DESIGN OF NASTRAN DEMONSTRATION PROBLEMS

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SUMMARY

Criteria and procedures are supplied for the selection, evaluation and maintenance of an optimum set of demonstration problems to be used for the purposes of checking out the NASTRAN program and demonstrating NASTRAN's capabilities. Also, suggestions are made for a new Demonstration Problem Manual that will better assist the user community in the selection of NASTRAN options and preparation of input data as well as allow the user to isolate the various options used in the set of demonstration problems.

INTRODUCTION

The versatility and scope of NASTRAN are large and increasing with each new release. For this reason a set of demonstration problems is used to checkout the NASTRAN program as well as to demonstrate its capabilities. The use of demonstration problems in this manner is a good practice and should be continued in the future as new features are added on to NASTRAN. However, care must be taken in the construction of this set of problems. Because of the many options available in NASTRAN, the set of demonstration problems should be both complete and efficient, i.e., it should utilize all the options of NASTRAN in a limited number of problems. It is the intention of this paper to supply criteria and procedures for the selection, evaluation and maintenance of an optimum set of demonstration problems. In order to carry out our objective a catalogue is constructed which lists all the NASTRAN options which are to be explicity checked out. This catalogue is then used to evaluate the present set of demonstration problems and a procedure is outlined for the construction of an optimum set of demonstration problems.

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It is also suggested that a new Demonstration Problem Manual be supplied which will assist the user community in the selection of NASTRAN options and preparation of input data. This will be a useful supplement to the User's Manual (ref. 1). To this end the present paper includes, as a by-product of the aforementioned objective, a complete listing of the options available in NASTRAN in an organized format. Also a complete catalogue of the present demonstration problems is constructed in a matrix form. This catalogue is displayed in the Appendix and can be used as a reference to locate the use of a particular option in the set of demonstration problems.

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CONSTRUCTION OF CATALOGUE

The first step in constructing a catalogue is to organize the NASTRAN features into general groups. These general groups, shown in Figure 1, are based on the flow through the NASTRAN data deck and represent the main features that the user is concerned with in order to set up his problem correctly and completely. The present Demonstration Problem Manual (ref. 2) contains a similar listing.

Next, an evaluation is made to determine which options must be explicitly checked out. This will help insure completeness and avoid duplication and unnecessary bookeeping. This evaluation leads to the following considerations:

1. All the modules in NASTRAN must be thoroughly evaluated. However, only those modules not used in the rigid formats will be listed in the catalogue (See A5.DMAP of Appendix). These modules can then be altered into the rigid formats or included in a separate DMAP program. In this way we will guarantee that all the modules are being used. In addition, all parameter options should be checked in a separate DMAP program.

2. The case control cards that are used for selecting bulk data input are not explicitly included in the list of data cards. These will automatically be checked when the corresponding bulk data cards are used. The case control cards necessary for selecting bulk data cards are listed in the Appendix under C. Bulk Data Deck Options. Also see section 2.3.1 of the User's Manual for this purpose. The case control cards TITLE, SUBTITLE, and LABEL are used in most problems and are therefore deleted from the list to be demonstrated.

3. Those bulk data cards that are necessarily referred to by other bulk data cards are not included in the catalogue. Generally, these are property cards. Other bulk data cards that fall in this category are EIGP, AXIC, AXSLOT, AXIF, ADUMi, DAREA and RANDPS.

4. Denoted by (*) in the catalogue list are those bulk data cards that are necessarily required for one or more rigid formats. This included the following cards (along with the corresponding rigid formats): EIGR (3, 11, 12), DSFACT (4), EIGB (5), PLFACT (6), EIGC (7), and TSTEP (9, 12).

All the NASTRAN options are listed under their appropriate headings. The final product, listed in the Appendix, contains a complete and efficient listing of all the options in NASTRAN which have to be explicitly checked out. Also, the catalogue is constructed in an easily usable manner, e.g., under any category of structural consideration the user can see at a glance the options available and which data cards are necessary for each option.

CONSTRUCTION OF OPTIMUM SET OF DEMONSTRATION PROBLEMS

Selection of Problems

In general, small prototype problems will be selected. This will enable the user to analyze prototype problems before attempting the solution of large-scale problems. A number of large-scale problems will also be included to checkout such things as spill logic. An individual problem will be kept realistic while utilizing as many different options as feasible. This is in keeping with the desired objective, namely, to utilize all the options available in NASTRAN in an efficient manner.

The initial set of demonstration problems will be comprised of those presently being used to checkout NASTRAN. Figure 2 represents three typical problems that will be considered as additions to or replacements for the initial set. In problem 1 subcase definitions are demonstrated on a simple truss. This problem uses all the static subcase options. In problem 2 we are considering the buckling of a simply supported square plate under edge compression. Instead of using just one element we incorporate all the plate elements into one problem. There are nine such elements. This problem checks out the reliability of the static stiffness and differential stiffness matrices of plate elements. We note that in both these problems there are many options (in a given category) used in a single problem, making it possible to use all the options in fewer problems, or, more appropriately, in less computer time. In problem 3 we are analyzing the nonlinear behavior of a rotating beam under axial compression. In addition to demonstrating the differential stiffness of the CBAR element, as presently demonstrated in demonstration problem 4-1, the present problem also includes the following; (1) the use of CELAS1 and CELAS2 elements, which have not been demonstrated in any current demonstration problem, (2) the use of a negative spring to simulate a rotating mass, and (3) an ALTER which allows the load factors, specified on the DSFACT bulk data card, to be applied to load P while not affecting load q (presently all loads are multiplied by the load factors).

Evaluation

A table is now set up in matrix form and can be used to evaluate a set of demonstration problems. A similar idea was suggested by Cuthill et al. in ref. 3. The rows of the matrix are the NASTRAN options, listed in the catalogue, while the columns refer to the different demonstration problems. For each problem we check off the options used. After a set of demonstration problems is catalogued, we can easily see from our matrix which options are used for a given problem, which problems utilize a given option, and in particular, which options have not been used. An evaluation of the demonstration problems used to check out level 15 has been made, and the complete evaluation matrix is given in the Appendix. The general observation is that the present set of demonstration problems utilizes most of the main features of NASTRAN, but that there are many minor options which are not used.

Construction and Maintenance

We can see at the outset that there is no unique set of optimum problems feasible. In fact it would be very inefficient to try to find the most efficient set of problems. The method outlined here is an iterative procedure, as shown in Figure 3. Starting with a given set of demonstration problems, catalogue and evaluate them as outlined previously, then update them by altering and deleting old problems and adding new problems. The updated set of problems can then be made more efficient by combining options in different ways, or possibly by combining problems. The cycle of evaluating and updating can be repeated as often as necessary. We must also make sure that we can easily maintain the set of demonstration problems. As new features are added to NASTRAN, the cataloguing tables are updated and the demonstration problems are altered or added to and the cycle repeated. This will lead to an efficient set of demonstration problems which can be maintained with a minimum of effort.

Once we have a set of problems we can demonstrate them on NASTRAN. With our cataloguing procedure we will know exactly which options are being checked out and which options remain to be checked out. Ultimately, we will have a complete set of problems, that is to say, a set of problems that utilizes all the features of NASTRAN.

DEMONSTRATION PROBLEM MANUAL

The proposed Demonstration Problem Manual will consist of a description of the demonstration problems, as appears presently (ref. 2). A useful addition will be the catalogue of NASTRAN options. This will enable the reader to follow and understand the selection of options used for a given problem. Also included, for easy reference, should be the evaluation matrix of the present set of demonstration problems. This will allow the user to isolate the use of a given option in the set of problems. It is suggested that the data decks for the demonstration problems also be included in this manual for easy reference and completeness. This has also been suggested by Cuthill, et al. in reference 3. Whether the data decks are included in the manual, since they are supplied to the user from COSMIC, they should include comments to help explain any misunderstandings that might arise in the preparation of data.

CONCLUDING REMARKS

The present text outlines procedures for constructing an optimum set of demonstration problems (one which utilizes all the options in an efficient manner) and a format for a new Demonstration Problem Manual (one which readily lends itself to isolating the use of individual options). This will allow both the management and user community of NASTRAN to take better advantage of the use of demonstration problems.

REFERENCES

1. The NASTRAN User's Manual, McCormick, C. W., ed., NASA SP-222, September 1970.

2. The NASTRAN Demonstration Manual, NASA SP 224, September 1970.

3. Cuthill, E.; Matula, P.; Hurwitz, M.; McKee, J.; and Messalle, R.: NASTRAN Evaluation Report, Naval Ship Research and Development Center, AML-49-70, August 1970.

APPENDIX

CATALOGUE OF NASTRAN OPTIONS, LEVEL 15

A. Executive Control Deck Options

1. Rigid Format - APP DISP/SOL K1, K2
    - 1.1 Static Analysis
    - 1.2 Static Analysis with Inertia Relief
    - 1.3 Normal Mode Analysis
    - 1.4 Static Analysis with Differential Stiffness
    - 1.5 Buckling Analysis
    - 1.6 Piecewise Linear Analysis
    - 1.7 Complex Eigenvalue Analysis, Direct Formulation
    - 1.8 Frequency and Random Response Analysis, Direct Formulation
    - 1.9 Transient Response Analysis, Direct Formulation
    - 1.10 Complex Eigenvalue Analysis, Modal Formulation
    - 1.11 Frequency and Random Response Analysis, Modal Formulation
    - 1.12 Transient Response Analysis, Modal Formulation
2. User's Master File
    - 2.1 Create or Edit - UMFEDIT
    - 2.2 Use in Execution - UMF K1, K2
3. Checkpoint and Restart
    - 3.1 Checkpoint - CHKPNT
    - 3.2 Restart - RESTART
        - 3.2.1 Restart with Rigid Format Change
        - 3.2.2 Restart with Case Control Change
        - 3.2.3 Restart with Bulk Data Change
4. Alter Rigid Format
   ALTER K/ALTER K1, K2/ENDALTER
5. Direct Matrix Abstraction Programming (DMAP)
   APP DMAP/BEGIN/END

5.1	Utility Modules	5.2	Matrix Operation Modules	
	MATPRN		ADD	PARTN
	MATPRT		ADD5	SOLVE
	SEEMAT		DECOMP	SMPYAD
	TABPRT		FBS	TRNSP
	TABPT		MERGE	UMERGE
	VEC		MPYAD	UPARTN
5.3	User Generated I/O	5.4	User Tape Modules	
	INPUT (a = 1, 7)		INPUTT1	OUTPUT1
	OUTPUT3		INPUTT2	OUTPUT2

6. Diagnostic Output - DIAG K (K = 1, 31)
7. Time - TIME N

B. Case Control Deck Options

1. Subcase Definition

SUBCASE	SYM	REPCASE
SUBCOM	SYMCOM	MODES
SUBSEQ	SYMSEQ	

B. Case Control Deck Options (cont.)

2. Printed Output Selection

ACCELERATION	MAXLINES	SPCFORCES
AXISYM=FLUID	NLLOAD	STRESS, ELSTRESS
DISP, VECTOR, PRESSURE	OFREQUENCY	SVELOCITY
ECHO	OLOAD	THERMAL
FORCE, ELFORCE	SACCELERATION	VELOCITY
HARMONICS	SDISP, SVECTOR	(SORT2)
LINE	SET	(PUNCH)

3. Plotted Output Selection
   - 3.1 Plotter (1) DD (2) CALCOMP (3) SC (4) EAI (5) BL
   - 3.2 Undeformed Plot
   - 3.3 Static Deformation Plot
   - 3.4 Modal Deformation Plot
   - 3.5 Transient Deformation Plot
   - 3.6 Undeformed and Deformed Plot
   - 3.7 Frequency Response Plot
   - 3.8 Transient Response Plot
   - 3.9 Structural Plot Options

ORTHOGRAPHIC PROJECTION	AXES
PERSPECTIVE PROJECTION	ORIGIN
STEREOSCOPIC PROJECTION	VIEW
PROJECTION PLANE SEPARATION	FIND
OCULAR SEPARATION	CAMERA
VANTAGE POINT	SYMBOLS

C. Bulk Data Deck Options

	Case Control	Bulk Data
1. Geometry		
1.1 Coordinate Systems		CORD1C
		CORD1R
		CORD1S
		CORD2C
		CORD2R
		CORD2S
1.2 Geometric Grid Points		GRDSET
		GRID
1.3 Scalar Points		SPOINT
1.4 Resequencing Grid and Scalar Points		SEQGP
1.5 Fluid Points		FREEPT
		FSLIST
		GRIDB
		RINGFL
		GRIDF
1.6 Slot Surface Points		GRIDS
1.7 Conical Shell Points		RINGAX
		SECTAX
2. Elements		
2.1 Bar		BAROR
		CBAR
Offset Bar connection, CBAR		Offset
2.2 Rod		CONROD
		CROD
2.3 Tube		CTUBE

C. Bulk Data Deck Options (cont.)	Case Control	Bulk Data
2.4 Shear Panel		CSHEAR
2.5 Twist Panel		CTWIST
2.6 Two-Dimensional Membrane		CQDMEM
		CTRMEM
2.7 Two-Dimensional Bending		CQDPLT
		CTRBSC
		CTRPLT
2.8 Two-Dimensional Combined Membrane		CQUAD1
and Bending		CQUAD2
		CTRIA1
		CTRIA2
2.9 Conical Shell, Isotropic		CCONEAX
2.10 Toroidal Shell, Isotropic or Orthotropic		CTORDRG
2.11 Revolved Ring, Isotropic or Orthotropic		CTRAPRG
		CTRIARG
2.12 Scalar Spring		CELAS1
		CELAS2
		CELAS3
		CELAS4
2.13 Fluid		CAXIF2
		CAXIF3
		CAXIF4
		CFLUID2
		CFLUID3
		CFLUID4
2.14 Slot-Acoustic Cavity Analysis		CSLOT3
		CSLOT4
2.15 Three-Dimensional, Isotropic		CHEXA1
		CHEXA2
		CTETRA
		CWEDGE
2.16 General		GENEL
2.17 Heat Boundary		CHBDY
2.18 Direct Input Matrices and		DMI
Input Tables		DTI
2.19 Plot		PLOTEL
3. Material Properties		
3.1 Linear, Temperature Independent;		
Isotropic		MAT1
Anisotropic		MAT2
Orthotropic		MAT3
3.2 Linear, Temperature Dependent;		TABLEM1
		TABLEM2
		TABLEM3
		TABLEM4
Isotropic	TEMPERATURE	MATT1
Anisotropic	(MATERIAL)	MATT2
Orthotropic	TEMP(MAT)	MATT3
3.3 Conduction Properties;		
Isotropic		MAT4
Anisotropic		MAT5
3.4 Nonlinear Material		TABLES1
		MATS1

C. Bulk Data Deck Options (cont.)

	Case Control	Bulk Data
4. Static Loads		
4.1 Concentrated Load	LOAD	FORCE
	LOAD	FORCE1
	LOAD	FORCE2
	LOAD	MOMENT
	LOAD	MOMENT1
	LOAD	MOMENT2
	LOAD	SLOAD
4.2 Pressure Load	LOAD	PLOAD
	LOAD	PLOAD2
4.3 Gravity Load	LOAD	GRAV
4.4 Combined Load	LOAD	LOAD
4.5 Centrifugal Load	LOAD	RFORCE
4.6 Thermal Load	TEMPERATURE	TEMP
	(LOAD)	TEMPD
	TEMP(LOAD)	TEMPP1
	TEMP(LOAD)	TEMPP2
	TEMP(LOAD)	TEMPP3
	TEMP(LOAD)	TEMPRB
4.7 Conical Shell Load	LOAD	FORCEAX
	LOAD	MOMAX
	LOAD	POINTAX
	LOAD	PRESAX
	TEMP(LOAD)	TEMPAX
4.8 Enforced Deformation	DEFORM	DEFORM
4.9 Heat Conduction	LOAD	QHBDY
4.10 Differential Stiffness Scale Factor, *(4)	DSCO	DSFACT
4.11 Piecewise Linear Scale Factor, *(6)	PLCOEFF	PLFACT
5. Dynamic Modeling		
5.1 Structural Mass, MATi		St. Mass
5.2 Nonstructural Mass		CMASS1
		CMASS2
		CMASS3
		CMASS4
5.3 Concentrated Mass		COMM1
		COMM2
5.4 Structural Damping, MATi or Prop.		St. Damp.
5.5 Viscous Damping		CVISC
5.6 Modal Damping	SDAMP	TABDMP1
5.7 Direct Input Matrices	B2PP	DMIG
	K2PP	DMIG
	M2PP	DMIG
5.8 Transfer Functions	TFL	TF
5.9 Extra Points		EPOINT
		SEQEP
5.10 Scalar Damping		CDAMP1
		CDAMP2
		CDAMP3
		CDAMP4
6. Constraints and Partitioning		
6.1 Multipoint Constraints	MPC	MPC
	MPC	MPCADD
	MPC	MPCAX

C. Bulk Data Deck Options (concluded)

	Case Control	Bulk Data
6.2 Single Point Constraints	SPC	SPC
	SPC	SPC1
	SPC	SPCADD
	SPC	SPCAX
6.3 Partitioning		OMIT
		OMIT1
		OMITAX
		ASET
		ASET1
Dynamic, Guyan Reduction (OMIT, ASET)		Guyan
6.4 Free Body Support		SUPORT
		SUPAX
6.5 Fluid Constraints		FLSYM
6.6 Fluid-Structure Boundary		BDYLIST
6.7 Slot Boundary List		SLBDY
7. Eigenvalue Extration Method, *(3,5,7,11,12)		
7.1 Determinant (DET)		EIGm
7.2 Inverse Power with Shifts (INV)		EIGm
7.3 Givens (GIV)		EIGm
8. Dynamic Excitation		
8.1 Frequency Response Dynamic Load	DLOAD	RLOAD1
	DLOAD	RLOAD2
8.2 Transient Response Dynamic Load	DLOAD	TLOAD1
		TLOAD2
8.3 Dynamic Load Tabular Function		TABLEDi
8.4 Loading Phase Angels		DPHASE
8.5 Loading Time Lags	DLOAD	DELAY
8.6 Combined Loads	DLOAD	DLOAD
8.7 Transient Initial Condition	IC	TIC
8.8 Transient Time Step,*(9, 12)	TSTEP	TSTEP
8.9 Random Analysis Power Spectral; Density Table	RANDOM	RANDT1
		TABRND1
8.10 Frequency Selections for Frequency Response Problem	FREQUENCY	FREQ
	FREQUENCY	FREQ1
	FREQUENCY	FREQ2
8.11 Nonlinear Transient Response Load	NONLINEAR	NOLINi
9. Rigid Format Optional Parameters, PARAM		
Grid Point Weight Generator		GRDPNT
Structural Mass Coefficient		WTMASS
Generates Coupled Mass Matrices,(Also CPelement)		COUPMASS
Uniform Structural Damping Coefficient		G
Pivotal Frequencies for Damping, Rigid Format9		W3, W4
Printing of Residual Vectors		IRES
Frequency Range of Modes, *(10,11,12) }		L,HFREQ
		LMODES
Mode Acceleration Method, Rigid Format 11, 12		MODACC
Optional Decomposition for Frequency Response		DECOMOPT
Generates Conductivity Matrix		OPT. HEAT
10. Miscellaneous		
10.1 Delete from OPTP or UMF		/
10.2 Comment		$
10.3 Large Field Bulk Data Card		TYPE*

DEMONSTRATION PROBLEMS

PROB. NO.		DESCRIPTION *
1A	1-1	Delta wing with biconvex cross section
1B	1-1A	Delta wing - Restart, load change
1C	1-1B	Delta wing - Restart, real eigenvalue analysis
2A	1-2	Spherical shell with pressure loading
2B	1-2A	Spherical shell - Restart, boundary condition change
3A	1-3	Free rectangular plate with thermal loading
3B	1-3	Free rectangular plate - User generated input
4A	1-4	5x50 long, narrow, orthotropic plate
4B	1-4	5x50 plate - User generated input
4C	1-4A	5x50 plate - Restart, modified output
4D	1-4	5x60 long, narrow, orthotropic plate
4E	1-4	5x60 plate - User generated input
4F	1-4A	5x60 plate - Restart, modified output
5	1-5	Nonsymmetric bending of a cylinder of revolution
6	1-6	Solid disc with radially varying thermal load
7	1-7	Spherical shell, external pressure loading
8	1-8	1x4x10 cantilever beam using cubic CHEXA1 elements
9	1-9	2x2x10 fixed-free beam using rectangular CHEXA2 elements
10	1-10	Thermal bending of a bar
11	1-11	Simply supported rectangular plate with thermal gradient
12	1-12	Heat conduction through a washer, surface film heat transfer
13	2-1	Inertia relief analysis of a circular ring
14A	3-1	Vibration of a 10x20 plate
14B	3-1	Vibration of a 10x20 plate - User generated input
14C	3-1	Vibration of a 20x40 half plate
14D	3-1	Vibration of a 20x40 half plate - User generated input
15	3-2	Vibration of a compressible gas in a rigid spherical tank
16	3-3	Vibration of a liquid in a half filled rigid sphere
17	3-4	Acoustic cavity analysis
18	4-1	Differential stiffness of a 100 cell beam
19	5-1	Symmetric buckling of a cylinder
20	6-1	Piecewise linear analysis of a cracked panel
21A	7-1	Complex eigenvalues of a 500 cell string
21B	7-1	Complex eigenvalues of a 500 cell string - User generated input
22A	7-2	Complex eigenvalues analysis of a gas-filled thin cylinder-harmonics 3
22B	7-2	Complex eigenvalues analysis of a gas-filled thin cylinder-harmonics 5
23A	8-1	Frequency response of a square plate - 10x10 mesh
23B	8-1	Frequency response of a square plate - User generated input
23C	8-1	Frequency response of a square plate - 20x20 mesh
23D	8-1	Frequency response of a square plate - User generated input
24	9-1	Transient analysis with direct matrix input
25A	9-2	Transient analysis of a 1000 cell string
25B	9-2	Transient analysis of a 1000 cell string - User generated input
26	9-3	Transient analysis of a fluid-filled elastic cylinder
27	10-1	Complex eigenvalue analysis of a rocket control system
28A	11-1	Frequency response and random analysis of a 10 cell beam
28B	11-1A	10 cell beam - Restart, static analysis
29A	11-2	Frequency response of a 500 cell string
29B	11-2	Frequency response of a 500 cell string - User generated input
30	12-1	Transient analysis of a free 100 cell beam
31		1972 User Master file - demonstration problems

* Descriptions refer to listing of demonstration problems for level 15.

DEMONSTRATION PROBLEMS — EVALUATION MATRIX

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
A.	Executive Control Deck Options																															
1.	1	AB	●	●	●	●	●	●	●	●	●	●	●																B			
	2													●																		
	3	C													●	●	●	●														
	4																		●													
	5																			●												
	6																				●											
	7																					●	●									
	8																							●								
	9																								●	●	●					
	10																											●				
	11																												A	●		
	12																														●	
2.1	UMFEDIT																															●
2.2	UMF	A	A	A	AD	●	●	●	●	●	●	●		●	AC	●	●		●	●	●	A	●	AC	●	A	●	●	A	A	●	
3.1	CHKPNT	A	A		ABDE																								A			
3.2.1	RESTART	C																											B			
.2	RESTART	B	B		CF																								B			
.3	RESTART	C																											B			
4.	ALTER			B	BE										BD							B		BD		B		●	A	B		
5.3	INPUT			B	BE										BD							B		BD		B				B		
	a =			3	3										3							5		3		5				5		
	OUTPUT3																															
B.	Case Control Deck Options																															
1.	SUBCASE									●	●		●						●	●									A			
	SUBCOM																															
	SUBSEQ																															
	SYM																															
	SYMCOM																															
	SYMSEQ																															
	REPCASE																															
	MODES																															
2.	ACCEL																												A			
	AXI=FLU																						●				●					
	DISP	●	●	●	CF	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
	ECHO	BC	B		CF			●																								
	FORCE		B			●		●			●	●		●					●	●	●								●			
	HARMONIC					●										●	●						●				●					
	LINE																															
	MAXLINES																				●								●			●
	NLLOAD																															
	OFREQU																							●								
	OLOAD			●	AD			●	●	●	●		●	●					●	●	●				●				●			
	SACCEL																															
	SDISP																											●		●		
	SET	●		●	CF	●	●							●	●	●		●	●		●	●		●		●	●	●	●	●	●	
	SPCFORCE	●	●		●				●	●	●	●	●	●	AB					●												
	STRESS	●	●	●	CF		●	●	●	●	●	●		●				●		●	●			●							●	
	SVELOCITY																								●							

Letters refer to problem number, e.g., A in column 4 refers to problem 4A.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	THERMAL												●																			
	VELOCITY																									●						
	(SORT2)																								●				A	●		
3.1	PLOTTER =		1												2 3			3		1					1		1		1	1	1	
3.2	PLOT														B D			●														
3.3	PLOT																															
3.4	PLOT														B D			●		●												
3.5	PLOT																														●	
3.6	PLOT		A																	●												
3.7	PLOT																												A	●		
3.8	PLOT																								●		●				●	
3.9	PERSPECT		A																	●												
	ORTHO																			●											●	
	STEREO																														●	
	PROJ SEP																															
	OCULAR																															
	VANTAGE		A																													
	AXES		A															●		●												
	ORIGIN																															
	VIEW		A															●		●												
	FIND		A												B D			●		●											●	
C.	Bulk Data Deck Options																															
1.1	CORD1C																															
	CORD1R																															
	CORD1S																															
	CORD2C												●	●						●			●				●					
	CORD2R																															
	CORD2S		●													●	●															
1.2	GRDSET	●	●	●	A D		●	●			●	●	●	●	●				●	●	●			A C				●	●		●	
	GRID	●	●	●	●		●	●	●	●	●	●	●	●	●			●	●	●	●			●				●	●		●	
1.3	SPOINT																											●				
1.4	SEQGP				●								●							●								●				
1.5	FREEPT																●															
	FSLIST																●						●				●					
	GRIDB																						●				●					
	GRIDF																	●														
	RINGFL															●	●						●				●					
1.6	GRIDS																	●														
1.7	RINGAX					●																										
	SECTAX																															
2.1	BAROR										●			●					●									●			●	
	CBAR										●			●					●									●	●		●	
	Offset													●																		
2.2	CONROD	●																														
	CROD	●																														
2.3	CTUBE																															
2.4	CSHEAR	●																														
2.5	CTWIST																															
2.6	CQDMEM	●		A																												

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	CTRMEM	●																			●											
2.7	CQDPLT																															
	CTRBSC																															
	CTRPLT																															
2.8	CQUAD1			B	●							●			●								●	●		●						
	CQUAD2																															
	CTRIA1																			●												
	CTRIA2		●																													
2.9	CCONEAX					●																										
2.10	CTORDRG							●																								
2.11	CTRAPRG						●																									
	CTRIARG																															
2.12	CELAS1																															
	CELAS2																															
	CELAS3																					A				A				A		
	CELAS4																					B				B		●		B		
2.13	CAXIF2																	●														
	CAXIF3																	●														
	CAXIF4																	●														
	CFLUID2															●	●						●				●					
	CFLUID3															●	●															
	CFLUID4																						●				●					
2.14	CSLOT3																	●														
	CSLOT4																	●														
2.15	CHEXA1								●				●																			
	CHEXA2									●			●																			
	CTETRA												●																			
	CWEDGE												●																			
2.16	GENEL																												●			
2.17	CHBDY												●																			
2.18	DMI																															
	DTI																															
2.19	PLOTEL		A												B D			●														
3.1	MAT1	●	●	●		●	●	●	●	●	●	●		●	●				●		●		●	●			●	●	●		●	
	MAT2				●																											
	MAT3																															
3.2	TABLEM1			●																												
	TABLEM2																															
	TABLEM3																															
	TABLEM4																															
	MATT1			●																												
	MATT2																															
	MATT3																															
3.3	MAT4												●																			
	MAT5																															
3.4	TABLES1																				●											
	MATS1																				●											
4.1	FORCE	A B			●			●	●					●					●	●												
	FORCE1									●									●													

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	FORCE2																															
	MOMENT							●											●													
	MOMENT1																															
	MOMENT2																															
	SLOAD																															
4.2	PLOAD																															
	PLOAD2		●																													
4.3	GRAV																												B			
4.4	LOAD													●					●													
4.5	RFORCE													●																		
4.6	TEMP			●			●						●																			
	TEMPD									●			●																			
	TEMPP1											●																				
	TEMPP2																															
	TEMPP3																															
	TEMPRB										●																					
4.7	FORCEAX																															
	MOMAX					●																										
	POINTAX					●																										
	PRESAX																															
	TEMPAX																															
4.8	DEFORM																												B			
4.9	QHBDY																															
4.10	DSFACT																		●													
4.11	PLFACT																				●											
5.1	St.Mass	C												●	●															●	●	
5.2	CMASS1																															
	CMASS2																															
	CMASS3																					A				A				A		
	CMASS4																					B				B		A		B		
5.3	CONM1																															
	CONM2																											A			●	
5.4	St. Damp.																					●										
5.5	CVISC																															
5.6	TABDMP1																												●		●	
5.7	DMIG(B2)																								●							
	DMIG(K2)																								●							
	DMIG(M2)																								●							
5.8	TF																											●				
5.9	EPOINT																								●			●				
5.10	CDAMP1																															
	CDAMP2																															
	CDAMP3																					A										
	CDAMP4																					B										
6.1	MPC																											●				
	MPCADD																											●				
	MPCAX																															
6.2	SPC		B	B	BC EF		●	●	●		●		●		B D				●	●				B D					●			
	SPC1	●	●	A	A D				●	●		●			A C					●	●		●	A C			●					

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	SPCADD				A D					●										●												
	SPCAX																															
6.3	OMIT																															
	OMIT1																		●												●	
	OMITAX																															
	ASET																															
	ASET1																															
	Guyan																														●	
6.4	SUPORT													●				●										●			●	
	SUPAX																															
6.5	FLSYM																						●				●					
6.6	BDYLIST																						●				●					
6.7	SLBDY																	●														
7.1	EIGm(DET)																			●		●	●					●				
7.2	EIGm(INV)	C													●	●	●	●										●	A	●	●	
7.3	EIGm(GIV)																															
8.1	RLOAD1																							●					A	●		
	RLOAD2																												A			
8.2	TLOAD1																								●							
	TLOAD2																										●				●	
8.3	TABLED1																							●	●				●	●		
	TABLED2																															
	TABLED3																															
	TABLED4																															
8.4	DPHASE																												A			
8.5	DELAY																												A			
8.6	DLOAD																												A			
8.7	TIC																									●						
8.8	TSTEP																								●	●	●				●	
8.9	RANDT1																												A			
	TABRND1																												A			
8.10	FREQ																							●								
	FREQ1																												A			
	FREQ2																													●		
8.11	NONLINi																															
9.	GRDPNT													●	●				●									●	●		●	
	WTMASS																		●													
	COUPMASS																															
	G																					●										
	W3,W4																															
	IRES	A B		●	●					●		●	●							●												
	L,HFREQ																															
	LMODES																											●	A	●	●	
	MODACC																													●		
	DECOMOPT																							AB D								
	OPT HEAT												●																			
10.1	/																		●				B									
10.2	$											●			●								B									
10.3	TYPE *																												●	●		

A. <u>EXECUTIVE CONTROL DECK OPTIONS</u>

1. RIGID FORMATS
2. USER'S MASTER FILE
3. CHECKPOINT AND RESTART
4. RIGID FORMAT ALTER
5. DIRECT MATRIX ABSTRACTION (DMAP)
6. DIAGNOSTIC OUTPUT

B. <u>CASE CONTROL DECK OPTIONS</u>

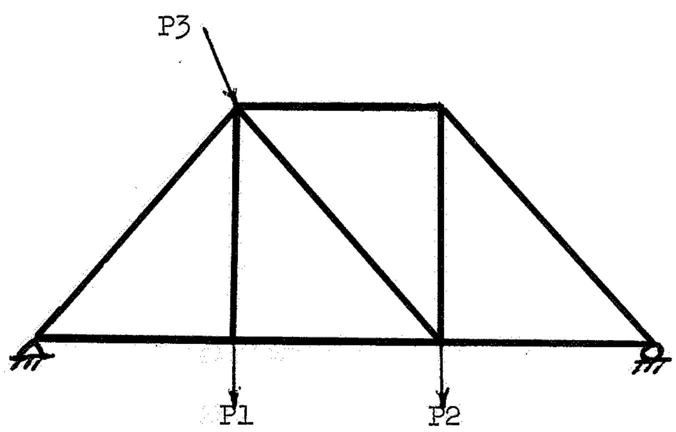
1. SUBCASE DEFINITIONS
2. PRINTED OUTPUT SELECTION
3. PLOTTED OUTPUT SELECTION

C. <u>BULK DATA DECK OPTIONS</u>

1. GEOMETRY
2. ELEMENTS
3. MATERIAL PROPERTIES
4. STATIC LOADS
5. DYNAMIC MODELING
6. CONSTRAINTS AND PARTITIONING
7. EIGENVALUE EXTRACTION
8. DYNAMIC EXCITATION
9. RIGID FORMAT OPTIONAL PARAMETERS
10. MISCELLANEOUS

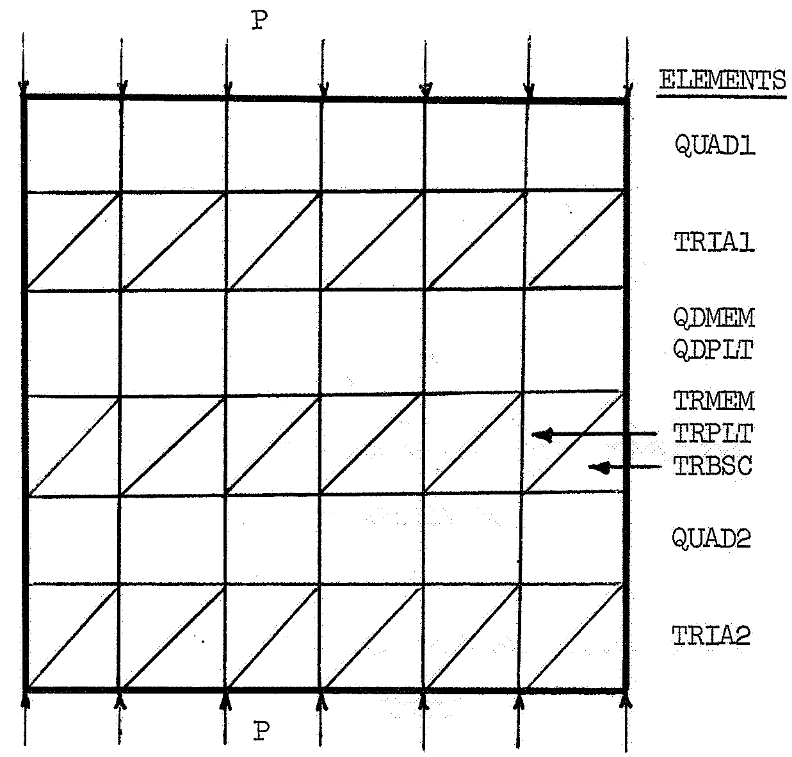
Figure 1. Catalogue-General Groups.

SAMPLE PROBLEM 1



SUBCASE 1
    Load P1
SUBCASE 2
    Load P2
SUBCASE 3
    Load P3
REPCASE 4
    Output Request
SYM 5
    Load b1*P1
SYM 6
    Load b2*P2
SYM 7
    Load b3*P3
SUBCOM 8
SUBCOM 9
SYMCOM 10 } Linear Combinations of SUBCASE's and SYM's

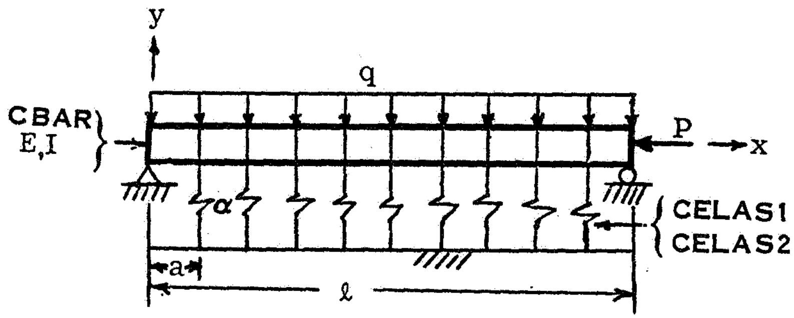
SAMPLE PROBLEM 2



BUCKLING OF A S.S. PLATE

USING 9 TWO-DIM. ELEMENTS

Figure 2. Sample Demonstration Problems.

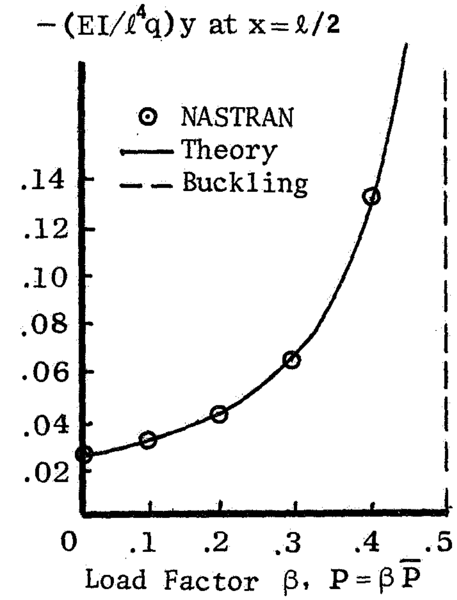


Load factors on **DSFACT** card multiply load P but not load q

```
SOL 4,0
ALTER 135
PARAM //C,N,NOP/V,N,TRUE=-1 $
PARTN PL,, Q/A11,A21,,/C,N,1 /C,N,1 /C,N,2 /C,N,1 $
PARTN PBL,,Q/B11,B21,,/C,N,1 /C,N,1 /C,N,2 /C,N,1 $
MERGE A11,B21,,,,Q /PPP/ C,N,1/C,N,1/C,N,2 $
EQUIV PPP,PBL/TRUE $
ENDALTER

DMI Q 0 2 1 1     m 1
DMI Q 1 n 1.0
```

where m = number of d.o.f. in L set and n specifies location of P load



$\alpha = -a\pi^4 EI/2\ell^4$
$\overline{P} = \pi^2 EI/\ell^2$

Nonlinear analysis of a rotating beam ($\rho\omega^2 = -\alpha/a$) under axial compression.

Figure 2. Concluded.

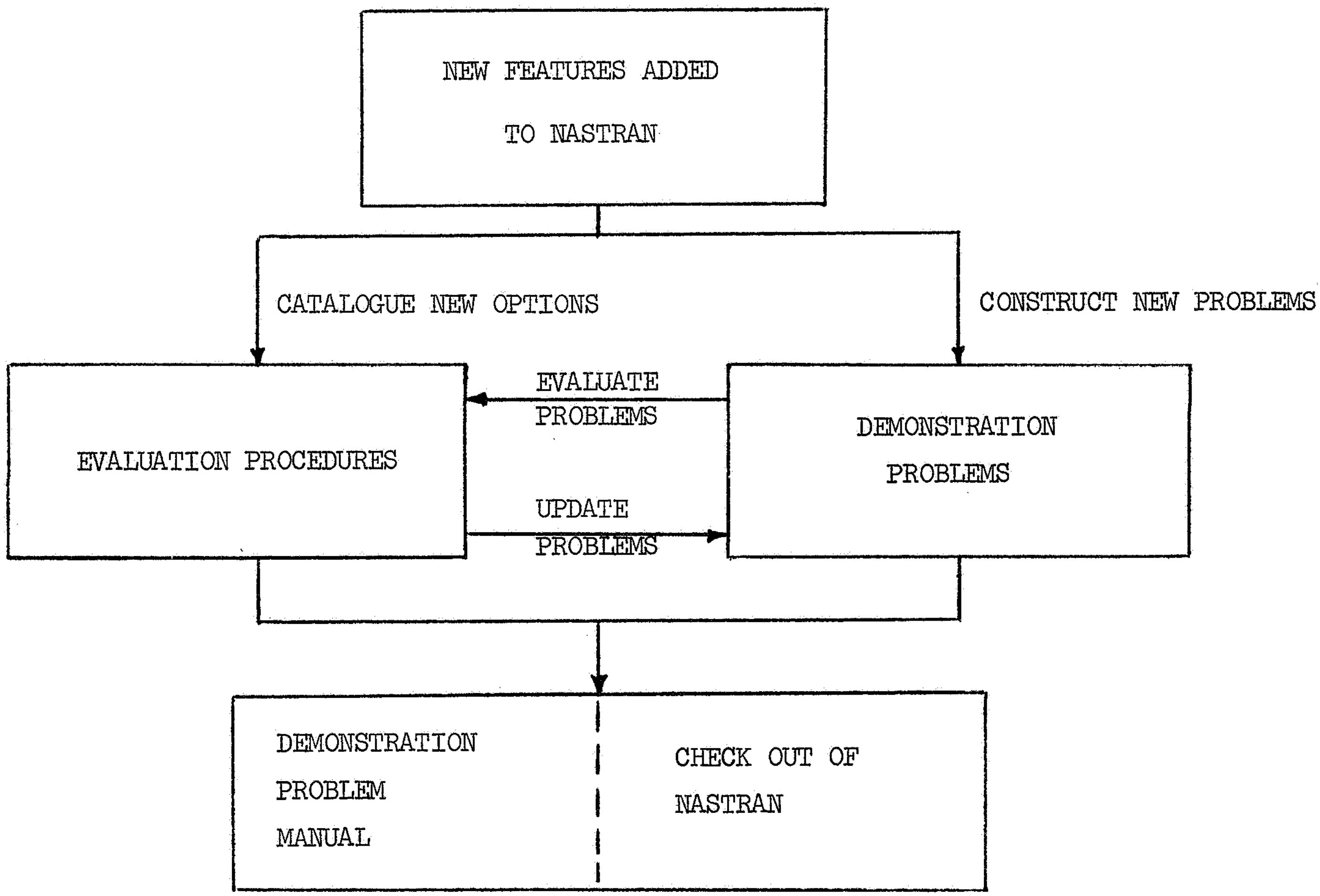


Figure 3. Construction and Maintenance of an Optimum Set of Demonstration Problems.

NASA-Langley, 1972 — 32 L-8553