf} & K_{ss} \end{array}\right] .$$

103. Equivalence $[K_{ff}]$ to $[K_{aa}]$ if no omitted coordinates.

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

106. SMP1 partitions constrained stiffness matrix

$$[K_{ff}] = \begin{bmatrix} \bar{K}_{aa} & K_{ao} \\ K_{oa} & K_{oo} \end{bmatrix} ,$$

solves for transformation matrix $[G_o] = -[K_{oo}]^{-1}[K_{oa}]$

and performs matrix reduction $[K_{aa}] = [\bar{K}_{aa}] + [K_{oa}^T][G_o]$.

109. Equivalence $[K_{aa}]$ to $[K_{\ell\ell}]$ 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

$$[K_{aa}] = \begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{r\ell} & K_{rr} \end{bmatrix} .$$

117. RBMG2 decomposes constrained stiffness matrix $[K_{\ell\ell}] = [L_{\ell\ell}][U_{\ell\ell}]$.

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

120. RBMG3 forms rigid body transformation matrix

$$[D] = -[K_{\ell\ell}]^{-1}[K_{\ell r}] ,$$

calculates rigid body check matrix

$$[X] = [K_{rr}] + [K_{\ell r}^T][D] ,$$

and calculates rigid body error ratio

$$\epsilon = \frac{||X||}{||K_{rr}||} .$$

123. SSG1 generates static load vectors $\{P_g\}$.

125. Add $\{P_g\}$ and $\{P_g^{ps}\}$ to form $\{P_g^{total}\}$.

126. Equivalence $\{P_g^{total}\}$ to $\{P_g\}$ if coupling phase.

129. Equivalence $\{P_g\}$ to $\{P_\ell\}$ if no constraints applied.

APPENDIX A

132. SSG2 applies constraints to static load vectors

$$\{P_g\} = \left\{\begin{array}{c}\bar{P}_n \\ \hline P_m\end{array}\right\} , \qquad \{P_n\} = \{\bar{P}_n\} + [G_m^T]\{P_m\} ,$$

$$\{P_n\} = \left\{\begin{array}{c}\bar{P}_f \\ \hline P_s\end{array}\right\} , \qquad \{P_f\} = \{\bar{P}_f\} - [K_{fs}]\{Y_s\} ,$$

$$\{P_f\} = \left\{\begin{array}{c}\bar{P}_a \\ \hline P_o\end{array}\right\} , \qquad \{P_a\} = \{\bar{P}_a\} + [G_o^T]\{P_o\} ,$$

$$\{P_a\} = \left\{\begin{array}{c}P_\ell \\ \hline P_r\end{array}\right\}$$

and calculates determinate forces of reaction $\{q_r\} = -\{P_r\} - [D^T]\{P_\ell\}$.

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

136. SSG3 solves for displacements of independent coordinates

$$\{u_\ell\} = [K_{\ell\ell}]^{-1}\{P_\ell\} ,$$

solves for displacements of omitted coordinates

$$\{u_o^o\} = [K_{oo}]^{-1}\{P_o\} ,$$

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

$$\{\delta P_\ell\} = \{P_\ell\} - [K_{\ell\ell}]\{u_\ell\} ,$$

$$\epsilon_\ell = \frac{\{u_\ell^T\}\{\delta P_\ell\}}{\{P_\ell^T\}\{u_\ell\}}$$

[illegible] vector (RUOV) and residual vector error ratio for omitted coordinates

$$\{\delta P_o\} = \{P_o\} - [K_{oo}]\{u_o^o\} ,$$

$$\varepsilon_o = \frac{\{u_o^T\}\{\delta P_o\}}{\{P_o^T\}\{u_o^o\}}$$

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 (RUØV).

145. Go to DMAP No. 149 if no omits.

146. FBS solve for displacements of the omitted coordinates

$$\{u_o^{ox}\} = [K_{oo}]^{-1}\{P_o\}$$

147. Equivalence $\{u_o^{ox}\}$ to $\{u_o^o\}$ if initial substructure data reduction (Phase I).

150. ØUTPUT1 write a user file on INPT containing analysis set information, $[K_{\ell\ell}]$ and $\{P_\ell\}$

152. UDBR recover $\{u_\ell^x\}$ from coupling phase user file for substructure SUBID (Phase III)

153. Equivalence $\{u_\ell^x\}$ to $\{u_\ell\}$ for substructure data recovery.

156. SDR1 recovers dependent displacements

$$\begin{Bmatrix} u_\ell \\ -- \\ u_r \end{Bmatrix} = \{u_a\} \quad , \qquad \{u_o\} = [G_o]\{u_a\} + \{u_o^o\} \quad ,$$

$$\begin{Bmatrix} u_a \\ -- \\ u_o \end{Bmatrix} = \{u_f\} \quad . \qquad \begin{Bmatrix} u_f \\ -- \\ Y_s \end{Bmatrix} = \{u_n\} \quad ,$$

$$\{u_m\} = [G_m]\{u_n\} \quad , \qquad \begin{Bmatrix} u_n \\ -- \\ u_m \end{Bmatrix} = \{u_g\} \quad ,$$

and recovers single-point forces of contraint

$$\{q_s\} = -\{P_s\} + [K_{fs}^T]\{u_f\} + [K_{ss}]\{Y_s\} \ .$$

158. Go to DMAP No. 163 if all constraint sets have been processed.

159. Go to DMAP No. 76 if additional sets of constraint nee 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 $\{u_g\}$ into substructure solution vectors and forms user file.

168. SDR2 calculates element forces and stresses (ØES1, ØES1) and prepares load vectors, displacement vectors and single-point forces of constraint for output (ØPG1, ØUGV1, PUGV1, ØQG1).

170. ØPTPR2 property optimization module for Level 16.

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

175. ØFP 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. PLØT 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 ERRØR MESSAGE NØ. 1 - ATTEMPT TØ EXECUTE MØRE THAN 100 LØØPS.

189. STATIC ANALYSIS ERRØR MESSAGE NØ. 2 - MASS MATRIX REQUIRED FØR WEIGHT AND BALANCE CALCULATIØNS.

191. STATIC ANALYSIS ERRØR MESSAGE NØ. 3 - NØ INDEPENDENT DEGREES ØF FREEDØM HAVE BEEN DEFINED.

193. STATIC ANALYSIS ERRØR MESSAGE NØ. 4 - NØ ELEMENTS HAVE BEEN DEFINED.

195. STATIC ANALYSIS ERRØR MESSAGE NØ. 5 - A LØØPING PRØBLEM RUN ØN NØN-LØØPING SUBSET.

APPENDIX B

RIGID FORMAT DMAP LISTING FOR SØL 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. ØUTPUT1, 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:

Subset	Capability
7	Structure plotter
8	Grid Point Weight Generator
9	Property optimization

Appendix A contains a full listing of Rigid Format 16.

APPENDIX B

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

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

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

```
DMAP-DMAP INSTRUCTION
 NO.

  1  BEGIN    NO.16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N $

  2  FILE     LLL=TAPE $

 10  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/  V,N,
              NOGPDT $

 11  SAVE     LUSET $

 12  CHKPNT   GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL $

 13  GP2      GEOM2,EQEXIN/ECT $

 14  CHKPNT   ECT $

 29  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/V,N,NOGRAV $

 30  SAVE     NOGRAV $

 31  PARAM    //C,N,AND/V,N,NOMGG/V,N,NOGRAV/V,Y,GRDPNT=-1 $

 32  PURGE    MGG,MELM,MDICT/NOMGG $

 33  CHKPNT   SLT,GPTT $

 34  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,/V,N,LUSET/   V,N,
              NOSIMP/C,N,1/V,N,NOGENL/V,N,GENEL $

 35  SAVE     NOSIMP,NOGENL,GENEL $

 36  PARAM    //C,N,AND/V,N,NOELMT/V,N,NOGENL/V,N,NOSIMP $

 37  COND     ERROR4,NOELMT $

 38  PURGE    KGGX,GPST/NOSIMP/OGPST/GENEL $

 39  CHKPNT   EST,GPECT,GEI,GPST,OGPST $

 45  COND     LBL1,NOSIMP $

 46  PARAM    //C,N,ADD/V,N,NOKGGX/C,N,1/C,N,0 $

 47  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
              N,NOMGG/C,N,/C,N,/C,N,/C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
              CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,
              CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $

 48  SAVE     NOKGGX,NOMGG $

 49  CHKPNT   KELM,KDICT,MELM,MDICT $
```

APPENDIX B

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
NO.

 50  COND      JMPKGG,NOKGGX $

 51  EMA       GPECT,KDICT,KELM/KGGX,GPST $

 52  CHKPNT    KGGX,GPST $

 53  LABEL     JMPKGG $

 54  COND      JMPMGG,NOMGG $

 55  EMA       GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $

 56  CHKPNT    MGG $

 57  LABEL     JMPMGG $

 62  LABEL     LBL1 $

 63  EQUIV     KGGX,KGG/NOGENL $

 64  CHKPNT    KGG $

 65  COND      LBL11A,NOGENL $

 66  SMA3      GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $

 67  CHKPNT    KGG $

 68  LABEL     LBL11A $

 74  PARAM     //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $

 77  GP4       CASECC,GEOM4,EQEXIN,SIL,GPDT/RG,YS,USET,ASET/V,N,LUSET/ V,N,
               MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/V,N,NSKIP/V,N,
               REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $

 78  SAVE      MPCF1,MPCF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,NOSET,NOL,NOA $

 79  COND      ERROR3,NOL $

 80  PARAM     //C,N,AND/V,N,NOSR/V,N,SINGLE/V,N,REACT $

 81  PURGE     KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
               KFS,KSS/SINGLE/QG/NOSR $

 82  CHKPNT    KRR,KLR,QR,DM,GM,GO,KOO,LOO,PO,UOOV,RUOV,PS,KFS,KSS,QG,USET,RG,
               YS,ASET $

 83  COND      LBL4,GENEL $

 84  GPSP      GPL,GPST,USET,SIL/OGPST/V,N,NOGPST $
```

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

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

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

```
DMAP-DMAP INSTRUCTION
 NO.

 85  SAVE     NOGPST $
 86  COND     LBL4,NOGPST $
 87  OFP      OGPST,,,,,//V,N,CARDNO $
 88  LABEL    LBL4 $
 89  EQUIV    KGG,KNN/MPCF1 $
 90  CHKPNT   KNN $
 91  COND     LBL2,MPCF2 $
 92  MCE1     USET,RG/GM $
 93  CHKPNT   GM $
 94  MCE2     USET,GM,KGG,,,/KNN,,, $
 95  CHKPNT   KNN $
 96  LABEL    LBL2 $
 97  EQUIV    KNN,KFF/SINGLE $
 98  CHKPNT   KFF $
 99  COND     LBL3,SINGLE $
100  SCE1     USET,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  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $
107  CHKPNT   GO,KAA,KOO,LOO $
108  LABEL    LBL5 $
109  EQUIV    KAA,KLL/REACT $
110  CHKPNT   KLL $
```

APPENDIX B

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

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

112  COND     LBL7,PHASE1 $

113  COND     LBL6,REACT $

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

115  CHKPNT   KLL,KLR,KRR $

116  LABEL    LBL6 $

117  RBMG2    KLL/LLL $

118  CHKPNT   LLL $

119  COND     LBL7,REACT $

120  RBMG3    LLL,KLR,KRR/DM $

121  CHKPNT   DM $

122  LABEL    LBL7 $

123  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/V,N,
              LUSET/V,N,NSKIP $

128  CHKPNT   PG $

129  EQUIV    PG,PL/NOSET $

130  CHKPNT   PL $

131  COND     LBL10,NOSET $

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

133  CHKPNT   QR,PO,PS,PL $

134  LABEL    LBL10 $

145  COND     SKIP,OMIT $

146  FBS      LOO,,PO/UOOVX $

147  EQUIV    UOOVX,UOOV/PHASE1 $

148  CHKPNT   UOOV $

149  LABEL    SKIP $

150  OUTPUT1  ASET,KLL,PL,,//C,N,-1/C,N,0/C,Y,USRTPID1 $
```

APPENDIX B

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

RIGID FORMAT 1S - SUBSET ONE, SEVEN, EIGHT, NINE

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

185  JUMP      FINIS $

188  LABEL     ERROR2 $

189  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     FINIS $

197  END       $

      **NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**
```

APPENDIX C

RIGID FORMAT DMAP LISTING FOR SØL 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:

Subset	Capability
6	Checkpoint
7	Structure Plotter
8	Grid Point Weight Generator
9	Property optimization

Appendix A contains a full listing of Rigid Format 16.

APPENDIX C

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

  1  BEGIN    NO.16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N $

  2  FILE     LLL=TAPE $

  3  FILE     UG=APPEND/PGG=APPEND/UGV=APPEND/GM=SAVE/KNN=SAVE $

  5  PARAM    //C,N,ADD/V,N,PHASE2/C,N,0/C,N,-1 $

  6  SSMA     GEOM4,UFTABLE/KGGPS,,,,PGPS,PSDATA/C,Y,PRTOPT/C,Y,GENSAME/ V,N,
              LUSET $

  7  SAVE     LUSET $

 10  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/  V,N,
              NOGPDT $

 11  SAVE     LUSET $

 12  CHKPNT   GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL $

 13  GP2      GEOM2,EQEXIN/ECT $

 29  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/V,N,NOGRAV $

 30  SAVE     NOGRAV $

 31  PARAM    //C,N,AND/V,N,NOMGG/V,N,NOGRAV/V,Y,GRDPNT=-1 $

 32  PURGE    MGG,MELM,MDICT/NOMGG $

 34  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,/V,N,LUSET/   V,N,
              NOSIMP/C,N,1/V,N,NOGENL/V,N,GENEL $

 35  SAVE     NOSIMP,NOGENL,GENEL $

 36  PARAM    //C,N,AND/V,N,NOELMT/V,N,NOGENL/V,N,NOSIMP $

 38  PURGE    KGGX,GPST/NOSIMP/OGPST/GENEL $

 45  COND     LBL1,NOSIMP $

 46  PARAM    //C,N,ADD/V,N,NOKGGX/C,N,1/C,N,0 $

 47  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
              N,NOMGG/C,N,/C,N,/C,N,/C,N,/C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
              CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,
              CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $

 48  SAVE     NOKGGX,NOMGG $
```

APPENDIX C

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
NO.

50  COND      JMPKGG,NOKGGX $

51  EMA       GPECT,KDICT,KELM/KGGX,GPST $

53  LABEL     JMPKGG $

54  COND      JMPMGG,NOMGG $

55  EMA       GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $

57  LABEL     JMPMGG $

62  LABEL     LBL1 $

63  EQUIV     KGGX,KGG/NOGENL $

65  COND      LBL11A,NOGENL $

66  SMA3      GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $

68  LABEL     LBL11A $

70  ADD       KGG,KGGPS/KGGT $

71  EQUIV     KGGT,KGG/PHASE2 $

74  PARAM     //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $

75  JUMP      LBL11 $

76  LABEL     LBL11 $

77  GP4       CASECC,GEOM4,EQEXIN,SIL,GPDT/RG,YS,USET,ASET/V,N,LUSET/ V,N,
              MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/V,N,NSKIP/V,N,
              REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $

78  SAVE      MPCF1,MPCF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,NOSET,NOL,NOA $

79  COND      ERROR3,NOL $

80  PARAM     //C,N,AND/V,N,NOSR/V,N,SINGLE/V,N,REACT $

81  PURGE     KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
              KFS,KSS/SINGLE/QG/NOSR $

89  EQUIV     KGG,KNN/MPCF1 $

91  COND      LBL2,MPCF2 $

92  MCE1      USET,RG/GM $

94  MCE2      USET,GM,KGG,,,/KNN,,, $
```

APPENDIX C

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 96  LABEL    LBL2 $

 97  EQUIV    KNN,KFF/SINGLE $

 99  COND     LBL3,SINGLE $

100  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $

102  LABEL    LBL3 $

103  EQUIV    KFF,KAA/OMIT $

105  COND     LBL5,OMIT $

106  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

108  LABEL    LBL5 $

109  EQUIV    KAA,KLL/REACT $

113  COND     LBL6,REACT $

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

116  LABEL    LBL6 $

117  RBMG2    KLL/LLL $

119  COND     LBL7,REACT $

120  RBMG3    LLL,KLR,KRR/DM $

122  LABEL    LBL7 $

123  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/V,N,
              LUSET/V,N,NSKIP $

125  ADD      PG,PGPS/PGT $

126  EQUIV    PGT,PG/PHASE2 $

129  EQUIV    PG,PL/NOSET $

131  COND     LBL10,NOSET $

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

134  LABEL    LBL10 $

136  SSG3     LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/V,N,OMIT/V,Y,IRES=-1/
              V,N,NSKIP/V,N,EPSI $
```

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

137  SAVE     EPSI $

139  COND     LBL9,IRES $

140  MATGPR   GPL,USET,SIL,RULV//C,N,L $

141  MATGPR   GPL,USET,SIL,RUOV//C,N,O $

142  LABEL    LBL9 $

156  SDR1     USET,PG,ULV,UOOV,YS,GO,GM,PS,KFS,KSS,QR/UGV,PGG,QG/V,N,NSKIP/
              C,N,STATICS $

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 $

166  SSVE     PSDATA,,UGV// $

168  SDR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/C,N,STATICS $

174  PARAM    //C,N,MPY/V,N,CARDNO/C,N,O/C,N,O $

175  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//V,N,CARDNO $

176  SAVE     CARDNO $

185  JUMP     FINIS $

186  LABEL    ERROR1 $

187  PRTPARM  //C,N,-1/C,N,STATICS $

188  LABEL    ERROR2 $

189  PRTPARM  //C,N,-2/C,N,STATICS $

190  LABEL    ERROR3 $

191  PRTPARM  //C,N,-3/C,N,STATICS $

194  LABEL    ERROR5 $
```

APPENDIX C

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

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

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

195  PRTPARM  //C,N,-5/C,N,STATICS $

196  LABEL    FINIS $

197  END      $

      **NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**
```

APPENDIX D

RIGID FORMAT DMAP LISTING FOR SØL 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. The 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:

Subset	Capability
6	Checkpoint
7	Structure Plotter
8	Grid Point Weight Generator
9	Property optimization

Appendix A contains a full listing of Rigid Format 16.

APPENDIX D

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

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

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

  1  BEGIN    NO.16 BASIC STATIC SUBSTRUCTURE ANALYSIS - SERIES N $

  2  FILE     LLL=TAPE $

 10  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/   V,N,
              NOGPDT $

 11  SAVE     LUSET $

 12  CHKPNT   GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL $

 13  GP2      GEOM2,EQEXIN/ECT $

 29  GP3      GEOM3,EQEXIN,GEOM2/SLT,GPTT/V,N,NOGRAV $

 30  SAVE     NOGRAV $

 31  PARAM    //C,N,AND/V,N,NOMGG/V,N,NOGRAV/V,Y,GRDPNT=-1 $

 32  PURGE    MGG,MELM,MDICT/NOMGG $

 34  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,/V,N,LUSET/    V,N,
              NOSIMP/C,N,1/V,N,NOGENL/V,N,GENEL $

 35  SAVE     NOSIMP,NOGENL,GENEL $

 36  PARAM    //C,N,AND/V,N,NOELMT/V,N,NOGENL/V,N,NOSIMP $

 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,1/C,N,0 $

 47  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
              N,NOMGG/C,N,/C,N,/C,N,/C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
              CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,
              CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $

 48  SAVE     NOKGGX,NOMGG $

 50  COND     JMPKGG,NOKGGX $

 51  EMA      GPECT,KDICT,KELM/KGGX,GPST $

 53  LABEL    JMPKGG $

 54  COND     JMPMGG,NOMGG $
```

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 55  EMA      GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $

 57  LABEL    JMPMGG $

 62  LABEL    LBL1 $

 63  EQUIV    KGGX,KGG/NOGENL $

 65  COND     LBL11A,NOGENL $

 66  SMA3     GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $

 68  LABEL    LBL11A $

 74  PARAM    //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $

 77  GP4      CASECC,GEOM4,EQEXIN,SIL,GPDT/KG,YS,USET,ASET/V,N,LUSET/ V,N,
              MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/V,N,NSKIP/V,N,
              REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $

 78  SAVE     MPCF1,MPCF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,NOSET,NOL,NOA $

 79  COND     ERROR3,NOL $

 80  PARAM    //C,N,AND/V,N,NOSR/V,N,SINGLE/V,N,REACT $

 81  PURGE    KRR,KLR,QR,DM/REACT/GM/MPCF1/GO,KOO,LOO,PO,UOOV,RUOV/OMIT/PS,
              KFS,KSS/SINGLE/QG/NOSR $

 83  COND     LBL4,GENEL $

 84  GPSP     GPL,GPST,USET,SIL/OGPST/V,N,NOGPST $

 85  SAVE     NOGPST $

 86  COND     LBL4,NOGPST $

 87  OFP      OGPST,,,,,//V,N,CARDNO $

 88  LABEL    LBL4 $

 89  EQUIV    KGG,KNN/MPCF1 $

 91  COND     LBL2,MPCF2 $

 92  MCE1     USET,RG/GM $

 94  MCE2     USET,GM,KGG,,,/KNN,,, $

 96  LABEL    LBL2 $

 97  EQUIV    KNN,KFF/SINGLE $
```

APPENDIX D

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

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

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 99  COND     LBL3,SINGLE $

100  SCE1     USET,KNN,,,/KFF,KFS,KSS,,, $

102  LABEL    LBL3 $

103  EQUIV    KFF,KAA/OMIT $

105  COND     LBL5,OMIT $

106  SMP1     USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

108  LABEL    LBL5 $

109  EQUIV    KAA,KLL/REACT $

113  COND     LBL6,REACT $

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

116  LABEL    LBL6 $

117  RBMG2    KLL/LLL $

119  COND     LBL7,REACT $

120  RBMG3    LLL,KLR,KRR/DM $

122  LABEL    LBL7 $

123  SSG1     SLT,BGPDT,CSTM,SIL,EST,MPT,GPTT,EDT,MGG,CASECC,DIT/PG/V,N,
              LUSET/V,N,NSKIP $

129  EQUIV    PG,PL/NOSET $

131  COND     LBL10,NOSET $

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

134  LABEL    LBL10 $

136  SSG3     LLL,KLL,PL,LOO,KOO,PO/ULV,UOOV,RULV,RUOV/V,N,OMIT/V,Y,IRES=-1/
              V,N,NSKIP/V,N,EPSI $

137  SAVE     EPSI $

139  COND     LBL9,IRES $

140  MATGPR   GPL,USET,SIL,RULV//C,N,L $

141  MATGPR   GPL,USET,SIL,RUOV//C,N,O $
```

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC STATIC SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

142  LABEL    LBL9 $

151  PARAM    //C,N,ADD/V,N,PHASE3/C,N,0/C,N,-1 $

152  ULBR     /ULVX,,,,/C,Y,SUBID/C,Y,UNIT/C,Y,USRTPID2 $

153  EQUIV    ULVX,ULV/PHASE3 $

156  SUR1     USET,PG,ULV,UOOV,YS,GC,GM,PS,KFS,KSS,QR/UGV,PGG,QG/V,N,NSKIP/
              C,N,STATICS $

161  PARAM    //C,N,NOT/V,N,TEST/V,N,REPEAT $

162  COND     ERROR5,TEST $

168  SUR2     CASECC,CSTM,MPT,DIT,EQEXIN,SIL,GPTT,EDT,BGPDT,,QG,UGV,EST,,PGG/
              OPG1,OQG1,OUGV1,OES1,OEF1,PUGV1/C,N,STATICS $

174  PARAM    //C,N,MPY/V,N,CARDNO/C,N,0/C,N,0 $

175  OFP      OUGV1,OPG1,OQG1,OEF1,OES1,//V,N,CARDNO $

176  SAVE     CARDNO $

185  JUMP     FINIS $

188  LABEL    ERROR2 $

189  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 $

194  LABEL    ERROR5 $

195  PRTPARM  //C,N,-5/C,N,STATICS $

196  LABEL    FINIS $

197  END      $

         **NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**
```

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:

Subset	Capability
6	Checkpoint
7	Structure Plotter
8	Grid Point Weight Cenerator

APPENDIX E

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

  1  BEGIN    NO.17 BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS - SERIES N $

  2  FILE     LLL=TAPE $

  4  PARAM    //C,N,ADD/V,N,PHASE2/C,N,0/C,N,-1 $

  5  SSMA     GEOM4,UFTABLE/KGGPS,MGGPS,,,,PSDATA/C,Y,PRTOPT/C,Y,GENSAME/V,N,
              LUSET $

  6  SAVE     LUSET $

  7  CHKPNT   KGGPS,MGGPS,PSDATA $

  9  GP1      GEOM1,GEOM2,/GPL,EQEXIN,GPDT,CSTM,BGPDT,SIL/V,N,LUSET/  V,N,
              NOGPDT $

 10  SAVE     LUSET $

 12  GP2      GEOM2,EQEXIN/ECT $

 28  GP3      GEOM3,EQEXIN,GEOM2/,GPTT/V,N,NOGRAV $

 30  TA1      ECT,EPT,BGPDT,SIL,GPTT,CSTM/EST,GEI,GPECT,/V,N,LUSET/   V,N,
              NOSIMP/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,NOSIMP $

 33  COND     ERROR1,NOELTS $

 34  PURGE    KGGX,GPST,MGG/NOSIMP/OGPST/GENEL $

 36  COND     LBL1,NOSIMP $

 37  PARAM    //C,N,ADD/V,N,NOKGGX/C,N,1/C,N,0 $

 38  PARAM    //C,N,ADD/V,N,NOMGG/C,N,1/C,N,0 $

 39  EMG      EST,CSTM,MPT,DIT,GEOM2,/KELM,KDICT,MELM,MDICT,,/V,N,NOKGGX/ V,
              N,NOMGG/C,N,/C,N,/C,N,/C,Y,COUPMASS/C,Y,CPBAR/C,Y,CPROD/C,Y,
              CPQUAD1/C,Y,CPQUAD2/C,Y,CPTRIA1/C,Y,CPTRIA2/  C,Y,CPTUBE/C,Y,
              CPQDPLT/C,Y,CPTRPLT/C,Y,CPTRBSC $

 40  SAVE     NOKGGX,NOMGG $

 42  COND     JMPKGG,NOKGGX $

 43  EMA      GPECT,KDICT,KELM/KGGX,GPST $
```

APPENDIX E

RIGID FORMAT DMAP LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS ***

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

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 45  LABEL    JMPKGG $

 46  COND     ERROR1,NOMGG $

 47  EMA      GPECT,MDICT,MELM/MGG,/C,N,-1/C,Y,WTMASS=1.0 $

 52  LABEL    LBL1 $

 53  EQUIV    KGGX,KGG/NOGENL $

 54  CHKPNT   KGG $

 55  COND     LBL11,NOGENL $

 56  SMA3     GEI,KGGX/KGG/V,N,LUSET/V,N,NOGENL/V,N,NOSIMP $

 58  LABEL    LBL11 $

 60  ADD      KGG,KGGPS/KGGT $

 61  EQUIV    KGGT,KGG/PHASE2 $

 63  ADD      MGG,MGGPS/MGGT $

 64  EQUIV    MGGT,MGG/PHASE2 $

 65  CHKPNT   MGG $

 67  PARAM    //C,N,MPY/V,N,NSKIP/C,N,0/C,N,0 $

 68  GP4      CASECC,GEOM4,EQEXIN,SIL,GPDT/RG,,USET,ASET/V,N,LUSET/    V,N,
              MPCF1/V,N,MPCF2/V,N,SINGLE/V,N,OMIT/V,N,REACT/V,N,NSKIP/V,N,
              REPEAT/V,N,NOSET/V,N,NOL/V,N,NOA/C,Y,SUBID $

 69  SAVE     MPCF1,MPCF2,SINGLE,OMIT,REACT,NSKIP,REPEAT,NOSET,NOL,NOA $

 70  COND     ERROR3,NOL $

 71  PURGE    KRR,KLR,DM,MLR,MR/REACT/GM/MPCF1/GO/OMIT/KFS/SINGLE/QG/NOSET $

 79  EQUIV    KGG,KNN/MPCF1/MGG,MNN/MPCF1 $

 81  COND     LBL2,MPCF2 $

 82  MCE1     USET,RG/GM $

 84  MCE2     USET,GM,KGG,MGG,,/KNN,MNN,, $

 86  LABEL    LBL2 $

 87  EQUIV    KNN,KFF/SINGLE/MNN,MFF/SINGLE $
```

```
RIGID FORMAT DMAP LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS ***

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

   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

 89  COND      LBL3,SINGLE $

 90  SCE1      USET,KNN,MNN,,/KFF,KFS,,MFF,, $

 92  LABEL     LBL3 $

 93  EQUIV     KFF,KAA/OMIT $

 94  EQUIV     MFF,MAA/OMIT $

 96  COND      LBL5,OMIT $

 97  SMP1      USET,KFF,,,/GO,KAA,KOO,LOO,,,,, $

 99  SMP2      USET,GO,MFF/MAA $

101  LABEL     LBL5 $

106  COND      LBL6,REACT $

107  RBMG1     USET,KAA,MAA/KLL,KLR,KRR,MLL,MLR,MRR $

109  RBMG2     KLL/LLL $

111  RBMG3     LLL,KLR,KRR/DM $

113  RBMG4     DM,MLL,MLR,MRR/MR $

115  LABEL     LBL6 $

116  DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/V,N,
               LUSET/V,N,LUSETD/V,N,NOTFL/V,N,NODLT/V,N,NOPSDL/V,N,NOFRL/  V,
               N,NONLFT/V,N,NOTRL/V,N,NOEED/C,N,/V,N,NOUE $

117  SAVE      NOEED $

118  COND      ERROR2,NOEED $

120  READ      KAA,MAA,MR,DM,EED,USET,CASECC/LAMA,PHIA,MI,OEIGS/C,N,MODES/V,N,
               NEIGV $

121  SAVE      NEIGV $

123  PARAM     //C,N,MPY/V,N,CARDNO/C,N,0/C,N,0 $

124  OFP       LAMA,OEIGS,,,,//V,N,CARDNO $

125  SAVE      CARDNO $

127  SSVE      PSDATA,LAMA,PHIA// $

133  COND      FINIS,NEIGV $
```

APPENDIX E

RIGID FORMAT DMAP LISTING
SERIES N *** BASIC NORMAL MODES SUBSTRUCTURE ANALYSIS ***

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

```
   N A S T R A N   S O U R C E   P R O G R A M   C O M P I L A T I O N
DMAP-DMAP INSTRUCTION
 NO.

134  SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,QG/C,N,1/C,N,REIG $

136  PARAM     //C,N,SUB/V,N,SCALAR/V,N,SIL/V,N,LUSET $

137  EQUIV     SIL,SIP/SCALAR/BGPDT,BGPDP/SCALAR $

139  COND      LBL7,SCALAR $

140  PLTTRAN   BGPDT,SIL/BGPDP,SIP/V,N,LUSET/V,N,LUSEP $

141  SAVE      LUSEP $

143  LABEL     LBL7 $

148  SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/ ,
               OQG1,OPHIG,OES1,OEF1,PPHIG/C,N,REIG $

149  OFP       OPHIG,OQG1,OEF1,OES1,,//V,N,CARDNO $

150  SAVE      CARDNO $

156  JUMP      FINIS $

157  LABEL     ERROR1 $

158  PRTPARM   //C,N,-1/C,N,MODES $

159  LABEL     ERROR2 $

160  PRTPARM   //C,N,-2/C,N,MODES $

161  LABEL     ERROR3 $

162  PRTPARM   //C,N,-3/C,N,MODES $

163  LABEL     FINIS $

164  END       $

        **NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**
```

APPENDIX F

UFTABLE USAGE WITH RIGID FORMATS 16 AND 17

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

DTI	UFTABLE	0							
DTI	UFTABLE	1	DUMMY	DATA	FØR	SUBSET	ZERØ	ENDREC	

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)

Card	1	2	3	4	5	6	7	8	9	10
1	DTI	UFTABLE	0	4	16					
2	DTI	UFTABLE	1	2		INP1	WIDGET02		ENDREC	
3	DTI	UFTABLE	2	4		INP2	WIDGET04		ENDREC	
4	DTI	UFTABLE	3	6		INP3	WIDGET06		ENDREC	
5	DTI	UFTABLE	4	9		INP4	WIDGET09		ENDREC	
6	DTI	UFTABLE	5	0		INPT	WDGTPH2		ENDREC	

EXAMPLE b. (five substructures, N=5)

Card	1	2	3	4	5	6	7	8	9	10
1	DTI	UFTABLE	0	5	17					+A00
2	DTI	UFTABLE	1	10		INP1	GRØUP4		ENDREC	+A01
3a	DTI	UFTABLE	2	13		INP4	PLT4	104823	NAMES	+A02
3b	+A02	A	AS138	K	KLL13	M	M134F		ENDREC	+A03
4	DTI	UFTABLE	3	23	1[illegible]				ENDREC	+A04
5	DTI	UFTABLE	4	16	10				ENDREC	+A05
6a	DTI	UFTABLE	5	237		INP3				+A06
6b	+A06	A	3	K	1	M	2		ENDREC	+A07

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.

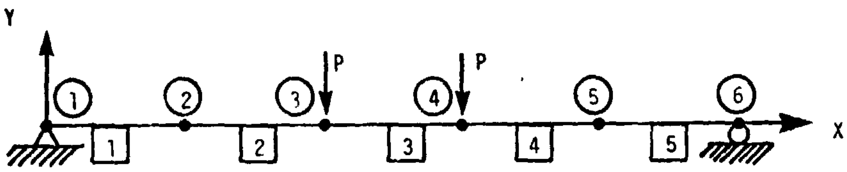
3. Optional data (shown in example b on card 3) is input whenever the data blocks required are not in the expected order on the User File as defined by the convention established for the Rigid Format being utilized. In the example, the ASET data block has the name AS13B, the stiffness matrix has the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

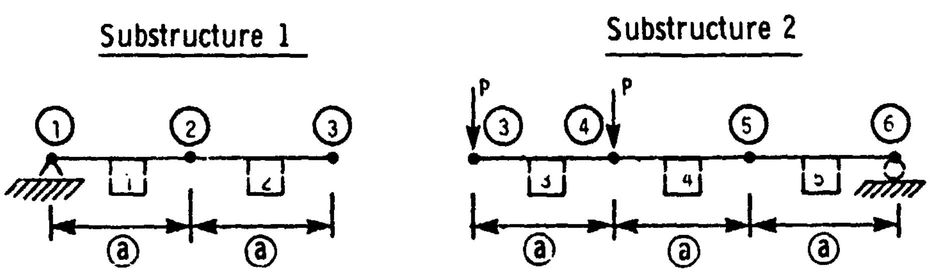
4. In example a, card 6 defines the User File Label and GINØ file name to be used by SSVE when writing the Phase II output onto a User File. In example b, since five substructures are present and no card 7 is input, default values will be automatically implied.

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.





(2) Grid point numbers

[3] Element numbers

(a) = 6.096 m (240 in)

E = 207 GPa (30×10^6 psi)

I = 2.08×10^{-4} m^4 (500 in^4)

P = 4.448 kN (1000 lb)

APPENDIX G

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

```
ID        PHASE ØNE $
TIME      2
CHKPNT    YES
APP       DISP
SØL       16,1
CEND
TITLE = PHASE ØNE - SUBSTRUCTURE 1 - RIGID FØRMAT 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     11        30.+6
PARAM    SUBID       10
PARAM    USRTPID1  BEAMS1
PBAR     10          11       60.    500.
SPC      101          1       12
ENDDATA
```

APPENDIX G

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

```
ID        PHASE ØNE $
TIME      2
CHKPNT    YES
APP       DISP
SØL       16,1
CEND
TITLE = PHASE ØNE - SUBSTRUCTURE 2 - RIGID FØRMAT 16
SPC = 201
LØAD = 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
FØRCE     202         3            1000.             -1.0
FØRCE     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     USRTPID1 BEAMS2
PBAR       10        11      60.    500.
SPC       201         6       2
ENDDATA
```

APPENDIX G

The following data deck is used for Phase II.

```
ID       PHASE TWØ
TIME     2
APP      DISP
SØL      16,2
CEND
TITLE = PHASE TWØ - RIGID FØRMAT 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 FRØM 3 $ RESTART DICTIØNARY FRØM UNIT 3
CEND
TITLE = PHASE THREE - SUBSTRUCTURE 1 - RIGID FØRMAT 16
DISP = ALL
ELFØRCE = ALL
ØLØAD = ALL
SPCFØRCE = ALL
BEGIN BULK
PARAM    USRTPID2 BEAMPH2
ENDDATA
```

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 FRØM 92 $ RESTART DICTIØNARY FRØM UNIT 92
CEND
TITLE = PHASE THREE - SUBSTRUCTURE 2 - RIGID FØRMAT 16
DISP = ALL
ELFØRCE = ALL
ØLØAD = ALL
SPCFØRCE = ALL
BEGIN BULK
PARAM     USRTPID2 BEAMPH2
ENDDATA
```

REFERENCES

1. MacNeal, R. H. (Editor): The NASTRAN Theoretical Manual (Level 15). NASA SP-221(01), April 1972.

2. McCormick, C. W. (Editor): The NASTRAN User's Manual (Level 15). NASA SP-222(01), June 1972.

3. Anon.: The NASTRAN Programmer's Manual (Level 15). NASA SP-223(01), September 1972.

4. Grooms, H. R. and Yahata, S.: Space Shuttle - The Need for Substructuring. NASTRAN: Users' Experiences. NASA TM X-2378, September 1971, pp. 769-778.

5. Hansen, S. D. and Hansteen, H. B.: Data Management Requirements for Large Problems. NASTRAN: Users' Experiences. NASA TM X-2378, September 1971, pp. 533-550.

6. Guyan, R. J.: "Reduction of Stiffness and Mass Matrices". AIAA Journal, Vol. 3, No. 2, February 1965.

TABLE 1

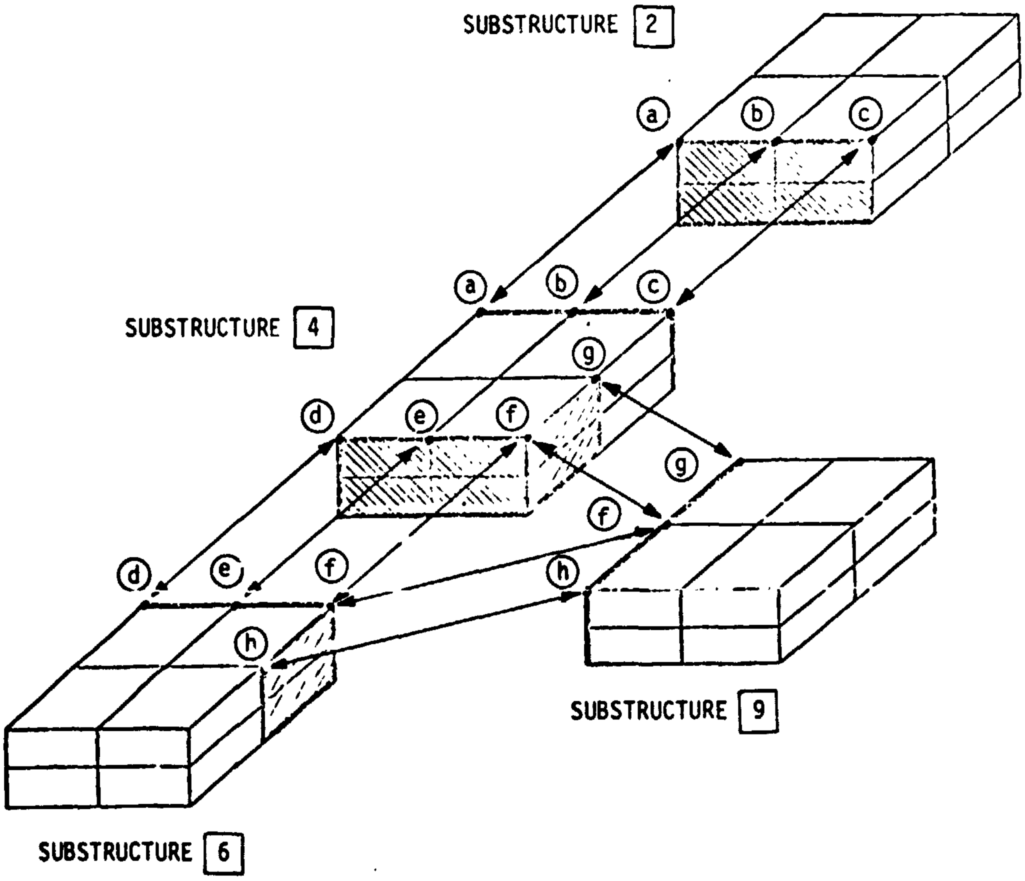
DATA REQUIREMENTS

Phase	ITEM	LEVEL 15	LEVEL 16	LEVEL 16.X
Phase I	• DMAP Alter Packet	Required	Required	None
	• CHKPNT File	Tape	Tape (or Disk)	Disk (or Tape)
	• Output User File	Tape for Module ØUTPUT1	Tape (or Disk) for Module ØUTPUT1	Disk (or Tape) for Module ØUTPUT1
Phase II	• DMAP (or Alter Packet)	Required	Required	None
	• Input User Files	Tape(s) for Module INPUTT1	Tape (or Disk) for Module INPUTT1	Disk (or Tape) Automatically Processed by Module SSMA
	• Treatment of Identical Subroutines	Possible by DMAP	Handled by Module PVEC Parameters and DMAP Alters	Automatic via Simple User Data
	• Coupling Information	USER CREATED (GOOD LUCK!)	Generated by Modules PVEC/VEC	Automatically Generated
	• Pseudomodel Description	User Supplied	Can be Obtained from PVEC on Extra Run	Automatic
	• Output User File	Tape for Module ØUTPUT1	Tape (or Disk) for Module ØUTPUT1	Disk (or Tape) Automatically Processed by Module SSVE
Phase III	• DMAP Alter Packet	Required	Required	None
	• Restart File	Tape	Tape (or Disk)	Disk (or Tape)
	• Restart Dictionary	Cards Required from Phase I	Cards Required from Phase I	Can be Requested from Ext. File
	• Input User File	Tape for Module INPUTT1	Tape (or Disk) for Module INPUTT1	Disk (or Tape) for Module UDBR

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. <u>SAMPLE STATIC SUBSTRUCTURE ANALYSIS PROBLEM MODEL</u>

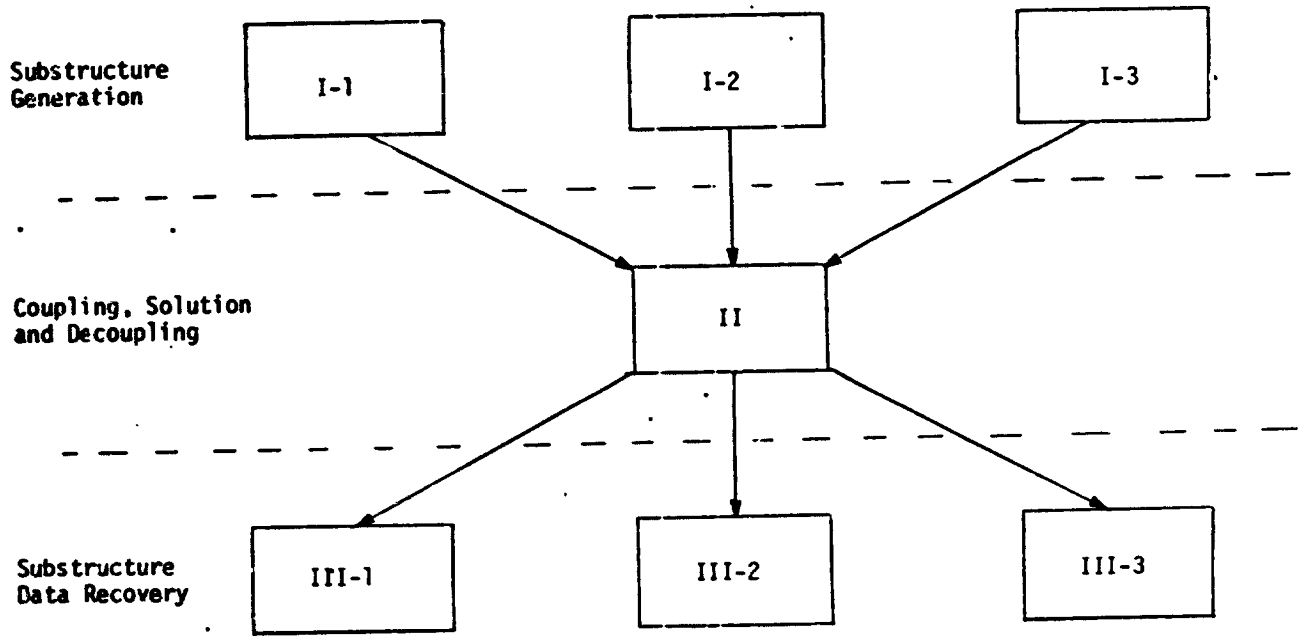


FIGURE 2. SUBSTRUCTURE ANALYSIS RUN FLOW

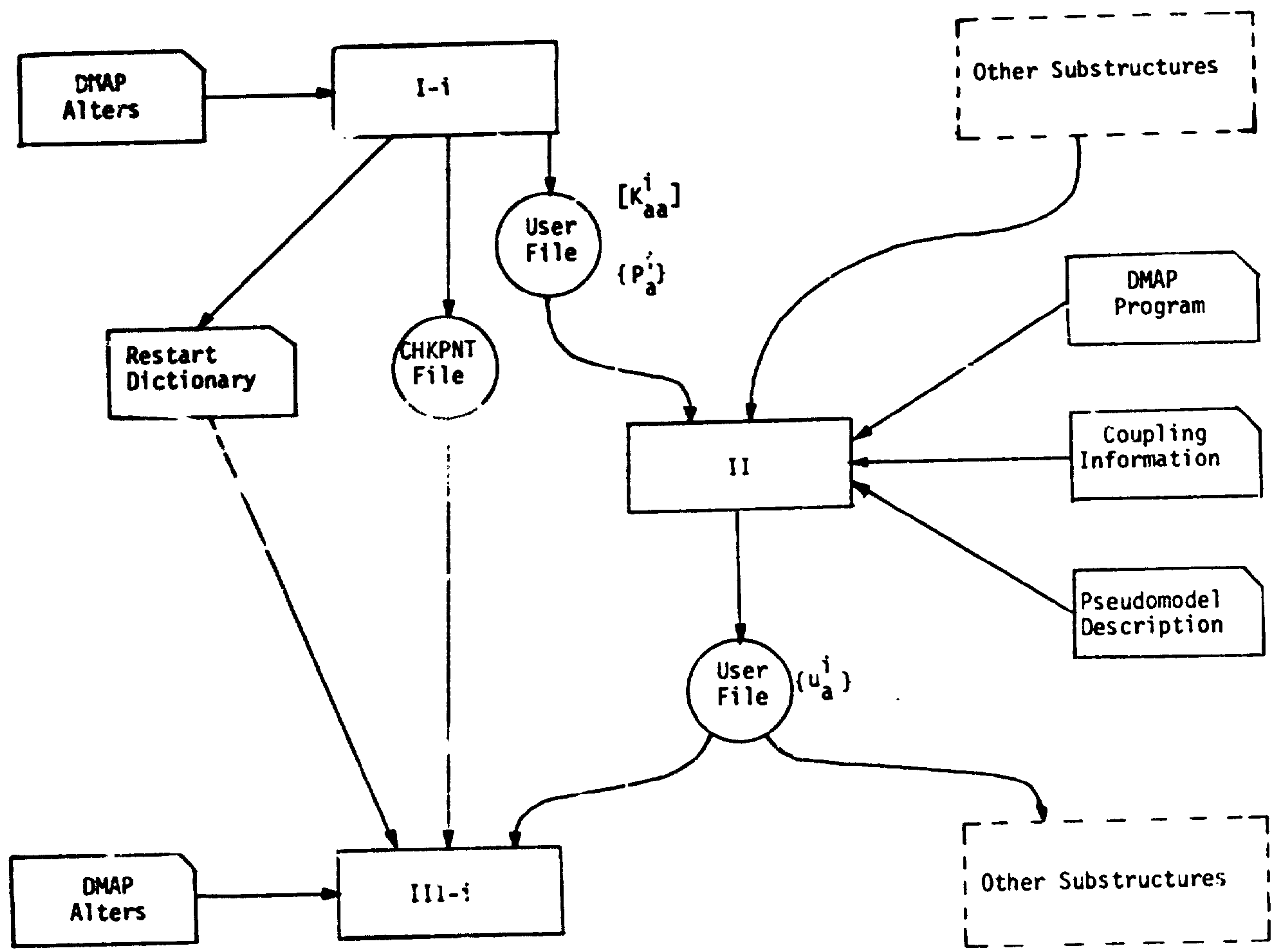


FIGURE 3. SUBSTRUCTURE ANALYSIS DATA LOGISTICS (STATICS)

The pseudomodel map shown below was generated by module PVEC for the structure shown in figure 1.

Internal DØF	Substructure Identification Number 2	4	6	9
3			6013-3	9001-3
6			6016-3	9004-3
9			6019-3	9007-3
12		4001-3	6021-3	
15		4002-3	6022-3	
18		4004-3	6024-3	
21		4005-3	6025-3	
24		4006-3	6026-3	9014-3
27		4007-3	6027-3	
30		4008-3	6028-3	
33		4009-3	6029-3	9017-3
36		4013-3		9021-3
39		4016-3		9024-3
42		4019-3		9027-3
45	2002-3	4022-3		
48	2003-3	4023-3		
51	2004-3	4024-3		
54	2005-3	4025-3		
57	2006-3	4026-3		
60	2007-3	4027-3		
63	2008-3	4028-3		
66	2009-3	4029-3		

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 ØNE
     TIME     10
     CHKPNT   YES,DISK
     APP      DISP
(1)  SØL      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.
3. User-specified User File identification code.

FIGURE 5

LEVEL 16.X PHASE I DATA DECK

```
        ID PHASE TWØ
        TIME     10
        APP      DISP
(1)     SØL      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   PRTØPT    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)    SØL      16,3 $ BASIC STATIC SUBSTRUCTURE ANALYSIS
(2)    READCARDS FRØM 3 $ RESTART DICTIØNARY FRØM UNIT 3
       CEND

         {Case Control Deck}

       BEGIN BULK
(3)    PARAM    USRTPID2  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

	1	2	3	4	5	6	7	8	9	10
	DTI	TPTABLE	0[a]	4[b]	16[c]					+DTI-000
	+DTI-000	ENDREC								
1st substructure	DTI	TPTABLE	1	10[d]		INP1[e]	SUB1[f]		ENDREC	+DTI-001
2nd substructure	DTI	TPTABLE	2	20		INP4	TRY2SUB2	104823[g]		+DTI-002
	+DTI-002	A[h]	3[i]	K	1	P	2		ENDREC	+DTI-003
3rd substructure	DTI	TPTABLE	3	-21[j]	20[j]				ENDREC	+DTI-004
4th substructure	DTI	TPTABLE	4	40		INP4	PLT4SUB4		NAMES[k]	+DTI-005
	+DTI-005	A	A04[ℓ]	K	K1048				ENDREC	+DTI-006
Combined structure (optional)	DTI	TPTABLE	5	1010		CØUPLE4			ENDREC	+DTI-007

(a) DTI Record Number
(b) Number of Substructures
(c) Rigid Format
(d) Substructure Identification Number
(e) User File GINØ Name
(f) User File Label (optional)
(g) Tape Reel Number (optional)
(h) Data Block Code } (optional)
(i) Data Block Position }
(j) Identical Substructure Reference
(k) Option Code } (optional)
(ℓ) Data Block Name }

FIGURE 8. USER FILE COUPLING DATA

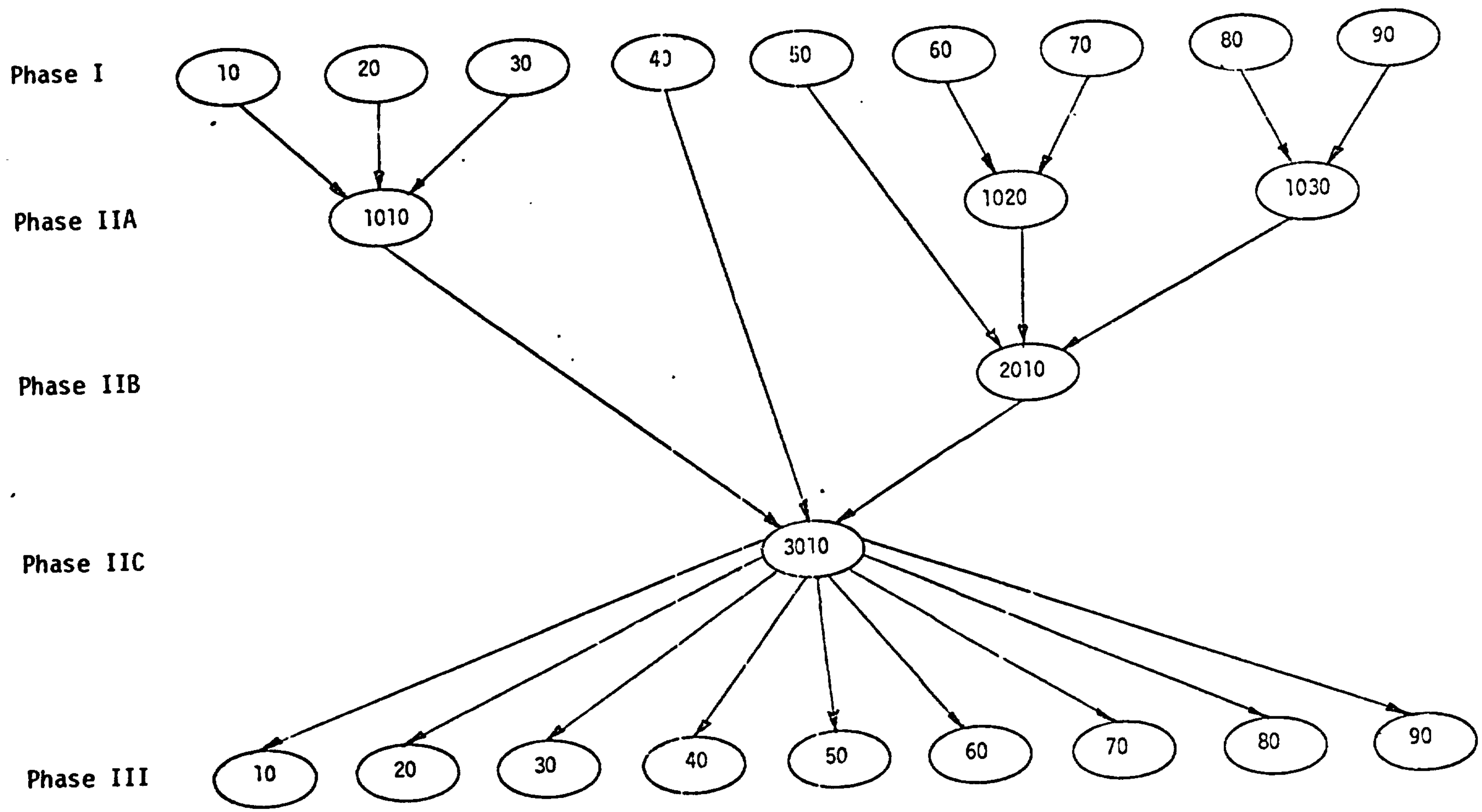


FIGURE 9. MULTI-LEVEL SUBSTRUCTURE ANALYSIS

Input Data Card SAME Joining Data

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

Format and Example:

1	2	3	4	5	6	7	8	9	10
SAME	S	G	S	G	S	G	S	G	abc
SAME	3	79	4	216	6	93			ABC

+bc	S	G	S	G	etc.				
+BC	7	42							

etc.

Alternate Form

SAME	S	G1	"THRU"	G2	S	G1	"THRU"	G2	+abc
SAME	10	1	THRU	60	20	101	THRU	160	ABC

+abc	S	G1	"THRU"	G2	etc.				
+BC	30	526	THRU	585					

etc.

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