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SOME ASPECTS OF THE NASTRAN PROGRAM OUTPUT

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Summary

This paper discusses the Nastran Program Output from a structural analysts point of view, and describes the simple modifications which have been made to the program in order to improve it in certain areas. In particular, the convenience of the output for use in original design work is critically appraised and compared with the output from Astral. It is shown that considerable hand calculation is necessary in order to extract useful load distribution data from the available Nastran output. For this reason, some effort has been directed towards providing additional force output for the Nastran shear panel element.*

Introduction

The output from any finite element structural analysis program must be in a form which is immediately useful to the stress or design engineer. The most sophisticated program is not being used efficiently if lengthy hand calculations are necessary before useful loads data can be extracted from the computer output. It is for this reason that Astral has been refined in a design environment over several years to provide a "Force" type output. This is the output that Grumman Engineers have found preferable to a stress output in most design situations where the structural model only approximates to the real structure. The output from Nastran is definitely not in a convenient form and this paper describes some of its shortcomings and the modifications made to the program in order to provide a force type output for the shear panel element. Similar modifications should also be made to the membrane and plate elements.

SYMBOLS

b	Shear panel width	in.
d	Shear panel depth	in.
F	Shear panel corner forces	#
n	Number of loading conditions	
Nx	Wing chordwise load distribution	#/in.
P	Shear panel diagonal forces	#
q	Shear flow	#/in.
r	Number of members in idealization	
t	Shear panel thickness	in.
x, y	Local coordinates	in.
ϕ, ψ, θ_2	Angles defining geometry of shear panel (See Figure 13)	

NASTRAN OUTPUT: COMPARISON WITH ASTRAL

In this section of the paper, Nastran Output is compared with Astral "M Print" for output format and form.

* Automated Structural Analysis Program developed by Grumman

Output Format. Nastran output is grouped by loading conditions whereas Astral groups output by member or grid point number. Grouping by loading condition is far less convenient when many loading conditions may be present as is often the case in a fuselage analysis. Also, grouping by member number enables a maximum minimum search to be made by the program with a minimum of additional programming. This maximum minimum output for loads and deflections is an indispensable feature of Astral "M Print" output.

As an example of the different grouping strategies, consider a hypothetical structure with r members and n loading conditions. Figure 1 compares the output formats for this structure.

Output Form. Figure 2 indicates the main differences in output between Nastran and Astral for some of the most commonly used finite elements. In general, Nastran provides average stresses and scant loads data, whilst Astral provides a comprehensive force output on a "node force" basis. Nastran also provides a Margin of Safety output for some elements if an allowable stress is specified by the user. This margin is based upon average stresses in idealized members and assumes a uniaxial stress field. As such it is a "misleading" output and should be disregarded in all but the most elementary truss type structure. Of more use, would be a stress ratio of the form:

$$\text{Stress Ratio} = \frac{\text{Stress}}{\text{Allowable Stress}}$$

Any stress output should be treated with caution, especially in final design work, since stresses output by Nastran are only correct if the idealized structure is identical to the real structure – rarely the case. In most cases, the Structural Analyst prefers to work with load distributions.

Axial Force Output. Nastran outputs average forces in rod elements, diagonal forces in shear panels and no forces for the membrane element. Hence, the element node forces can not be calculated when using membranes, but can be calculated from rod and shear panel output at the expense of tedious hand calculations. The following procedure shows how node forces are obtained from rectangular shear panels and rods. Note that for the more general case of non rectangular panels, the required calculations are more tedious and an approximate graphical approach would be used in most cases.

Assume a situation were a rod is bounded by two rectangular shear panels as shown in Figure 3:

Nastran Output:	Panel I Diagonal forces P_1 and P_2	(#)
	Rod Average Force P_3	(#)
	Panel 2 Diagonal Forces P_4 and P_5	(#)

Required:	*Node Forces at Rod Ends F_1 and F_2*	*(#)*
	Shear Flows Adjacent to Rod q_1 and q_2	*(#/in)*

Resolving diagonal forces along panel edges, adding and dividing by length of rod:

$$q_1 = \frac{(P_1 + P_2)}{\sqrt{b^2 + d_1^2}} \#/IN$$

$$q_2 = \frac{(P_4 + P_5)}{\sqrt{b^2 + d_2^2}} \#/IN$$

Summing corner forces and rod average force at each end of rod:

$$F_1 = P_3 + \frac{P_1 b}{\sqrt{b^2 + d_1^2}} - \frac{P_5 b}{\sqrt{b^2 + d_2^2}}$$

$$F_2 = P_3 - \frac{P_2 b}{\sqrt{b^2 + d_1^2}} + \frac{P_4 b}{\sqrt{b^2 + d_2^2}}$$

These equations would be modified appropriately if more than two shear panels were adjacent to the rod. Typically, for a wing rib and beam intersection, four panels would be involved.

H3-T Orbiter Wing Analysis

This analysis has been chosen to illustrate how loads are extracted from both Nastran and Astral for use in design work.

Briefly, the idealization consists of quadrilateral and triangular membranes for the upper and lower covers, and rods and shear panels for the ribs, beams (spars) and vertical studs (posts). A drawing of the idealization is shown in Figure 4.

Main features of the idealization are as follows:

130	*Grid Points*
80	*Quadrilateral Membranes*
14	*Triangular Membranes*
107	*Shear Panels*
71	*Rods*
364	*Degrees of Freedom*

The Nastran Bulk Data Deck used for the analysis was generated automatically from the Astral Input Deck using an in house conversion program. Only the Control Decks were produced by hand. A comparison of computer running times for the two analyses is shown in Figure 5.

Load distributions useful to the Structural Analyst and Designer are shown at sample wing sections, and the method of deriving them from the raw program output is detailed. The general agreement between the two analyses, as indicated by overall wing flexibility, is good as expected, since both use the stiffness method of finite element analysis and both have approximately equivalent elements. The difference in wing tip deflection for one typical loading condition amounted to less than .02%.

Wing Cover Axial Loads

Cover axial loads are most often presented at Grumman as a series of chordwise running load distributions(#/in.) along each rib line. As an example, the distribution for the upper cover at rib 10 is determined in Figures 6 and 7 and shown plotted in Figure 8. The Astral node or cap loads are divided by the effective panel width. The Nastran average stresses in panels on the inboard and outboard sides of the rib must be converted to running load and then averaged.

Note that both analyses require a finer grid in the area adjacent to the rear beam due to the discontinuity at grid points 91 and 92. Additional stringers between the beams which carry through to the airplane center line are also needed, in order to predict the shear lag effect caused by the cover discontinuity across rib 11.

Rib and Beam Shear Flows

All shear flows are output directly by Astral "M Print". Nastran output consists of maximum and average shear stresses which may be converted to shear flows by multiplying by the panel thickness. If, however, all four shear flows are required, then the procedure outlined previously for rectangular panels or the procedure below for extracting stud loads must be used. Figure 9 shows the extraction of maximum shear flows only, for rib 10.

Stud Cap Forces

Stud forces or cap forces are the most difficult to extract from Nastran output. In this example the cap forces for stud 85 at the intersection of rib 10 and beam 5 will be determined. None of the adjacent four shear panels are rectangular; therefore, the simplified equations of the Appendix may not be used. Instead, an approximate graphical approach is taken. First the four shear panels are drawn to scale on Figure 10 with the diagonal forces and rod average forces as shown. Next, the components of the diagonal forces acting along the stud are scaled and added:

At the upper cover: $\text{Force} = 3055 + 16292 \times \frac{1.67}{2.49} - 2514 \times \frac{1.43}{3.17} + 4393 \times \frac{1.39}{1.87} - 10911 \times \frac{1.78}{2.06}$

$= 6660\,\#$

At the lower cover: $\text{Force} = 3055 + 2626 \times \frac{1.71}{3.30} - 15416 \times \frac{1.45}{2.35} + 12199 \times \frac{1.55}{1.84} - 3960 \times \frac{1.67}{2.09}$

$= 1990\,\#$

These stud forces are not in good agreement with the corresponding forces output directly by Astral which are 7610# at the upper cover and 710# at the lower cover. This is probably due partly to the graphical approach used, and partly to the relative insensitivity of wing flexibility and deflection to stud loading. A Nastran wing solution with rigid studs, imposed by multipoint constraints, showed only a 4.6% reduction in wing deflections.

Program Modifications to Improve the Shear Panel Output

This section of the paper describes in detail the changes made in Nastran Module SDR2 as a first step in providing an improved "force" type output. Perhaps the most inconvenient aspect of the present output is the use of shear panel diagonal forces, and it was decided to improve this output as quickly as possible. This has been accomplished by modifying the appropriate routines and subroutines in Module SDR2 and outputting the additional data directly from this module, without recourse to User Modules or changes in the Output File Processor. The additional output includes corner forces (#), shear flows(#/in), panel edge lengths and internal node numbers. This output in no way affects the regular Nastran printout which follows it. (See Appendix.)

In order to make these changes, the necessary equations were derived for resolving diagonal forces into corner forces and combining corner forces into shear flows. Next, a working knowledge of how Nastran interfaces "horizontally" between routines and "vertically" between modules was obtained, mostly on a trial and error basis, since this information is not specifically given in the Programmers Manual. The layout chart for Module SDR2 shown in Figure 11 was then drawn and proved invaluable when modifying routines and deciding on the best data paths between routines. At first it was hoped to accomplish all data transfer by means of common blocks; however, it was soon realized that due to the looping that takes place within the module this was not possible. Instead, use was made of the data file ESTA when necessary. The necessary changes to module SDR2 are described in some detail below and summarized in Figure 12. (See Appendix.)

The basic problem consists of bringing together the diagonal forces and local mean plane coordinates, performing the necessary calculations and printing the results. The diagonal forces are calculated in subroutine SPANL2 and the local coordinates in subroutine SPANL1. A convenient place to calculate the forces and shear flows and print them is in routine SDR2E. The following list of modifications to the routines have been made.

- *The local coordinates of the four corners of each panel are loaded into common block SDR2X5 as SPOUT (8) in subroutine SPANL1 for transfer to SDR2B. These coordinates are X and Y values for corners 1 to 4 (Figure 13).*
- *In routine SDR2B, the local coordinates from common block SDR2X5 are transferred to Data File ESTA for the "vertical" transfer to SDR2E (Figure II). ESTA assembles a block of data for each shear panel element processed, whereas the common blocks are rewritten for each pass through a loop.*
- *The block data subroutine SDR2BD must be updated to redimension the enlarged ESTA file. The block size is increased from 25 to 33 words to include the coordinates.*
- *The shear panel diagonal forces P13 and P24 are loaded into common block SDR2X7 in SPANL2 and transferred to SDR2E where they are available as BUFB(2) and BUFB(3) respectively. This does not require any additional coding.*
- *Data file ESTA is moved into common as ELESTA in routine SDR2E and element numbers and internal grid point numbers are already available as BUFB(I) and ELESTA(2-5) respectively. Hence, all the necessary data is assembled in SDR2E.*

Local Coordinates	*ELESTA (25-32)*
Node Number	*ELESTA (2-5)*
Diagonal Forces	*BUFB (2-3)*
Member Number	*BUFB (I)*
Subcase Number	*Z (ICC + 1)*

- *In routine SDR2E the corner forces, shear flows and panel edge lengths are calculated.*
- *The calculated data is output with appropriate headings.*

Appendix A summarizes the equations used, shows a listing of the major SDR2E module coding changes and provides an example of the additional program output.

Recommended Changes in Nastran Output

The following changes in the form and format of Nastran Output would greatly ease the task of the Structural Analyst in design work. They would reduce the amount of hand calculation necessary, eliminate the likelihood of not designing to the most critical loading condition and increase the accuracy of most load distributions.

Output Format

- *The output should be grouped by member or grid point number, not by loading condition.*
- *The maximum and minimum loads for each member should be output if more than two loading conditions are present.*
- *Loads should be output in decimal form, not in exponential form, when of a suitable size. For example, a load of 5650# should be output as 5650.0 or 5650, not as 5.650000E 03 which is far more difficult to read correctly.*

Output Form

- *The shear panel should have a shear flow (#/in.) output for all four sides, and the resolved corner forces should be used in a "Force" type output including "kick" loads due to warping.*
- *Rod and bar elements should have cap or grid point forces output, not average forces. These are determined using the above panel corner forces.*
- *The membrane element should have a "force" type output consisting of shear flows (#/in.) along all four sides and cap forces along imaginary rod elements.*
- *The Margin of Safety output should be deleted.*
- *The length of all sides of all panels should be output, together with their direction cosines in the global coordinate system.*
- *A check on the free body equilibrium of the structure is essential output for any finite element analysis. This should be a summation of all forces and moments about the origin.*

Recommended Additions to Documentation

- *Inclusion of Module Layouts in the Programmers Manual (see Figure II).*
- *Inclusion of full instructions for implementation of user modules in the programmers manual.*

Concluding Remarks

The output from these two finite element analyses, Nastran and Comap Astral, differ in concept. Nastran in general outputs average stresses in elements and some forces which are not in an immediately usable form. Comap Astral provides no stress output (unless specifically requested) but gives a comprehensive force type output. Generally in all but the most elementary of structures, the force type output is preferred by structural analysts at Grumman. The Nastran Shear panel output is particularly difficult to use and the necessary modifications to the program to quickly provide a more suitable output have been described. At this time work is under way to provide a better output form and format for all the commonly used Nastran Elements.

Reference

AFFDL-TR-70-118 An Automated Procedure for the Optimization of Pratical Aerospace Structures. Section 4.3 "Nodal Stress Method."

APPENDIX

Summary of Equations:

Trigonometric Functions:

$$\cos\varphi_1 = \frac{y_4}{\sqrt{x_4^2 + y_4^2}} \qquad \sin\varphi_1 = \frac{x_4}{\sqrt{x_4^2 + y_4^2}}$$

$$\cos\varphi_2 = \frac{y_3}{\sqrt{x_3^2 + y_3^2}} \qquad \sin\varphi_2 = \frac{x_3}{\sqrt{x_3^2 + y_3^2}}$$

$$\cos\psi_1 = \frac{y_3}{\sqrt{(x_2 - x_3)^2 + y_3^2}} \qquad \sin\psi_1 = \frac{(x_2 - x_3)}{\sqrt{(x_2 - x_3)^2 + y_3^2}}$$

$$\cos\psi_2 = \frac{y_4}{\sqrt{(x_2 - x_4)^2 + y_4^2}} \qquad \sin\psi_2 = \frac{(x_2 - x_4)}{\sqrt{(x_2 - x_4)^2 + y_4^2}}$$

$$\cos\theta_2 = \frac{(y_3 - y_4)}{\sqrt{(x_3 - x_4)^2 + (y_3 - y_4)^2}} \qquad \sin\theta_2 = \frac{(x_3 - x_4)}{\sqrt{(x_3 - x_4)^2 + (y_3 - y_4)^2}}$$

$$F_{12} = P_{13} \cdot \frac{\sin\varphi_2 \cos\varphi_1 - \cos\varphi_2 \sin\varphi_1}{\cos\varphi_1} \qquad F_{11} = P_{13} \cdot \frac{\cos\varphi_2}{\cos\varphi_1}$$

$$F_{22} = P_{24} \cdot \frac{\cos\psi_2}{\cos\psi_1} \qquad F_{21} = P_{24} \cdot \frac{\sin\psi_2 \cos\psi_1 - \cos\psi_2 \sin\psi_1}{\cos\psi_1}$$

$$F_{32} = P_{13} \cdot \frac{\sin\varphi_2 \cos\psi_1 + \cos\varphi_2 \sin\psi_1}{\sin\theta_2 \cos\psi_1 + \cos\theta_2 \sin\psi_1} \qquad F_{31} = P_{13} \cdot \frac{\sin\theta_2 \cos\varphi_2 - \cos\theta_2 \sin\varphi_2}{\sin\theta_2 \cos\psi_1 + \cos\theta_2 \sin\psi_1}$$

$$F_{42} = P_{24} \cdot \frac{\sin\psi_2 \cos\theta_2 + \cos\psi_2 \sin\theta_2}{\sin\theta_2 \cos\varphi_1 - \cos\theta_2 \sin\varphi_1} \qquad F_{41} = P_{24} \cdot \frac{\sin\varphi_1 \cos\psi_2 + \cos\varphi_1 \sin\psi_2}{\sin\theta_2 \cos\varphi_1 - \cos\theta_2 \sin\varphi_1}$$

$$q_1 = \frac{F_{21} - F_{12}}{\ell_{12}} = \frac{F_{21} - F_{12}}{x_2} \qquad \#/IN$$

$$q_2 = \frac{F_{22} - F_{31}}{\ell_{23}} = \frac{F_{22} - F_{31}}{\sqrt{y_3^2 + (x_2 - x_3)^2}} \qquad \#/IN$$

$$q_3 = \frac{F_{41} - F_{32}}{\ell_{34}} = \frac{F_{41} - F_{32}}{\sqrt{(y_3 - y_4)^2 + (x_3 - x_4)^2}} \qquad \#/IN$$

$$q_4 = \frac{F_{42} - F_{11}}{\ell_{41}} = \frac{F_{42} - F_{11}}{\sqrt{y_4^2 + x_4^2}} \qquad \#/IN$$

SHEAR PANEL OUTPUT FOR SUBCASE 1

SHEAR PANEL NUMBER	CORNER 1 NODE NO. FORCE 11 FORCE 12	CORNER 2 NODE NO. FORCE 21 FORCE 22	CORNER 3 NODE NO. FORCE 31 FORCE 32	CORNER 4 NODE NO. FORCE 41 FORCE 42	SIDE 1-2 LENGTH SHEAR	SIDE 2-3 LENGTH SHEAR	SIDE 3-4 LENGTH SHEAR	SIDE 4-1 LENGTH SHEAR
40	1	31	25	7	0.500	1.250	0.500	1.250
	204.523	-81.809	204.523	-81.809	-327.237	-327.237	-327.237	-327.237
	81.809	-204.523	81.809	-204.523				
41	7	25	19	13	0.500	1.250	0.500	1.250
	204.539	-81.815	204.539	-81.815	-327.262	-327.262	-327.262	-327.262
	81.815	-204.539	81.815	-204.539				
42	37	67	61	43	1.250	1.625	1.250	1.625
	-42.758	32.891	-42.758	32.891	52.625	52.625	52.625	52.625
	-32.891	42.758	-32.891	42.758				
43	43	61	55	49	1.250	1.625	1.250	1.625
	-42.748	32.883	-42.748	32.883	52.612	52.612	52.612	52.612
	-32.883	42.748	-32.883	42.748				
44	1	31	67	37	0.500	10.010	1.250	10.010
	3348.872	-418.184	3348.872	-167.273	-1672.739	-669.096	-267.637	-669.096
	418.184	-3348.872	167.273	-3348.872				
45	25	31	67	61	1.250	10.010	1.625	10.008
	-2006.089	325.735	-2006.559	250.565	521.177	400.905	308.388	400.905
	-325.735	2006.559	-250.566	2006.089				
46	19	25	61	55	1.250	10.008	1.625	10.019
	-513.731	83.319	-513.131	64.091	133.310	102.546	78.882	102.546
	-83.319	513.131	-64.091	513.731				
47	13	19	55	49	0.500	10.019	1.250	10.019
	655.799	-81.815	655.799	-32.726	-327.261	-130.905	-52.362	-130.905
	81.815	-655.799	32.726	-655.799				
48	13	7	43	49	1.250	10.008	1.625	10.019
	513.731	-83.319	513.131	-64.091	-133.310	-102.546	-78.882	-102.546
	83.319	-513.131	64.091	-513.731				
49	7	1	37	43	1.250	10.010	1.625	10.008
	2006.089	-325.735	2006.559	-250.565	-521.177	-400.905	-308.388	-400.905
	325.735	-2006.559	250.566	-2006.089				
50	37	67	103	73	1.250	10.010	2.000	10.010
	1001.758	-200.148	1001.758	-125.092	-320.237	-200.148	-125.093	-200.148
	200.148	-1001.758	125.093	-1001.758				

APPENDIX – Continued

61	61 -743.416 -148.567	67 148.567 743.590	103 -743.590 -120.711	97 120.711 743.416	1.625 182.852	10.010 148.567	2.000 120.711	10.008 148.567
62	55 -403.849 -80.613	61 80.612 403.377	97 -403.377 -65.498	91 65.498 403.849	1.625 99.215	10.008 80.613	2.000 65.498	10.020 80.613
63	49 -0.764 -0.153	55 0.153 0.764	91 -0.764 -0.095	85 0.095 0.764	1.250 0.244	10.020 0.153	2.000 0.095	10.020 0.153
64	49 403.849 80.613	43 -80.612 -403.377	79 403.377 65.498	85 -65.498 -403.849	1.625 -99.215	10.008 -80.613	2.000 -65.498	10.020 -80.613
65	43 743.414 148.567	37 -148.567 -743.588	73 743.588 120.710	79 -120.710 -743.414	1.625 -182.851	10.010 -148.567	2.000 -120.710	10.008 -148.567

```
          C INITIALIZE ESTA POINTERS.
          C*****
ISN 0045        IF( STRESX.EQ.0  .AND.  FORCEX.EQ.0 ) RETURN
          C  HEADINGS - FOLLOW LINE 111 IN ROUTINE SDR2E
ISN 0047        WRITE(6,101) Z(ICC61)
ISN 0048    101 FORMAT(1H1,63H  S H E A R   P A N E L   O U T P U T   F O R   S U
               1B C A S E   ,I10,//)
ISN 0049        WRITE(6,102)
ISN 0050    102 FORMAT(1X,9H   SHEAR ,12H   CORNER  1,12H   CORNER  2,12H   CORNER
               1  3,12H   CORNER  4,12H   SIDE  1-2,12H   SIDE  2-3,12H   SIDE  3-
               24,12H   SIDE  4-1)
ISN 0051        WRITE(6,103)
ISN 0052    103 FORMAT(1X,9H   PANEL ,12H   NODE  NO.,12H   NODE  NO.,12H   NODE
               1NO.,12H   NODE  NO.,12H   LENGTH  ,12H   LENGTH  ,12H   LENGTH
               2 ,12H   LENGTH  )
ISN 0053        WRITE(6,104)
ISN 0054    104 FORMAT(1X,9H   NUMBER,12H   FORCE  11,12H   FORCE  21,12H   FORCE
               1 31,12H   FORCE  41,12H   SHEAR  ,12H   SHEAR  ,12H   SHEAR
               2 ,12H   SHEAR  )
ISN 0055        WRITE(6,105)
ISN 0056    105 FORMAT(10X,12H   FORCE  12,12H   FORCE  22,12H   FORCE  32,12H   F
               1ORCE  42,//)
          C  THIS COMPLETES HEADINGS FOR SHEAR PANEL OUTPUT AS OF 3/17/72
ISN 0057        IC ESTAWD = IESTA
ISN 0058        IX = ICC + HARMS
ISN 0059        AGAIN = .FALSE.
ISN 0060        OHARMS = Z(IX)
ISN 0061        IF( OHARMS .LT. 0 ) OHARMS = NHARMS
ISN 0063        ISAVE  = IVEC
ISN 0064        ELTYPE = Z(ESTAWD)
ISN 0065        FILE   = ESTA
ISN 0066        IX = ICC + ISTR + 2
ISN 0067        SPHASE = IABS( Z(IX) )
ISN 0068        IX = ICC + IELF + 2
ISN 0069        FPHASE = IABS( Z(IX) )
ISN 0070        IF( NESTA .NE. 0 ) GO TO 30
ISN 0072        CALL REWIND ( ESTA )
ISN 0073     20 CALL READ( $950, $990, ESTA, ELTYPE, 1, 0, FLAG )
          C*****
          C ELEMENT PARAMETERS FOR NEW ELEMENT TYPE
          C*****
ISN 0074     30 IELEM  = (ELTYPE-1)*INCR + 1
ISN 0075        NWDSA  = ELEM(IELEM+4)
ISN 0076        NPTSTR = ELEM(IELEM+7)
ISN 0077        NPTFOR = ELEM(IELEM+8)
ISN 0078        NWDSTR = ELEM(IELEM+5)
ISN 0079        NWDFOR = ELEM(IELEM+6)
ISN 0080        LSTRES = NWDSTR
ISN 0081        LFORCE = NWDFOR
ISN 0082        IDSTRS = .FALSE.
ISN 0083        IDFORC = .FALSE.
ISN 0084        IF( KTYPE.NE.1 .AND. NPTSTR.EQ.0 .AND. NPTFOR.EQ.0 ) GO TO 40
ISN 0086        IF( NWDSTR + NWDFOR .GT. 0 ) GO TO 70
          C*****
          C NO STRESS OR FORCE WORDS POSSIBLE FOR THIS ELEMENT TYPE IF FALL HERE
          C*****
ISN 0088     40 IF( NESTA ) 60,50,60
          C
```

```
ISN 0189          IF(Z(I).EQ.ELEMID) GO TO 360
ISN 0191      350 CONTINUE
ISN 0192          GO TO 370
ISN 0193      360 DEFORM = ZZ(I&1)
            C*****
            C MOVE ESTA DATA INTO /SDR2X7/
            C*****
ISN 0194      370 IPART = 0
ISN 0195          NSESTA = ESTAWD
ISN 0196      380 IPART = IPART & 1
ISN 0197          DO 390 I=1,NWDSA
ISN 0198          ESTAWD = ESTAWD & 1
ISN 0199      390 ELESTA(I) = Z(ESTAWD)
            C*****
            C CALL APPROPRIATE ELEMENT ROUTINE FOR STRESS AND FORCE COMPUTATIONS
            C*****
ISN 0200          GO TO(400,410,400,420,430,450,460,470,480,400,490,490,490,490,500,
                 1520,450,540,540,610,610,610,610,610,610,610,610,610,610,610,610,61
                 20,610,560,570,580,590,600),ELTYPE
ISN 0201      400 CALL SROD2
ISN 0202          GO TO 620
ISN 0203      410 CALL SBEAM2
ISN 0204          GO TO 620
ISN 0205      420 K= 4
ISN 0206          GO TO 440
ISN 0207      430 K= 5
ISN 0208      440 CALL SPANL2(K)
ISN 0209          P13=XBUFB(2)
ISN 0210          P24=XBUFB(3)
ISN 0211          IIDD=BUFB(1)
ISN 0212          NODE1=(ELESTA(2)-1)/6&1
ISN 0213          NODE2=(ELESTA(3)-1)/6&1
ISN 0214          NODE3=(ELESTA(4)-1)/6&1
ISN 0215          NODE4=(ELESTA(5)-1)/6&1
ISN 0216          X2=XLESTA(27)
ISN 0217          X3=XLESTA(29)
ISN 0218          X4=XLESTA(31)
ISN 0219          Y3=XLESTA(30)
ISN 0220          Y4=XLESTA(32)
ISN 0221          CA1=Y4/SQRT(X4*X4&Y4*Y4)
ISN 0222          SA1=X4/SQRT(X4*X4&Y4*Y4)
ISN 0223          CA2=Y3/SQRT(X3*X3&Y3*Y3)
ISN 0224          SA2=X3/SQRT(X3*X3&Y3*Y3)
ISN 0225          CA3=Y3/SQRT((X2-X3)**2&Y3*Y3)
ISN 0226          SA3=(X2-X3)/SQRT((X2-X3)**2&Y3*Y3)
ISN 0227          CA4=Y4/SQRT((X2-X4)**2&Y4*Y4)
ISN 0228          SA4=(X2-X4)/SQRT((X2-X4)**2&Y4*Y4)
ISN 0229          CA5=(Y3-Y4)/SQRT((X3-X4)**2&(Y3-Y4)**2)
ISN 0230          SA5=(X3-X4)/SQRT((X3-X4)**2&(Y3-Y4)**2)
            C     CALCULATION OF CORNER FORCES
ISN 0231          F12=P13*(SA2*CA1-CA2*SA1)/CA1
ISN 0232          F11=P13*CA2/CA1
ISN 0233          F22=P24*CA4/CA3
ISN 0234          F21=P24*(SA4*CA3-CA4*SA3)/CA3
ISN 0235          F32=P13*(SA2*CA3&CA2*SA3)/(SA5*CA3&CA5*SA3)
ISN 0236          F31=P13*(SA5*CA2-CA5*SA2)/(SA5*CA3&CA5*SA3)
ISN 0237          F42=P24*(SA4*CA5&CA4*SA5)/(SA5*CA1-CA5*SA1)
ISN 0238          F41=P24*(SA1*CA4&CA1*SA4)/(SA5*CA1-CA5*SA1)
```

```
          C  WRITE OUT DATA IN ROUTINE SDF2E -- FOLLOWS LINE  F41=P24*(SA1*CA4....
ISN 0239        AL1=X2
ISN 0240        AL2=SQRT(Y3*Y3&(X2-X3)**2)
ISN 0241        AL3=SQRT((Y3-Y4)**2&(X3-X4)**2)
ISN 0242        AL4=SQRT(Y4*Y4&X4*X4)
ISN 0243        S1=(F21-F12)/AL1
ISN 0244        S2=(F22-F31)/AL2
ISN 0245        S3=(F41-F32)/AL3
ISN 0246        S4=(F42-F11)/AL4
ISN 0247        WRITE(6,106) IIDD,NODE1,NODE2,NODE3,NODE4,AL1,AL2,AL3,AL4
ISN 0248    106 FORMAT(1X,I8,1X,4(I10,2X),4F12.3)
ISN 0249        WRITE(6,107) F11,F21,F31,F41,S1,S2,S3,S4
ISN 0250    107 FORMAT(10X,8F12.3)
ISN 0251        WRITE(6,108) F12,F22,F32,F42
ISN 0252    108 FORMAT(10X,4F12.3,//)
          C  THIS COMPLETES DATA CALCULATION AND OUTPUT      3/17/72
ISN 0253        GO TO 620
ISN 0254    450 K= 3
ISN 0255        GO TO 550
ISN 0256    460 K= 0
ISN 0257        GO TO 510
ISN 0258    470 K= 3
ISN 0259        GO TO 510
ISN 0260    480 K= 1
ISN 0261        GO TO 530
ISN 0262    490 CALL SELAS2
ISN 0263        GO TO 620
ISN 0264    500 K= 4
ISN 0265    510 CALL SBSPL2(K)
ISN 0266        GO TO 620
ISN 0267    520 K= 2
ISN 0268    530 CALL STONE2(K)
ISN 0269        GO TO 620
ISN 0270    540 K= 4
ISN 0271    550 CALL STROD2(K)
ISN 0272        GO TO 620
ISN 0273    560 CALL SBAR2
ISN 0274        GO TO 620
ISN 0275    570 AGAIN = .FALSE.
ISN 0276        CALL SCONE2( SORC )
ISN 0277        GO TO 620
ISN 0278    580 CALL STRIR2(TGRID)
ISN 0279        GO TO 620
ISN 0280    590 CALL STRAP2(TGRID)
ISN 0281        GO TO 620
ISN 0282    600 CALL STORD2(TGRID)
ISN 0283        GO TO 620
ISN 0284    610 GO TO 900
          C*****
          C CALL ELEMENT 2 TIMES FOR COMPLEX VECTOR.  IMAGINARY FIRST, REAL SECOND
          C CALL ELEMENT ROUTINE TWICE IF AXIC PROBLEM
          C ONCE FOR EACH OF THE 2 VECTORS IN CORE
          C*****
ISN 0285    620 IF( AXIC .AND. MIDVEC.NE.0 .AND. IPART.EQ.1 ) GO TO 625
ISN 0287        IF( IPART .GE. KTYPE ) GO TO 615
ISN 0289    625 IVEC = MIDVEC
          C*****
          C  FOR CONICAL SHELL ONLY
```

Output Format Comparison

Nastran	Loading Condition	Member
	1	1 → r
	2	1 → r
	.	.
	.	.
	.	.
	.	.
	n	1 → r
Astral	**Member**	**Loading Condition**
	1	1 → n
	2	1 → n
	.	.
	.	.
	.	.
	.	.
	r	1 → n

FIG. 1

Member Output Form Comparison

Element Type	Astral M Print Output	Nastran Output
Astral Bar Nastran Rod	Node forces at each end of bar	Average force in bar Average stress in bar
Astral Beam Nastran Bar	Node forces at each end of Beam. Moments, torque and shear at each end of beam	Average force in beam Moments, torque and shear as for Astral. All respective stresses
Shear Panel (Astral Type 6) (Nastran Shear)	Shear flow (#/in.) along all four sides Length of each side	Four diagonal forces on shear panel Average and maximum shear stress $\#/in^2$
Quadrilateral Membrane (Astral Type 8) (Nastran QDMEM)	Node cap forces along each side Shear flow (#/in.) along each side Length of each side	No force type output Average stresses in local x and y directions and shear stress Principal stresses and maximum shear stress
Triangular Membrane (Astral Type 4) (Nastran TRMEM)	Node cap forces only	No force type output Stress output as for Quadrilateral membrane

FIG. 2

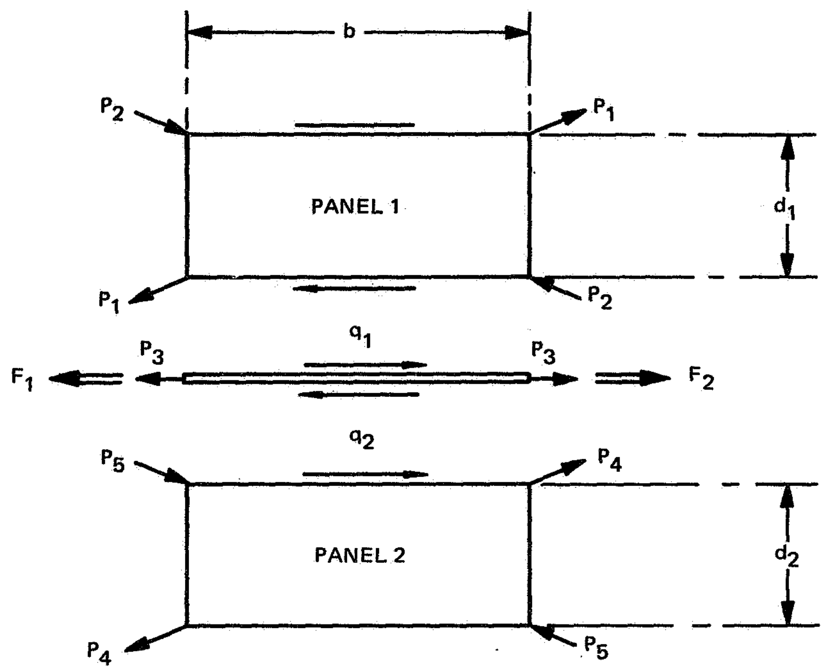

FIG. 3 ROD AND RECTANGULAR PANEL–EXAMPLE

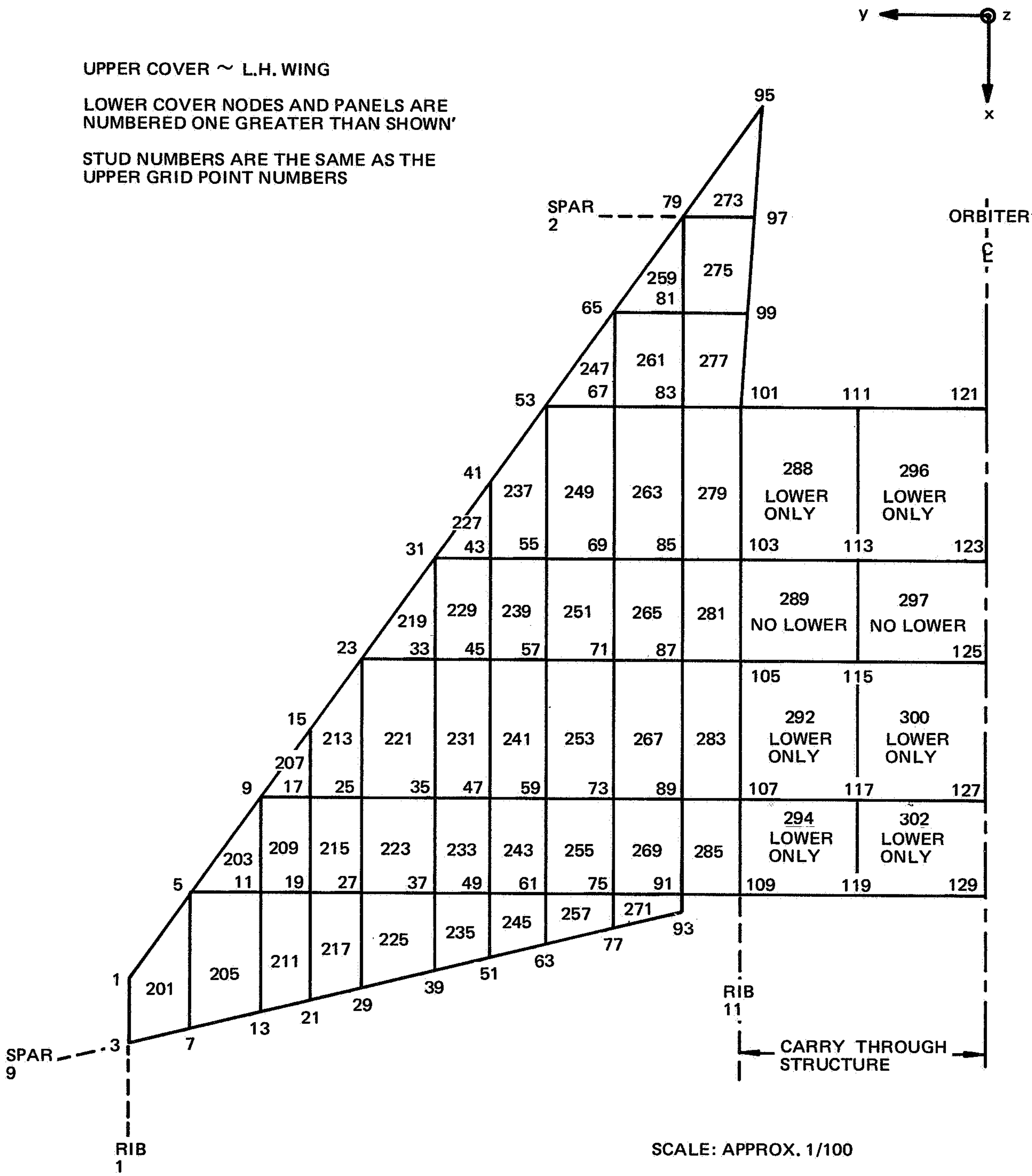

FIG. 4 ORBITER WING IDEALIZATION

Program Running Times - Comparison

Time in Seconds	*Comap Astral*	*Nastran*
CPU	*101.2*	*214.3*
Job	*157.7*	*241.3*

FIG. 5

Spanwise Load Intensity Distribution

Astral Results (M Print)

Node Number	Spanwise Load #	Effective* Width in.	N_x #/in	Distance From F. Bm in.
79	+1100	35.63	+31	0
81	-4133	70.66	-59	71.3
83	-69980	91.57	-764	141.3
85	-130990	93.66	-1399	254.4
87	-150400	88.43	-1701	328.6
89	-118790	86.62	-1370	431.3
91	-93280	41.57	-2240	501.9
93	0	6.26	0	514.4

* Effective width is equal to the sum of half the panel widths on each side of the node.

Fig. 6

Nastran Results

Panels	Inbd of	Panel	N_x	Panels	Inbd of	Panel	N_x	Average	Distance
Rib 10	F_x* #/in^2	t in	#/in	Rib 10	F_x* #/in^2	t in	#/in	N_x	Aft of Front Beam
259	-7680	.025	-192	275	-4210	.0250	-19	-105	35.6
261	-12990	.025	-325	277	-16510	.0250	-500	-412	106.3
263	-35350	.025	-884	279	-39820	.0256	-1134	-1009	197.8
265	-49500	.0277	-1371	281	-52060	.0317	-1732	-1552	291.5
267	-50000	.0282	-1410	283	-51800	.0307	-1646	-1528	379.9
269	-51400	.0294	-1511	285	-57820	.0369	-2371	-1942	466.6

* F_x is the average membrane stress in the panel, in the local coordinate system x direction.

Fig. 7

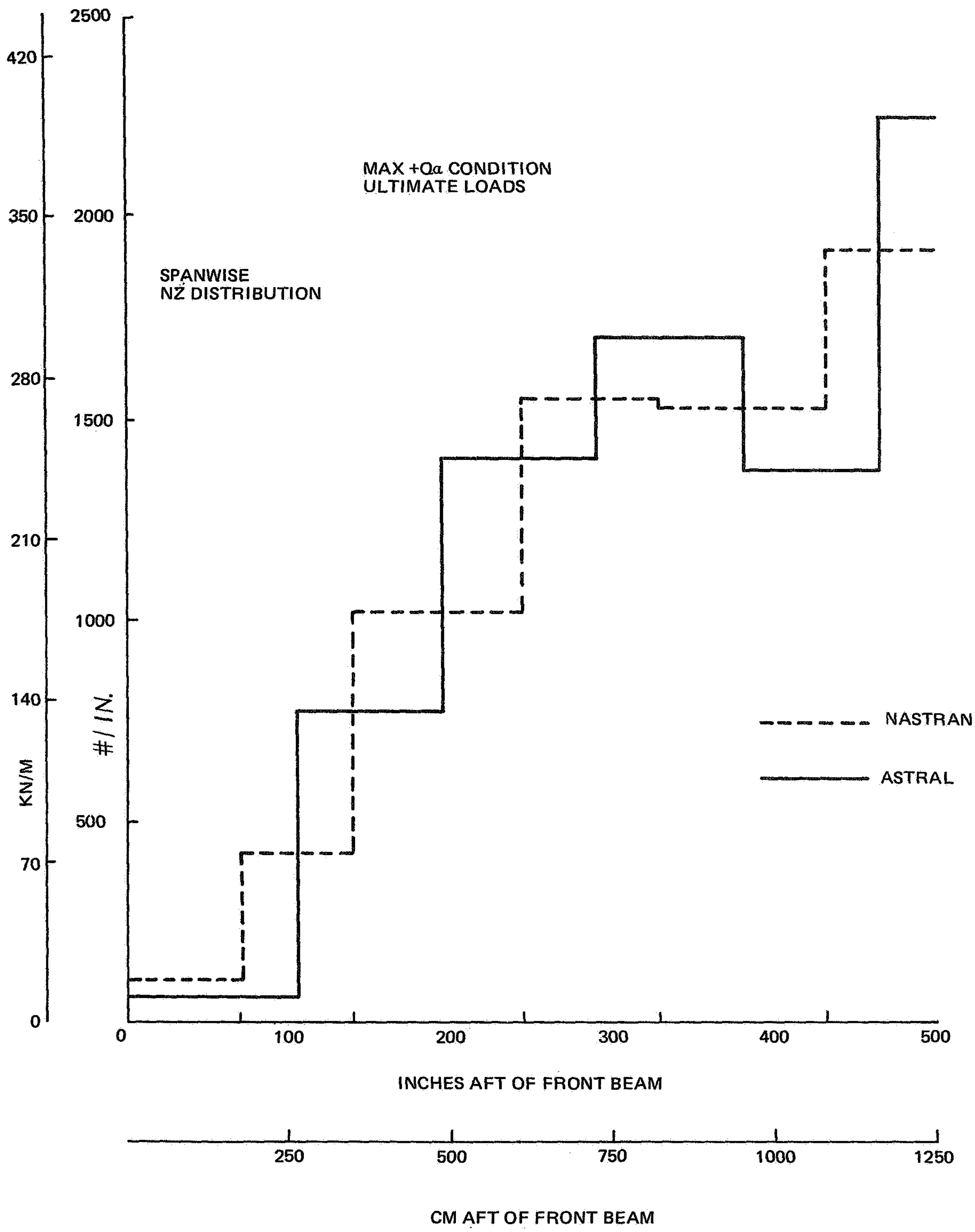

FIG. 8 ORBITER WING – ASTRAL/NASTRAN COMPARISON UPPER COVER RIB 10 LOAD DISTRIBUTION

Nastran and Astral Maximum Shear Flows in Rib 10

Panel Number	Nastran Max. Shear Stress #/in.	Panel Thickness in.	Nastran Max. Shear Flow #/in.	Astral Max. Shear Flow #/in.
461	11212	.02	224	233
463	10473	.02	210	244
465	2086	.02	42	37
467	17297	.02	346	327
469	9235	.02	185	160
471	10915	.02	218	289
473	19476	.02	389	343

FIG. 9

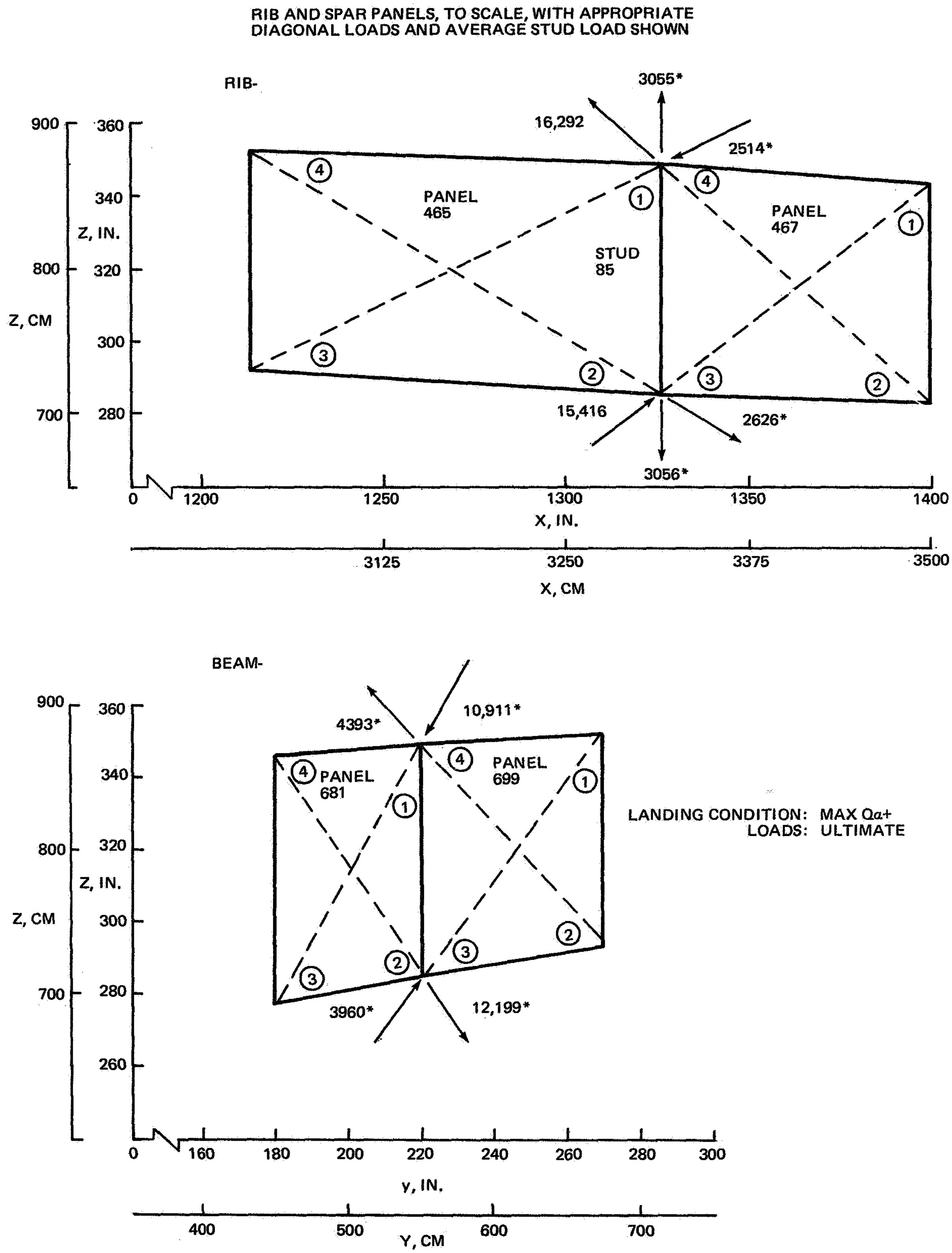

FIG. 10 NASTRAN—EXTRACTION OF STUD LOADS

NASTRAN MODULE SDR2

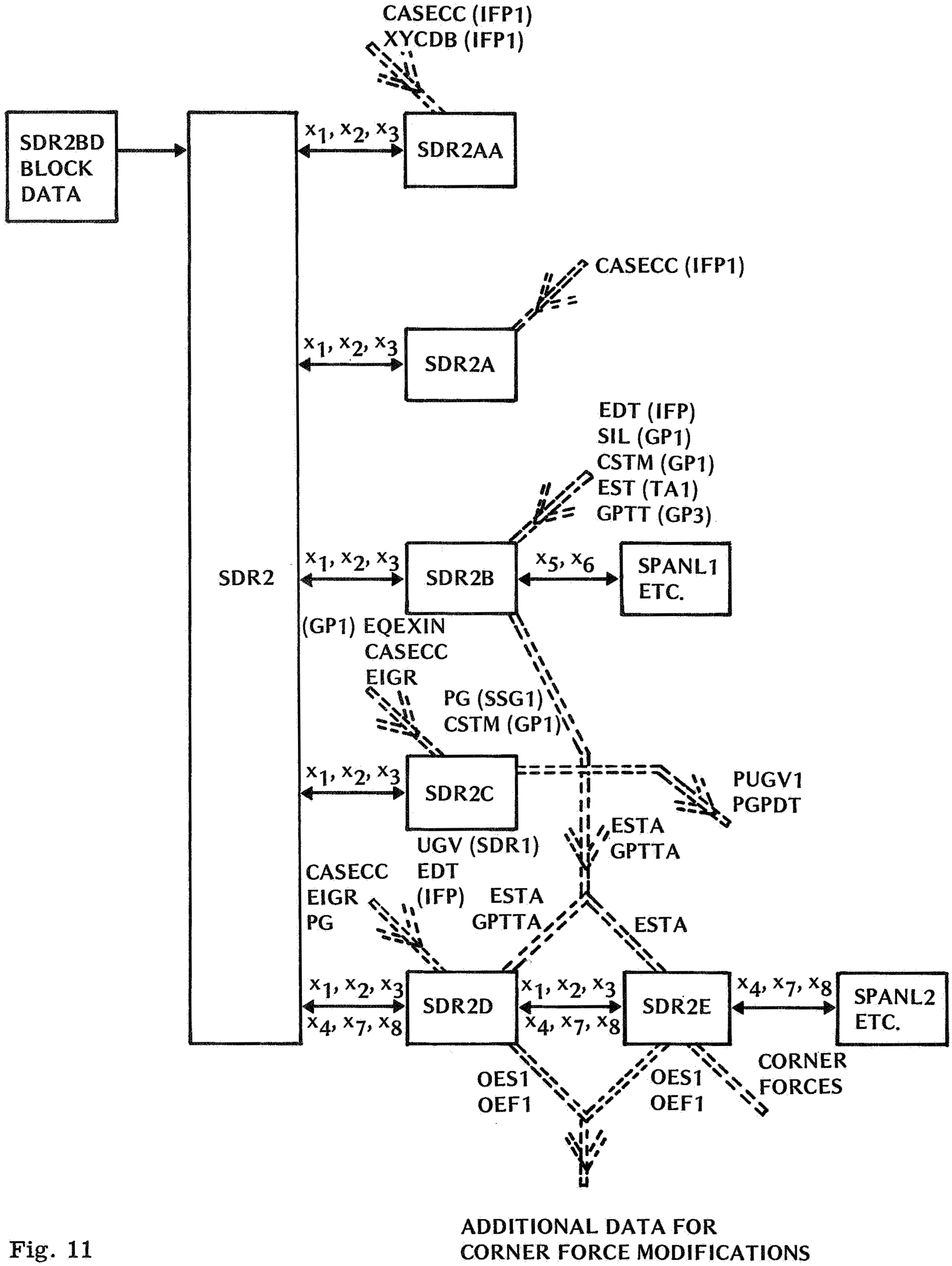

Fig. 11

Summary of Changes to SDR2 Module to Provide Shear Panel Corner Force Output

Routine	Location	Change or Inclusion
SDR2BD	Line 88 "Data Elem 1"	Increase "ESTA" block for "shear" element by number of words being added (8 in this case) column 40 . . . 33 (was 25)
SDR2E	Line 36	Add: "Dimension XLESTA (100), XBUFB (200)" These are 'real' array equivalents of integer arrays 'ELESTA' and BUFB
SDR2E	Line 96	Add: "Equivalence (ELESTA (1), XLESTA (1)), (SBUFB (1), BUFB (1))"
SDR2E	Line 111	Add Headings for each subcase. This output will appear at the beginning of each subcase.
SDR2E	Line 289	Add: a) calculations for shear flows, etc. b) output of shear flows, etc.
SPANL1	Line 69 "common"	In common "/SDR2X5/" and SPOUT (8) (to hold corner coordinates) Continuation card 3: "3, SPOUT (8), yyyyy (94)"
SPANL1	Line 191	Add: SPOUT (1),,,, SPOUT (8) = 0.0, 0.0, X2, 0.0, X3, Y3, X4, Y4

Fig. 12

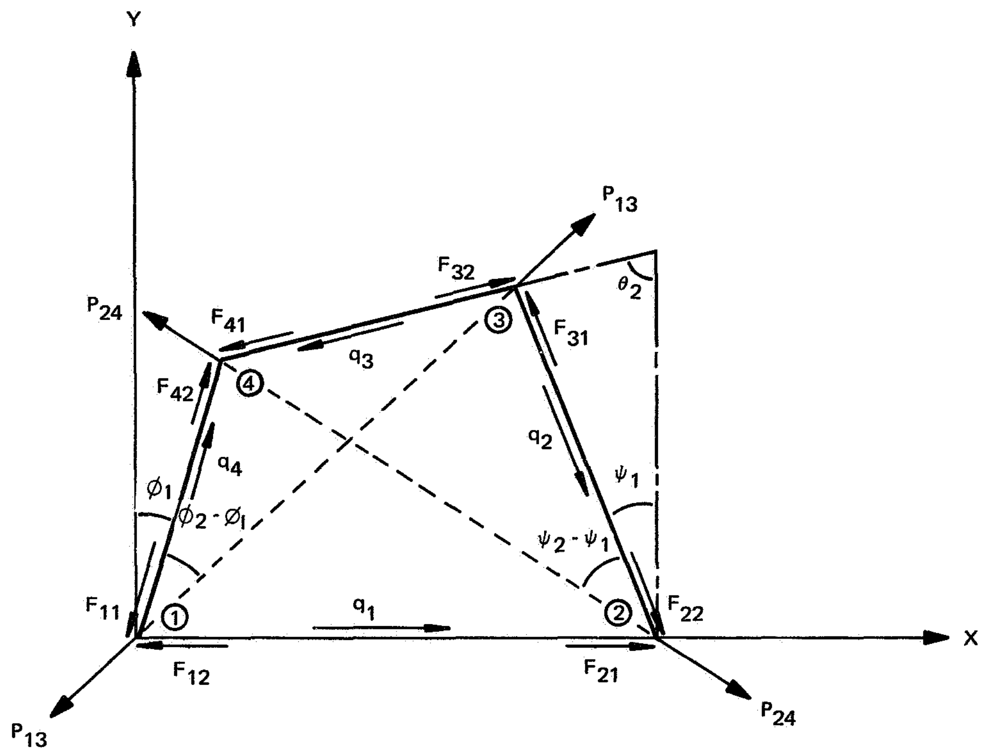

FIG. 13 SHEAR PANEL NOMENCLATURE, LOCAL COORDINATES