ABSTRACT

The objective is to demonstrate in a VAX environment, the working relationships interfacing a 3-dimensional CAD/CAM model to a graphic pre and post processor. Upon developing an all composite preprocessed finite element model. The preprocessed file will thus be translated into a readable MSC/NASTRAN bulk data file. At which point a subsequent nonlinear buckling analysis will be performed employing MSC/NASTRAN. The MSC/NASTRAN output, namely the eigenvectors, will be postprocessed to illustrate graphically the buckled mode shape by means of color contour fringe plots.

INTRODUCTION

It is well known that much of the time consumed in performing a finite element analysis involves model development. In the process of design often much, if not all, of the geometry is created in 3-D on a CAD/CAM system. This CAD/CAM file can be made readily available to aid in the development of a finite element model.

With the aid of CAD/CAM and preprocessor file translators, the CAD/CAM file becomes an invaluable source of data. The analyst may directly use the translated entities to aid in the development of the preprocessed finite element file.

Upon the completion of this file, it may be translated into a MSC/NASTRAN bulk data deck. The necessary executive and case control cards will be included to employ the nonlinear buckling solution sequence. The buckled mode shape of this composite structure will be displayed graphically by means of PATRAN'S post processing capabilities. The postprocessed data will enable the analyst to evaluate and interpret the results much quicker than by conventional means. This paper will explore and illustrate these processes.

CAD/CAM SYSTEM

The CAD/CAM system considered in this evaluation is UNIGRAPHICS. UNIGRAPHICS is a trademark of the McDonnell Douglas Manufacturing and Engineering Systems Company.

UNIGRAPHICS (UGII), is an interactive computer-aided design and computer-aided manufacturing (CAD/CAM) system, designed as a flexible and cost-effective method of automating design, drafting, and manufacturing functions. This system allows for the creation of complete three-dimensional models.

This file can be used to:

1) Produce fully-dimensioned engineering drawings.
2) Generate instructions for NC machining.
3) Generate entities for preprocessors for analytical processes. These entities are fully functional, they include points, lines, splines, and surfaces.

Version 6.0 of the PDDI-based CAD/CAM/CAE model translator is a multi-functional interface module. Bi-directional translation can be performed between two basic formats: UNIGRAPHICS II, Data-base and PATRAN neutral files.

The UGII/PATRAN interface module will convert UGII part files into PATRAN readable PHASE-I geometry files via the PDDI neutral data structure.

The following entities are currently supported by the UGII/PATRAN Translator as shown in table 1: Point, Line, Arc, Conic, Spline, B-Spline, Curve, Sphere, Cylinder, Cone, Surface of Revolution, Sculptured Surface, Ruled Surface, Tabulated Cylinder, B-Spline Surface, and Bonded Plane.

PATRAN PHASE-I geometry Node, Grid, Line, Patch.

TRANSLATION ENTITY CONVERSION TABLES

The following tables describe entity conversions for the UGII/PATRAN Translator:

UGII to PATRAN CONVERSION TABLE

WIREFRAME			
UNIGRAPHICS II		PATRAN	
CODE	NAME	CODE	NAME
2	Point	31	Grid
3	Line	32	Line
5	Arc	32	Line(s)
5	Circle	32	Line(s)
6	Closed Ellipse	32	Line(s)
6	Partial Ellipse	32	Line(s)
6	Parabola	32	Line(s)
6	Hyperbola	32	Line(s)
8	Spline	32	Line(s)
9	B-Spline	32	Line(s)
SURFACE			
CODE	NAME	CODE	NAME
16	Cylinder	33	Patch(es)
17	Cone	33	Patch(es)
18	Sphere	33	Patch(es)
19	Surface of Revolution	33	Patch(es)
20	Tabulated Cylinder	33	Patch(es)
21	Ruled Surface	33	Patch(es)
22	Bounded Plane	33	Patch(es)
24	Sculptured Surface	33	Patch(es)
43	B-Spline Surface	33	Patch(es)

PATRAN to UGII ENTITY CONVERSION TABLE

PATRAN		UNIGRAPHICS II	
CODE	NAME	CODE	NAME
1	Node	2	Point
31	Grid	2	Point
32	Line	8	Spline
33	Patch	24	Sculptured Surface

The main menu of the UGII/PATRAN translator (Menu 1), includes a list of options that require examination before translation is performed. Option 2 (Examine/Change UGII information), provides information that is UGII specific. Namely, the UGII file directory, the UGII part name, UGII user ID, and password. All such information must be in reference to the UGII file of interest.

MENU 1

UNIGRAPHICS II TO PATRAN TRANSLATION (UGPAT)

MAIN MENU - Unigraphics II to PATRAN

```
----------------------------------------------------------------
|                  ---- UGII/PATRAN 6.0 ----                   |
|  1 -- Perform Translation                                    |
|  2 -- Examine/Change UGII Information                        |
|  3 -- Examine/Change PATRAN Information                      |
|  4 -- Examine/Change Translation Parameters                  |
|  5 -- Selective Entity Transfer                              |
|  6 -- Examine Transfer Status                                |
|  7 -- Help                                                   |
| 99 -- End                                                    |
----------------------------------------------------------------
```

Entities to be translated from UGII to PATRAN will reside on various layers within the UGII file. Some or all of the data within the UGII file may be translated. Thus it is important to work with designers (the originator of the UGII files), not only to find layers of interest, but designers may also generate more complete UGII files that will contain more viable data for the analyst.

It should be noted that UGII files often times contain extensive amounts of entities. If UGII files are translated without regard to specific layers of interest, the translator may experience difficulty in retrieving all of the data on the 225 layers of the UGII file.

Option number 4 of the UGII/PATRAN translator (menu 2), provides a list of parameters the analyst may wish to change.

MENU 2

UNIGRAPHICS II TO PATRAN TRANSLATOR (UGPAT)

MAIN MENU - OPTION 4: Examine/Change Translation Parameters

1 --	START LAYER	==> 1	6 --	LOFT TOL	==> 1.0E-07
2 --	ENDING LAYER	==> 255	7 --	ACCURACY TOL	==> 1.0E-07
3 --	QUEUE PRIORITY	==> HI	8 --	GENERAL TOL	==> 1.0E-07
4 --	LOFT TRANSFER	==> N	9 --	SURF ANGLE TOL	==> 35.0
5 --	ACCURACY TEST	==> N	10 --	CURVE ANGLE TOL	==> 20.0
			11 --	CURVE SIZE TOL	==> 0.5

PATRAN provides a PATRAN/MSC-NASTRAN application interface (PATNAS). This translator converts the PATRAN file (Phase - II geometry) into MSC/NASTRAN readable files. Option one of the PATNAS main menu (menu 3) will initiate the translation. The user will thus be prompted to include a MSC/NASTRAN executive and case control decks. The user will also be asked to state the neutral file to be translated.

Upon exercising these options a readable MSC/NASTRAN file will be created.

MENU 3

<*><*><*> PATNAS 2.2 <*><*><*>

Main Menu

---

1) Translate

2) Report

3) Display Set/Show Parameters

4) Help

5) End

ANALYSIS

This paper considers the evaluation of the trailing edge vertical stabilizer of McDonnell Douglas' NOTAR (No Tail Rotor) helicopter (see figure 1). This air craft's primary structure (tailboom) consists entirely of composite material, as does the empennage and variable thruster. Great care was exercised in substantiating the air craft's components.

MSC/NASTRAN was employed to determine the stability of the vertical stabilizer. While performing a linear buckling analysis, buckling failure was experienced sooner than was initially expected. The mode of failure was also unexpected. Figures III - V show the linear buckling failure mode shapes of the structure. As a result of the nature of the structure, buckling failure would not be allowed below 2 times limit load. Initial buckling failure was experienced at 1.02 times limit load. The first three mode shapes indicate that buckling occurred in the first panel. It was suspected that in the "real world" the beads would play a greater role in carrying the load. Resulting, ultimately in the beaded sections involvement in the buckling failure mode of the vertical stabilizer. A nonlinear analysis, with its stiffness matrix updates, would redistribute the internal loads as a function of its new stiffness.

It was anticipated that this redistribution of internal loads would result in a higher load distribution in the beads, in the nonlinear analysis. Thus allowing the structure to carry higher loads overall. This was the thrust behind the analysis.

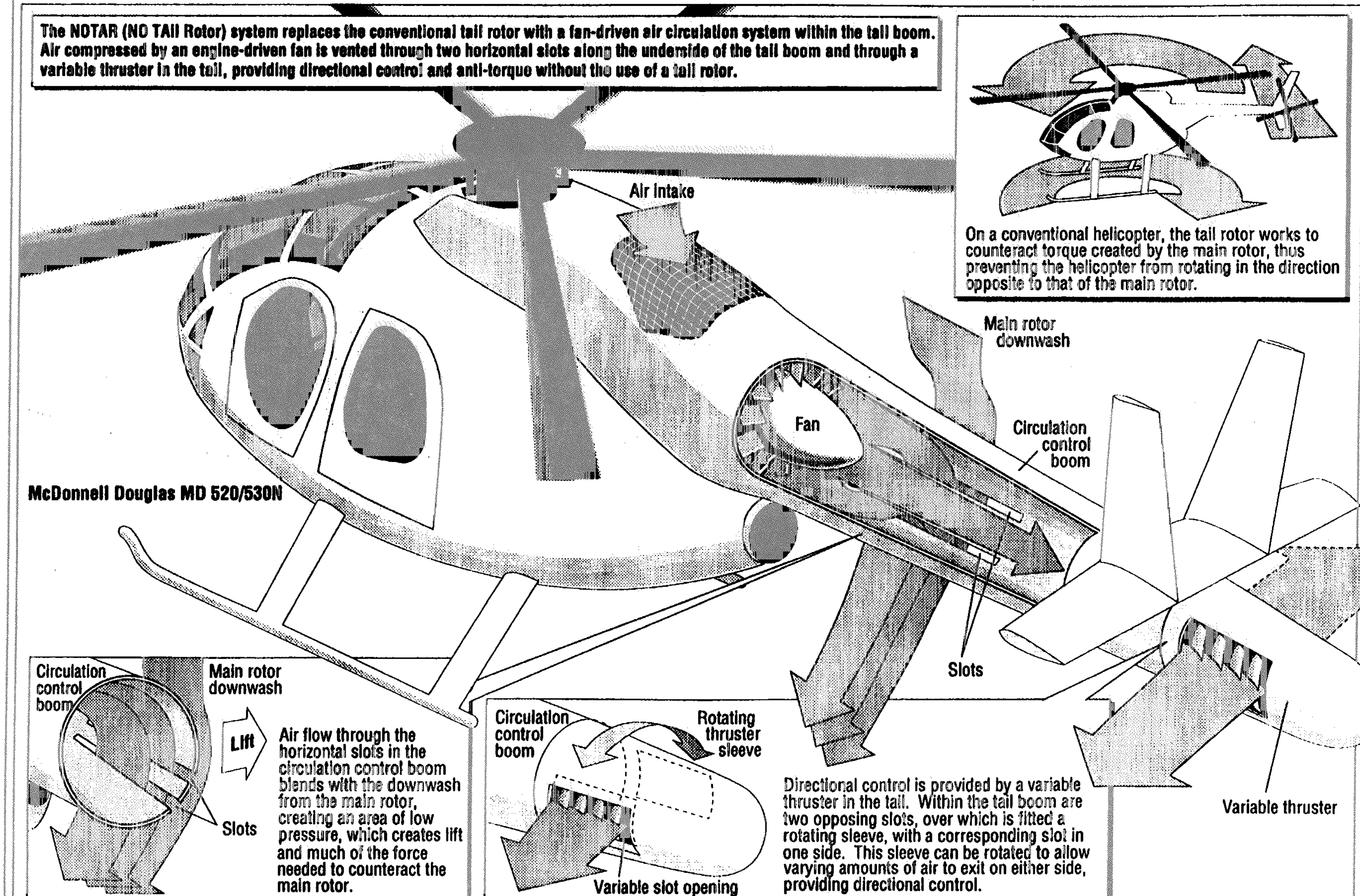
The anticipated results met with reality. Not only did the buckling failure occur at a higher load application (1.29 times limit load), each of the three mode shapes involved the beaded sections of the structure (see figures VI - VIII).

Figure I

COPTERS IN NEW ERA

McDONNELL DOUGLAS' NOTAR

By replacing the helicopters tail rotor with an air circulation system, engineers at McDonnell Douglas have pioneered a way to increase helicopter maneuverability and reduce pilot workload, while simplifying the mechanical requirements to overcome torque and increase operational safety.



METHOD OF EVALUATION

The area or region in which buckling will occur in the nonlinear buckling solution must be established. Ultimately while executing the nonlinear solution, a series of stiffness matrix updates must be performed, via the ITER method on the NLPARM card. The internal loads will be redistributed accordingly. Therefore, the nonlinear buckling bifurcation point may tend to be higher than the point determined by the linear buckling solution, depending on your structure.

Solution 5 was employed to establish the linear buckling point. The importance of establishing this point is two fold.

One: If the point where nonlinear buckling occurs is exceeded the solution sequence will not converge to a viable solution.

Two: Nonlinear analyses tend to be very CPU intensive. This type of analyses will be impractical if the starting point is far from the converged solution.

Once the linear buckling point has been determined, solution 66 was used in two parts to determine the load which results in buckling in the nonlinear mode.

Subcase 1 in solution 66 is the static solution. The load in this subcase is 80% of the load determined to result in buckling from the solution 5 run.

Subcase 1 must reference the NLPARM card in the bulk data to perform the static analysis. The function of the NLPARM card is to define the parameters for a nonlinear solution sequence strategy.

For the static subcase the method for controlling the tangent stiffness updates is AUTO. Upon convergence in subcase 1, subcase 2 will be required to perform a series of stiffness matrix updates. To follow these updates DIAG 50 must be included in the executive control deck. DIAG 50 will track the iteration process and list the subcase ID, the load increment, and the loop ID in the nonlinear iteration module solution data. The NLPARM in subcase 2 must reference the NLPARM in the bulk data that defines the chosen strategy to perform the nonlinear buckling analysis.

In choosing a strategy to perform a nonlinear analysis, the method for controlling tangent stiffness updates (KMETHOD), the number of increments (INC), as well as the convergence test (CONV), must be selected on the NLPARM card. Some manipulation of these parameters may be required to reach convergence. For example, with a given increment and method of controlling tangent stiffness updates, certain convergence factors (U,W,P) may converge much faster than others, requiring a large number of iterations to converge for that load increment. One of the convergence factors may be removed, or the load increment may be reduced to reach convergence in a reasonable amount of time. A careful review of the Non-Linear Iteration Module Output is essential in this determination. It is recommended that all three convergence factors be included in the initial run.

It is likely that the iterative process will come to an end before a negative term on the factor diagonal is found. The users information message 4550 will state the reason for the ending of the run. It should be noted here that to determine the point of buckling in a nonlinear solution, the load application must be large enough to cause a negative term on the factor diagonal to be encountered, at which point buckling has occurred.

Once the run has completed, the job must be restarted. A list of parameters must be included to indicate the location for restart. If, as in this problem the last complete convergence was subcase record 2, load increment 1, loop 2, restart with added parameters in the bulk data:

PARAM, SUB ID, 2

PARAM, LOAD INC, 2

PARAM, LOOP ID, 2

These parameters consider that there are 3 load increments in subcase 2, one of which has completed. The loop ID will be taken at face value upon restarting.

RUN II (see table III)

In performing the second run, difficulty was experienced in reaching convergence. Some forty iterations were performed yet convergence was not reached. Thus a new strategy had to be adopted. Naturally, as in any endeavor there is no definitive strategy. In this case the load in subcase 2 was reduced from 2.0 to 1.2 times limit load. The number of increments were increased for 3 to 10. Since the load applied in subcase 2 was changed the next run was restarted from the end of subcase 1.

RUN III (see table IV)

Restart run from

Subcase Record 2

Load Inc 1

Loop ID 1

In reaching the buckling point in the nonlinear solution, the user's strategy may change depending on the convergence trend. In this case, as buckling was approached, the number of iterations required to reach convergence increased. Thus the SEMI method was adopted. This method allowed for faster convergence, and a negative term on the factor diagonal was found. The job was restarted with the parameter, PARAM, BUCKLE, 1 included the deck and the restart parameters backed up two increments to determine the actual point of buckling failure.

To determine the load application that results in buckling, the following calculations are used:

$P_{cr} = P_n + \text{Alpha (DeltaP)}$

$P_n = 1.2 \text{ (Limit Load)}$

$\text{DeltaP} = .035 \text{ (Limit Load)}$

Where $\text{Alpha} = 2.65$

$P_{cr} = 1.2 + 2.65 (.035) = 1.29 \text{ (Limit Load)}$

It is important to note that the resulting displacement vectors included in the output of the solution 66 buckling run is not the buckled eigenvector. It is simply the displaced shape immediately before buckling occurs. To get a plot of the buckled eigenvector employing PATRAN, the following must be included in the MSC/NASTRAN deck (versions 65 & 65c).

```
Alter   839
Output2 OPHIG//-1/11/V.N.Z
CEND
DISPLACEMENT  =  ALL
```

The results can be postprocessed employing PATRAN to illustrate the buckled mode shape (see figure VI - VIII).

RESULTS

The nonlinear buckling analysis indicated that buckling failure would occur at 1.29 times limit loads. As compared with 1.02 times limit load predicted in the linear analysis.

Though the target of 2.0 times limit load was not reached in the nonlinear analysis, the analysis did provide important insight. The beads would carry more load than the linear solution suggested. As a result of this finding, the beads were modified. A slight modification to the bends, resulted in load carrying capability of the structure to far exceed the desired 2.0 times limit load.

SUMMARY

1) "Be All That You Can Be"

One purpose of the paper is to make Designers cognizant of the possible interface of a comprehensive 3-D CAD/CAM model to a preprocessed finite element model.

2) "Work Smarter Not Harder"

Facilitate the process of finite element modeling by utilizing the existing 3-D CAD/CAM files to develop finite element models.

3) "A Picture is Worth a Thousand Words"

Displaying graphically the results of a finite element analysis expresses the output in terms which are easily and immediately understandable.

4) "Man's Mind Stretched to a New Ideal Never Returns to its Original Dimensions"

Once analyses are performed employing these available systems. Analyses will not be performed any other way.

TABLE II

Run 1

SUBCASE #	ITERATIONS	LOAD FACTOR	STRATEGY/NLPARM				CONVERGENCE FACTORS		
			KMETHOD	INC	KSTEP	CONV	U	P	W
1	18	0.0 — 1.0	AUTO	1	1	UPW	1.27-5	3.515-4	5.673-9
2	14	1.0 - 1.33	ITER	3	1	UPW	1.581-4	7.316-4	2.008-9

LAST COMPLETE CONVERGENCE

SUBCASE RECORD 2
LOAD INCREMENT 1
LOOP ID 2

RESTART FROM

SUBCASE RECORD 2
LOAD INCREMENT 2
LOOP ID 2

LOAD

SUBCASE 1 0.0 — .85 (LIMIT LOAD)
SUBCASE 2 .85 — 2.0 (LIMIT LOAD)

LAST CONVERGENCE

———————— LOAD FACTOR 1.33

TABLE III

RUN 2

SUBCASE #	ITERATIONS	LOAD FACTOR	STRATEGY/NLPARM				CONVERGENCE FACTORS		
			K METHOD	INC	KSTEP	CONV	U	P	W
2	8	1.1	ITER	10	1	UP	1.3195-4	1.4983-4	6.7465-10
2	9	1.2	ITER	10	1	UP	7.1744-5	1.0660-4	5.1021-10
2	11	1.3	ITER	10	1	UP	7.2229-5	1.0500-4	1.2854-9
2	12	1.4	ITER	10	1	UP	1.3743-4	1.3298-4	1.4663-9
2	14	1.5	ITER	10	1	UP	1.0704-4	1.0668-4	1.1449-9
2	16	1.6	ITER	10	1	UP	9.792-5	1.0249-4	1.1098-9
2	18	1.7	ITER	10	1	UP	1.0408-4	1.1621-4	1.2490-9
2	20	1.8	ITER	10	1	UP	9.9368-5	1.1756-4	1.0550-9

LAST COMPLETE CONVERGENCE

SUBCASE RECORD 2
LOAD INCREMENT 8
LOOP ID 9

RESTART NEXT RUN FROM

SUBCASE RECORD 2
LOAD INCREMENT 9
LOOP ID 9

TOTAL CPU TIME = 6 Hours
3 Min.
42 Sec

Elapsed time = 18 Hours
31 Min.
49 Sec.

Machine

VAX 6100

LOAD

SUBCASE 2 1.2 X LIMIT

LAST CONVERGENCE .85 ....*.1.2

TABLE IV

RUN 3

SUBCASE #	ITERATIONS	LOAD FACTOR	STRATEGY/NLPARM				CONVERGENCE FACTORS		
			K METHOD	INC	KSTEP	CONV	U	P	W
2	22	1.9	ITER	10	1	UP	1.1020-4	1.1280-4	1.1088-9
2	26	2.0	ITER	10	1	UP	1.4323-4	1.5888-4	2.5039-9
3	26	2.1	ITER	10	1	UP	2.4007-5	9.9021-4	1.2698-9

LAST COMPLETE CONVERGENCE

SUBCASE RECORD 3
LOAD INCREMENT 1
LOOP ID 12

RESTART NEXT RUN FROM

SUBCASE RECORD 3
LOAD INCREMENT 2
LOOP ID 12

LAST CONVERGENCE 1.2*........2.0

TABLE V

RUN 4

SUBCASE #	ITERATIONS	LOAD FACTOR	STRATEGY/NLPARM				CONVERGENCE FACTORS		
			K METHOD	INC	KSTEP	CONV	U	P	W
3	11	2.111	SEM I	-	-	PW	1.3281-6	8.4989-4	2.1121-9
3	12	2.222	SEM I	-	-	PW	6.3112-7	3.8557-4	1.0393-9

LAST COMPLETE CONVERGENCE

SUBCASE RECORD 3
LOAD INCREMENT 2.2
LOOP ID 12

RESTART THIS RUN FROM

SUBCASE RECORD 3
LOAD INCREMENT 2
LOOP ID 12

LAST CONVERGENCE 1.2.*.......2.0

Figure II
Undeformed shape

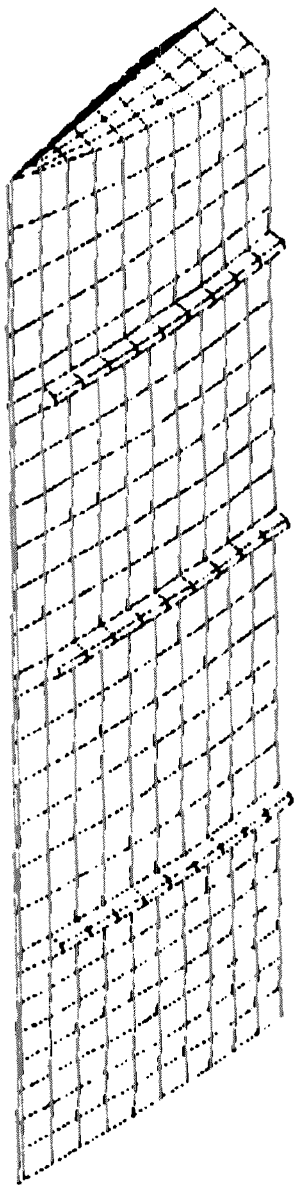


Figure III
Linear Buckled Eigenvector
Mode I

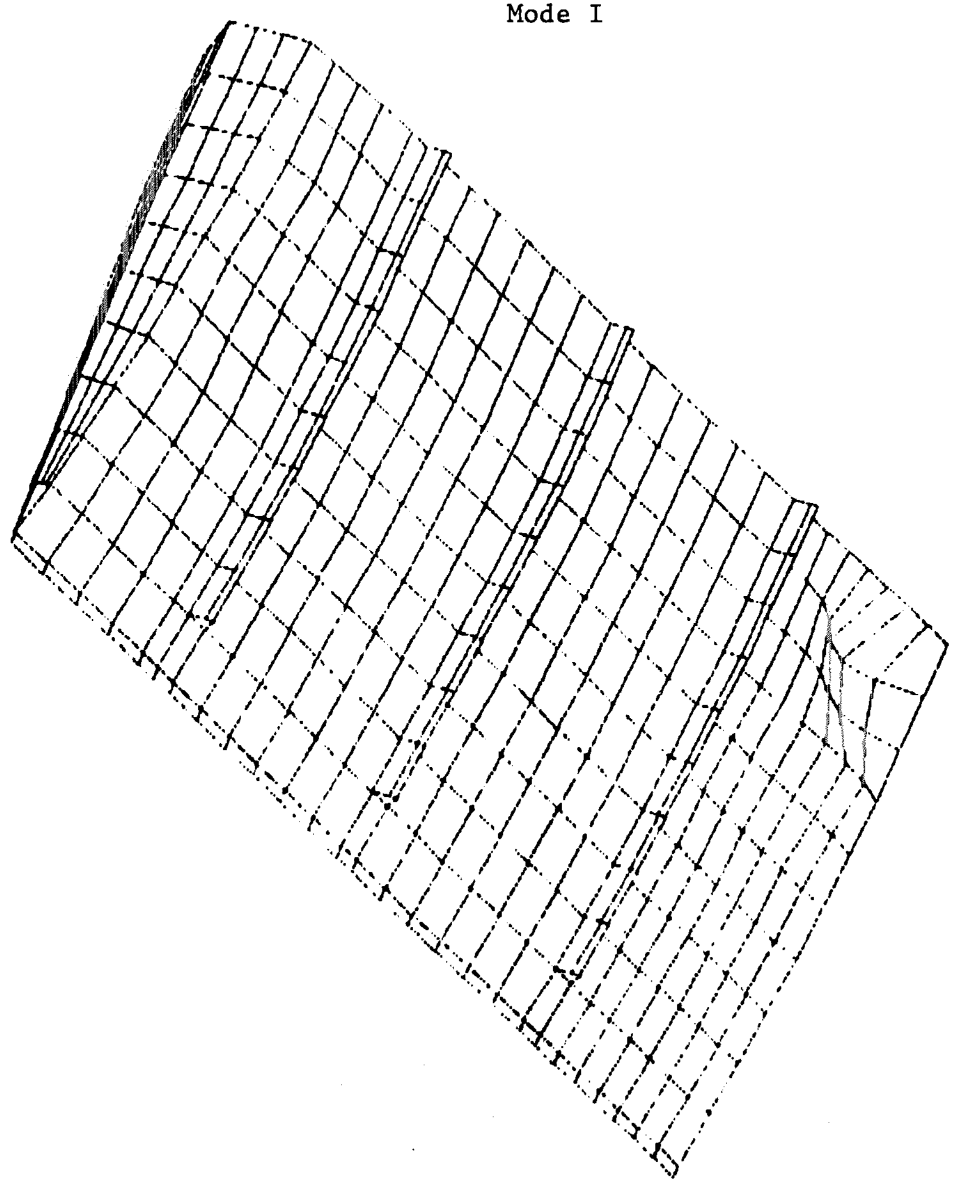


Figure IV
Linear Buckled Eigenvector
Mode II

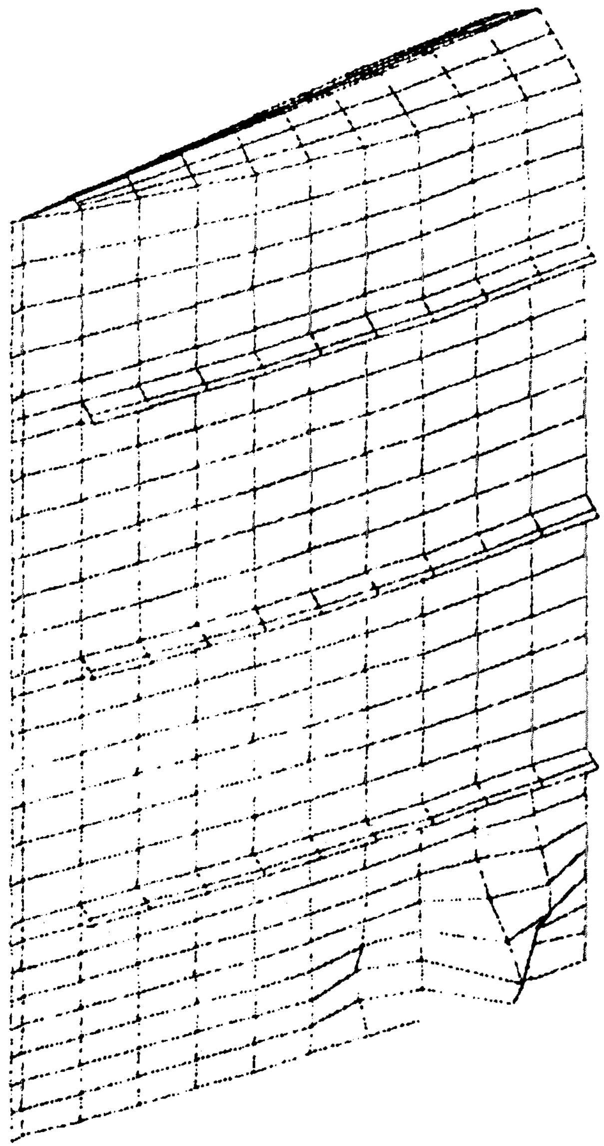
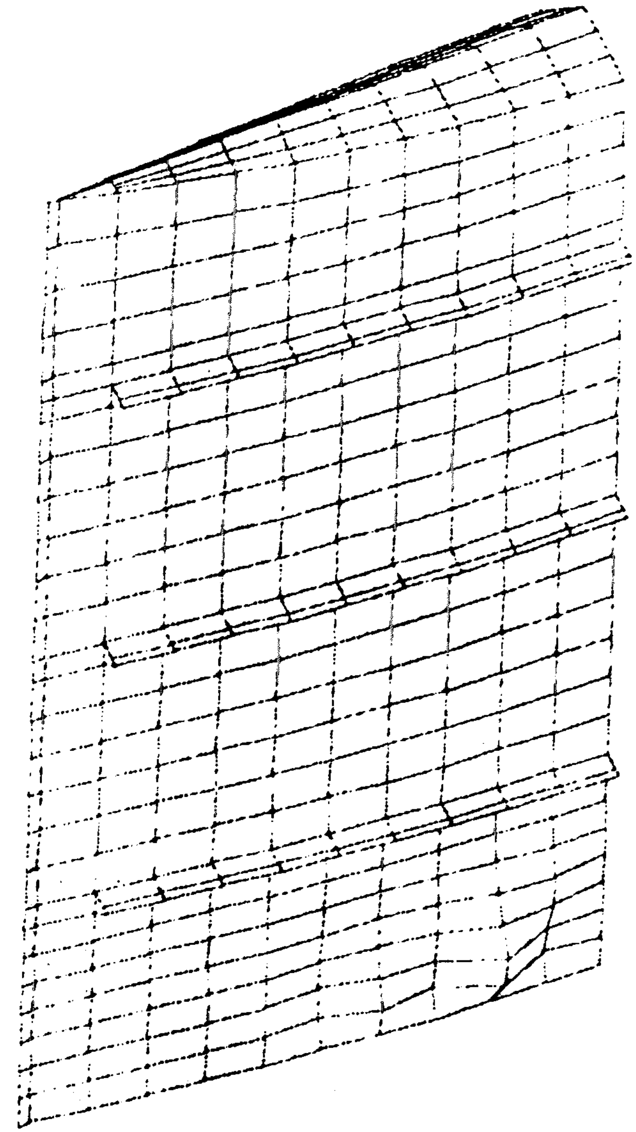


Figure V
Linear Buckled Eigenvector
Mode III



Nonlinear Buckled Eigenvectors

Figure VI
Mode I

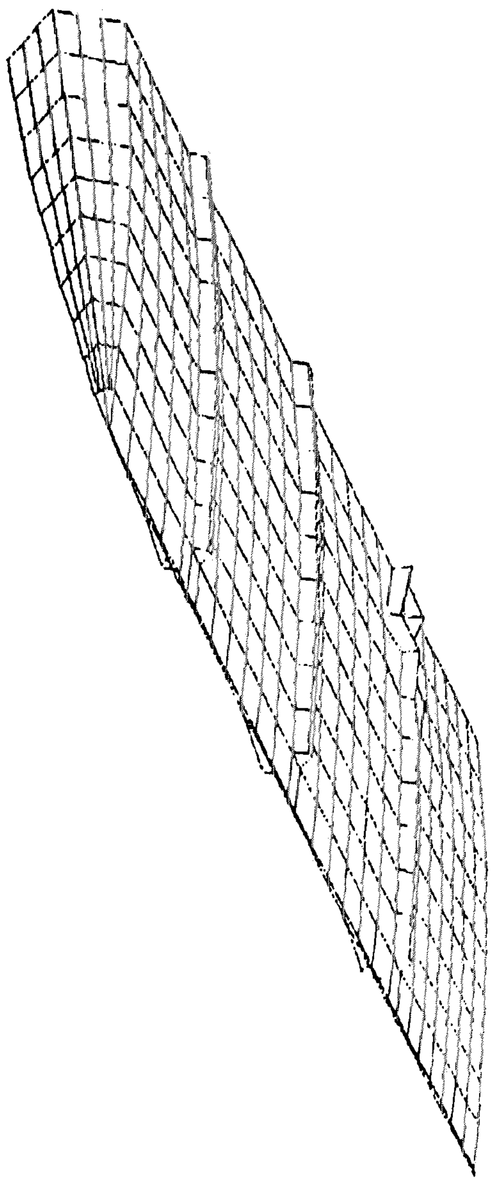


Figure VII
Mode II

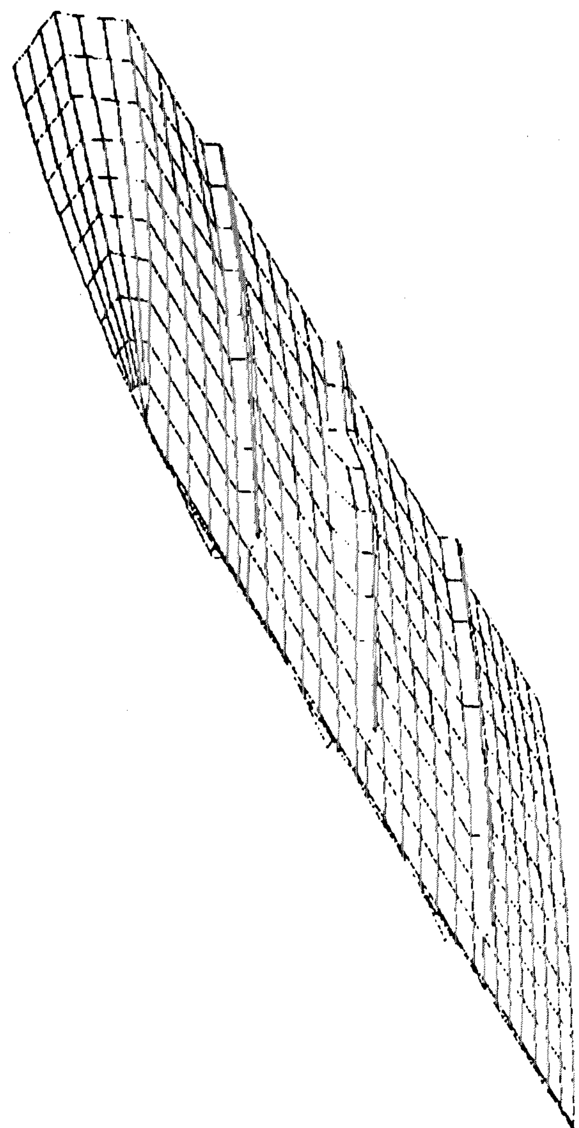


Figure VIII
Mode III