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NASTRAN
FINITE ELEMENT ANALYSIS ACTIVITY AT NORTHROP

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SUMMARY

This paper briefly summarizes the NASTRAN-related internal loads support activity at the Aircraft Group of the Northrop Corporation. Finite Element Analysis, in the present form, started at the Aircraft Group in the late sixties. NASTRAN was selected as the primary finite element tool for static analysis in 1972. Extensive pre- and postprocessing programs have been brought on-line since then to facilitate handling of the massive input and output data for the program.

In-house evaluation of the various analytical capabilities of the MSC version of NASTRAN, prior to production release, is a continuous effort. The NASTRAN superelement and subsonic aero features are presently being tested and brought on-line for production use.

Two examples of recent NASTRAN structural solutions are also presented in this paper.

INTRODUCTION

Finite Element Analysis in the structural analyses groups at Northrop started in the late nineteen sixties with the in-house developed NORAN Program. This program, although offering a good element library and relatively fast solution time, suffered from a lack of user-oriented features. Consequently, a changeover to Level 15 of COSMIC NASTRAN was made in 1972.

The MacNeal-Schwendler Corporation (MSC) version of NASTRAN was adopted as the standard finite element program of the Aircraft Division in 1974. It has yielded significant improvements in accuracy, user-oriented features, increased capability for larger more complex solutions, and reduced modeling and running times.

The responsibility for NASTRAN within the Aircraft Group resides in the Advanced Structural Computer Methods group (ASCM). The core of the effort involves the NASTRAN Utilization Improvement effort initiated in 1975 to provide interactive graphics programs in support of production analyses.

The ASCM group, in addition, provides program assistance, in-house training and documentation for the NASTRAN users at Northrop. Key members of the Group also reside in the major stress groups to ensure timely interaction between the NASTRAN production and development effort.

COMPUTER GRAPHICS

Northrop embarked on an extensive pre- and postprocessor interactive graphics development in 1975 in support of the NASTRAN analyses. This task is being performed in three phases.

Phase I - Geometry

A series of programs was written to define the geometry of major airplane structural components using parametric cubics (P.C.'s), splines and Coon's patches (fig. 1). These components are then cut at the required stations and the contours interfaced with programs in Phase II and Phase III. Digitizing programs were also developed which allow grid points to be directly digitized from blueprints and curve-fitted into loft lines (fig. 2).

Phase II - Preprocessors

The loft lines, P.C. cross-section cuts or GRID points are passed into the GEN3D program in Phase II for NASTRAN grid and element generation. This program is flexible enough to give the user complete control of very complex models and to take advantage of repeated sets of geometry patterns. The models thus generated may then be plotted on a Tektronix 4014 using such features as ZOOM, LABEL (element and grids), 3D rotation MOVE, SLICE, THICKNESS and AREA of elements for verification (fig. 3 and 4). A limited capability for generating property cards for the elements is also available. An added feature is the ability to use the 3D P.C. geometry from Phase I to calculate the area and volume of a fuel tank and also automatically generate pressure load cards for various fuel heads and acceleration vectors (fig. 5).

Phase III - Postprocessors

The analytical results from NASTRAN are stored for postprocessing. Stresses and strains can be recovered at any arbitrary angle, running loads computed, and a min-max search performed. Selected results are then printed in report format. The postprocessed data can also be plotted, superimposed on the structural plots, by the POSTPLOT Program. These plots can be displayed in either vector or alphanumeric form (fig. 6).

NASTRAN TESTING

All major analysis features of NASTRAN are tested by the ASCM group prior to their introduction into the analysis process.

Extensive evaluation of the MSC NASTRAN Superelement Analysis features has been concluded recently. This evaluation, in preparation for new major internal loads analysis work, shows substantial savings in computer costs and reduced turnaround time for analysis of large structures.

The evaluation of subsonic aeroelastic analyses using NASTRAN was initiated in 1978. Results to date indicate a very good correlation with previous flutter analyses conducted using in-house programs. Again, significant time savings are indicated, both within NASTRAN and from using structural models common to the static analyses.

PRODUCTION SUPPORT ACTIVITY

The Advanced Structural Computer Methods group serves as a pool of specialized NASTRAN talent in support of the production effort, in addition to the development work. Key Group engineers are also assigned to the major production programs, where they are responsible for the NASTRAN model development and internal loads generation in support of stress analyses.

FUTURE DEVELOPMENT EFFORT

In conjunction with other groups at Northrop, the ASCM group is studying a data base system which will provide a basis for an integrated computerized structural analysis system. A greatly enhanced geometry handling capability is evolving around parametric cubics. Other finite element methods in and outside of NASTRAN are also being reviewed. These include nonlinear approaches, optimization through fully-stressed design, and aeroelastic/flutter analysis.

NASTRAN ANALYSIS EXAMPLES

T-38 Local Model

A detailed (fine mesh) model of a T-38 wing lower skin was incorporated into a three substructure wing model in the vicinity of the root rib, rear spar intersection. This detail was generated to obtain very accurate stress levels and gradients for fracture and fatigue analyses (fig. 7 and 8).

Flutter Analysis

Flutter analysis using a vertical stabilizer supported by a general element was conducted using the NASTRAN Subsonic Aeroelastic package. The results compare well with the previous flutter analyses using in-house programs. The single submittal NASTRAN process provided significant improvements in calendar time and computer CPU time (fig. 9).

CONCLUSIONS

The dedicated NASTRAN support at Northrop has effectively moved the structural analysis groups along the NASTRAN learning curve. Significant reductions in internal loads analysis time have been demonstrated as the result of the pre- and postprocessor development and NASTRAN user support (fig. 10).

The increasingly tighter development schedules for new aircraft projects dictate still faster and more efficient analysis processes in the future. Greater details in modeling and new analysis techniques yielding more accurate solutions are also required to satisfy future design criteria in the field of static, fracture, and dynamic analyses.

ADVANCED STRUCTURAL COMPUTER METHODS

NASTRAN SUPPORT ACTIVITY

SYSTEM SUPPORT BY NORTHROP DATA PROCESSING

NASTRAN UTILIZATION IMPROVEMENT GROUP

- PROVIDES EFFECTIVE NASTRAN PRODUCTION SUPPORT
- IS RESPONSIBLE FOR PRODUCTION MODELS
- PROVIDES INTERACTIVE GRAPHICS SUPPORT
  - PRE PROCESSORS
  - POST PROCESSORS
- TESTS AND EVALUATES NASTRAN FEATURES
- GENERATES NASTRAN IN-HOUSE DOCUMENTATION
- PROVIDES NASTRAN IN-HOUSE TRAINING
- PROVIDES NASTRAN ASSISTANCE TO PRODUCTION STRESS GROUP ON COMPLEX NASTRAN SOLUTIONS
- PLANS FOR INTEGRATED STRUCTURAL ANALYSIS

ADVANCED STRUCTURAL COMPUTER METHODS

NORTHROP CORPORATION

AIRCRAFT GROUP

FINITE ELEMENT ANALYSIS ACTIVITY

HISTORY

- o PRE FINITE ELEMENT PROGRAMS
- o 1969 - NORAN IN-HOUSE FINITE ELEMENT PROGRAM
- o 1972 - NASTRAN COSMIC LEVEL 15
- o 1973 - NASTRAN COSMIC LEVEL 15.5
- o 1974 - MSC NASTRAN
- o 1978 - MSC NASTRAN 38 TO 46
- o UP TO 1000 JOB SUBMITTALS PER MONTH

WHY MSC NASTRAN?

- o CPU TIME IMPROVEMENT
- o IMPROVED FEATURES
- o FREQUENT UPDATES
- o PROXIMITY OF MSC

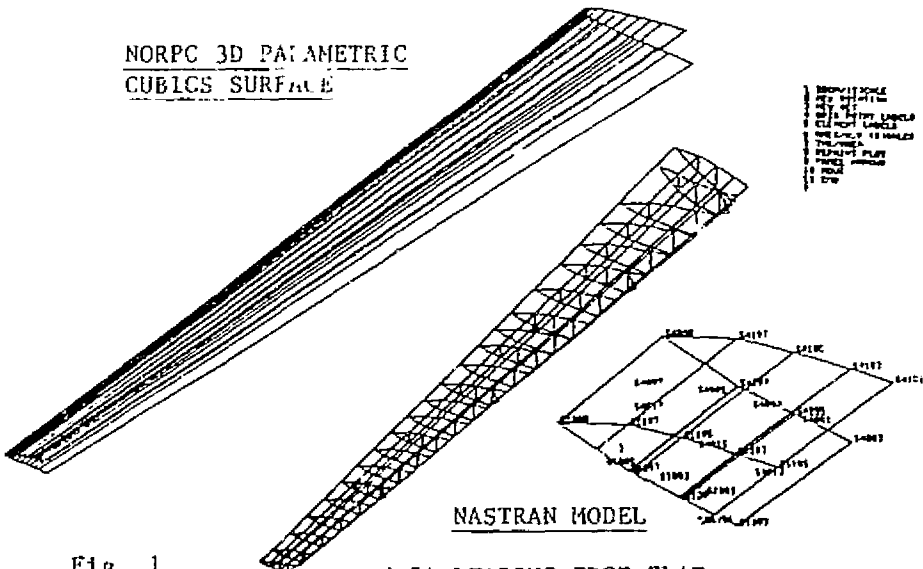
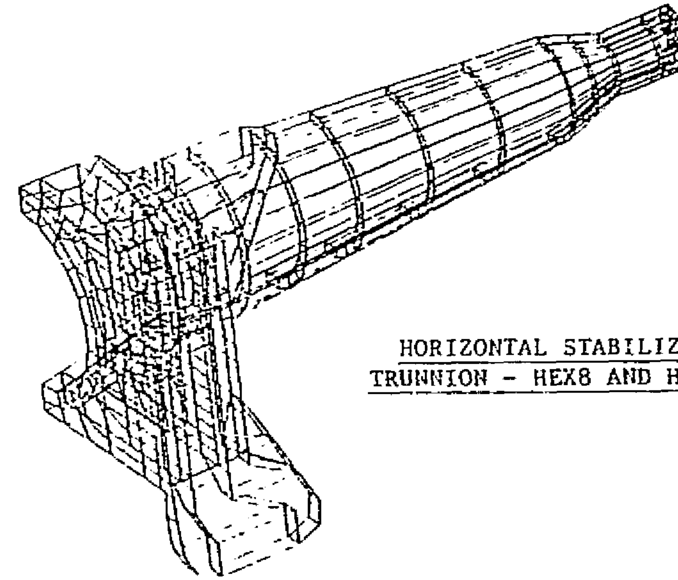


Fig. 1 F-5A LEADING EDGE FLAP



HORIZONTAL STABILIZER TRUNNION - HEX8 AND HEX20

YF-17

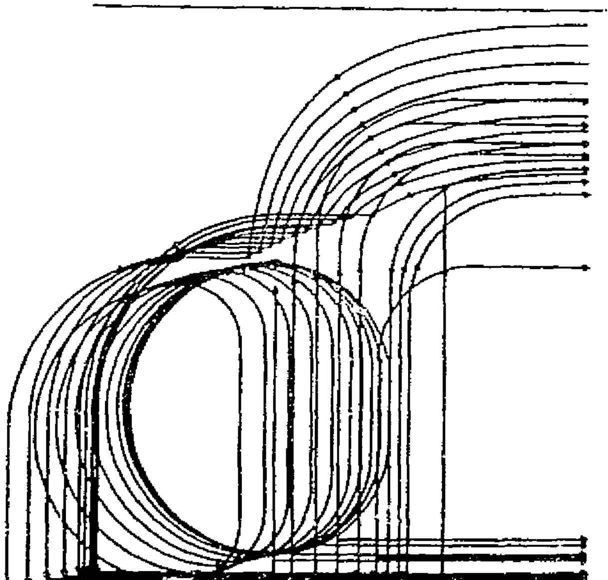


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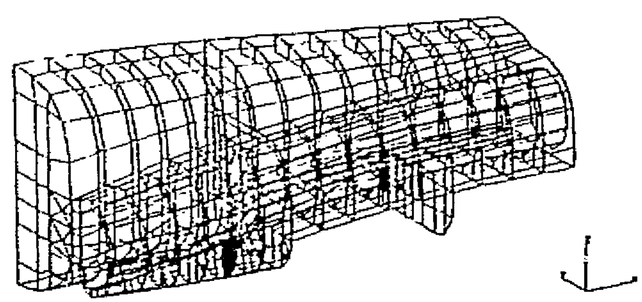
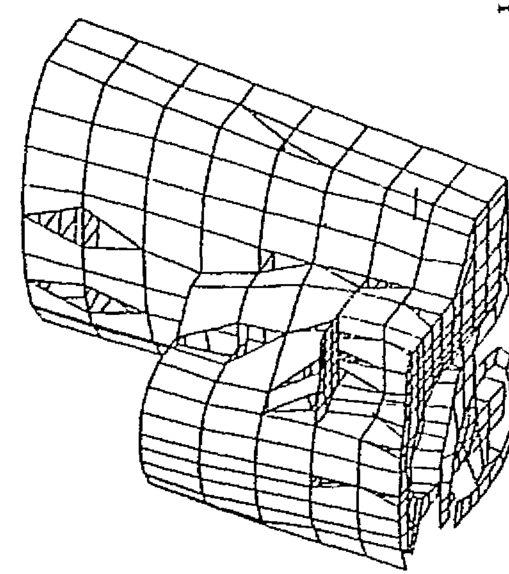
Fig. 2



T-38 CENTER FUSELAGE

Fig. 3



HIDDEN LINES

Fig. 4

MODEL GENERATION

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PARAMETRIC CUBICS (P.C.) LOADS APPLICATIONS

F U E L   T A N K   L O A D S

EXAMPLE: F-18 FUEL TANK

- o VERY COMPLEX NASTRAN MODEL INPUT
- o EXTERNALLY SURFACED BY P.C.'s
- o APPLIED LOAD FACTOR IN ANY DIRECTION
- o DETERMINES FREE FUEL SURFACE
- o COMPLETE NASTRAN LOAD CARDS OUTPUT

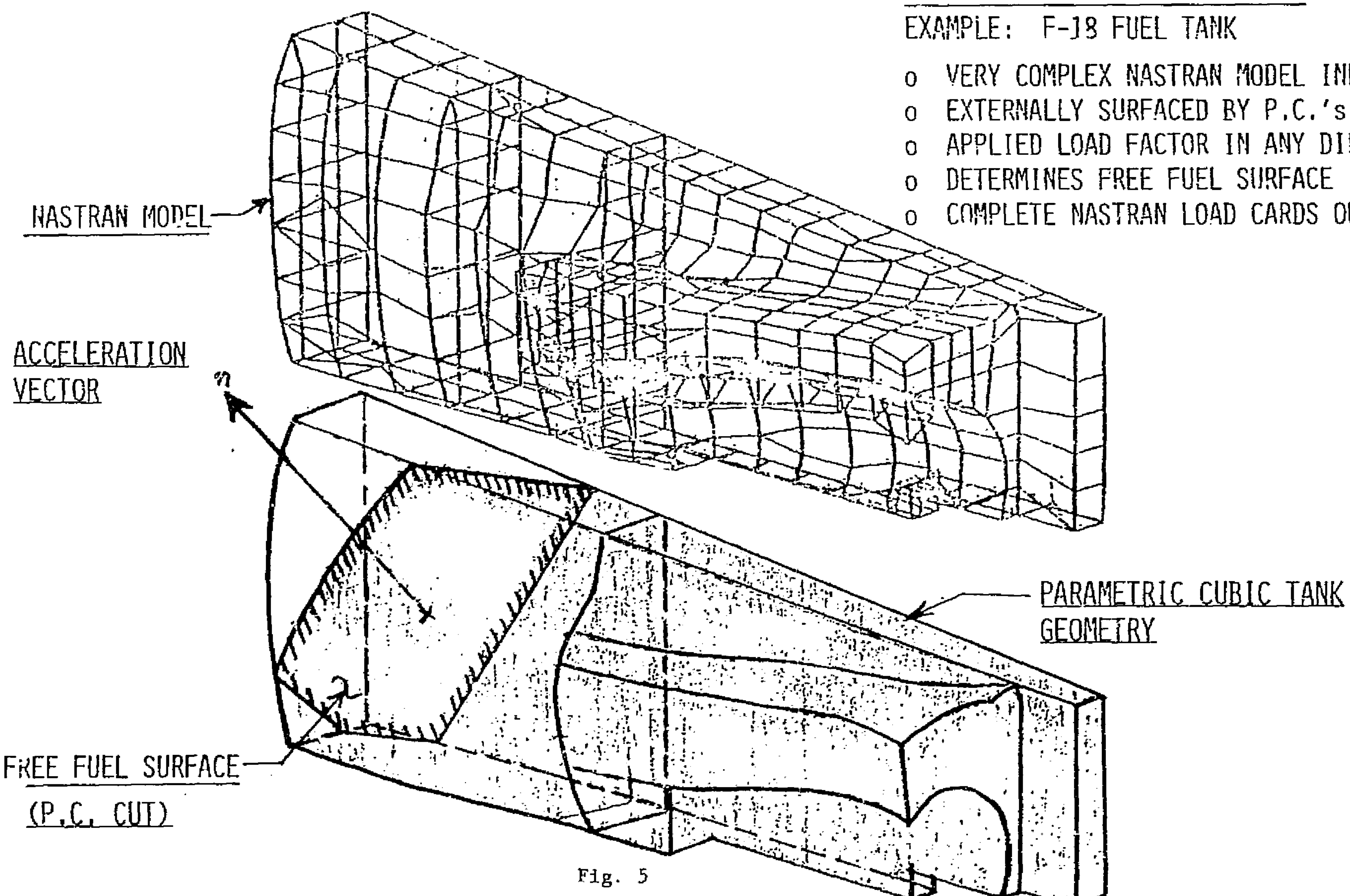
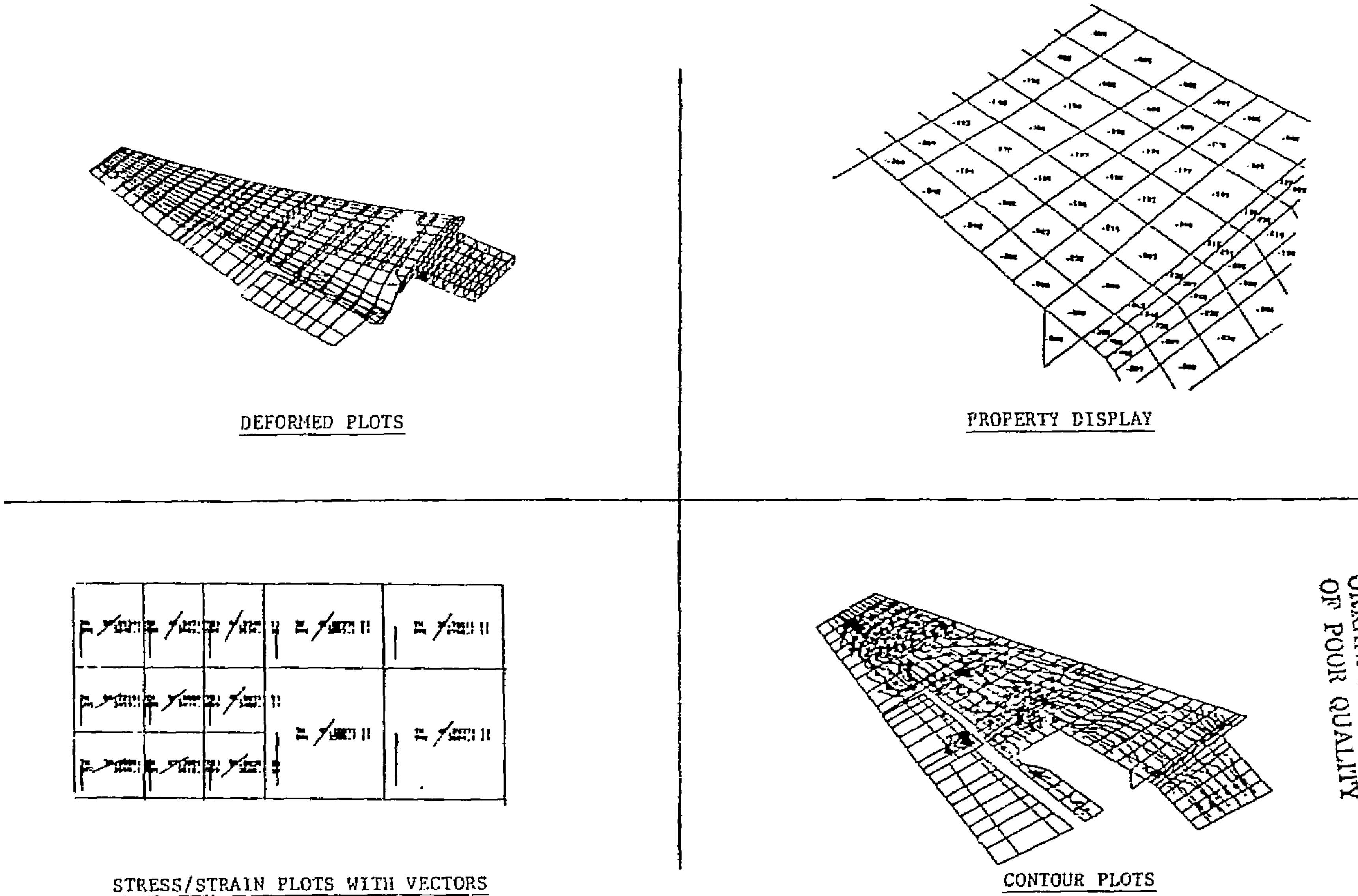


Fig. 5



NASTRAN DATA VISIBILITY

Fig. 6

T-38 WING SUBSTRUCTURE ANALYSIS

Model Generation

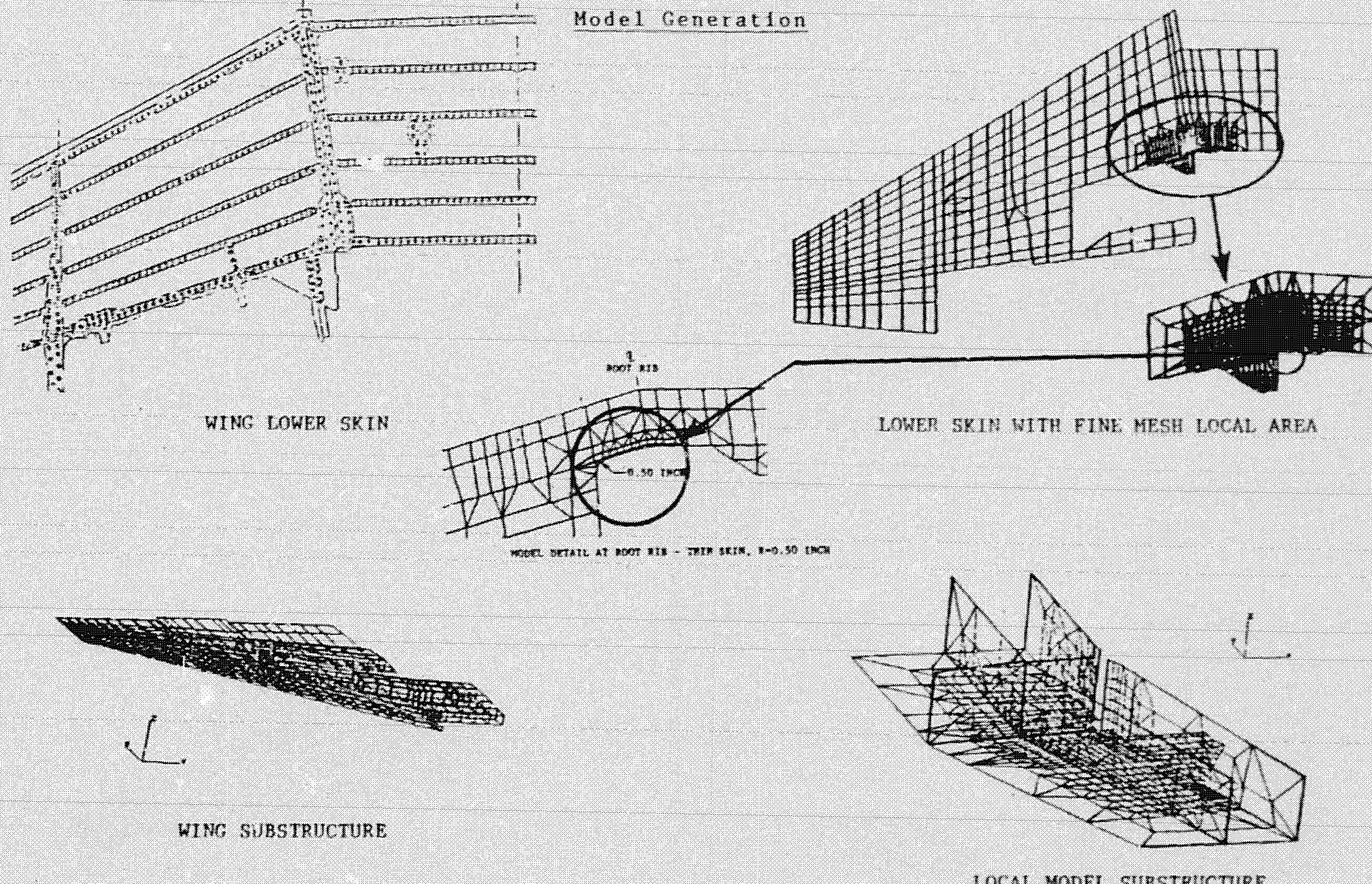
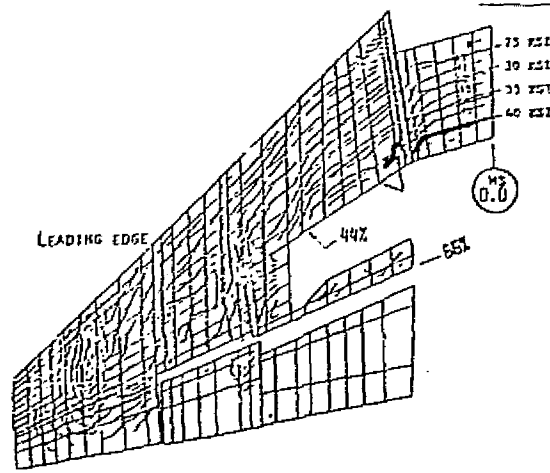


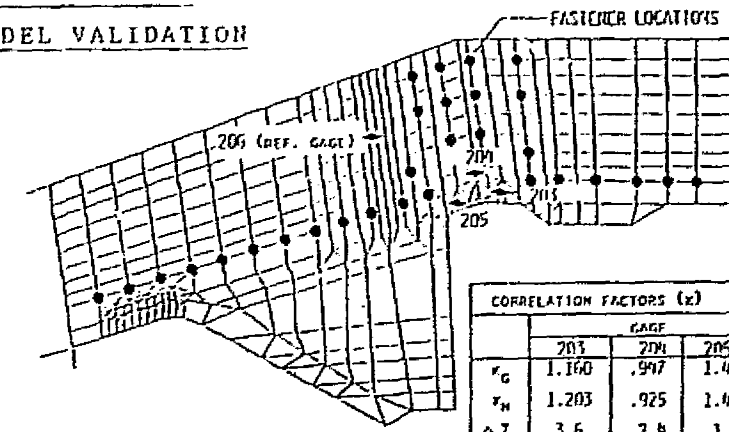
Fig. 7

T-38 WING SUBSTRUCTURE ANALYSIS

NASTRAN STRESSES AND MODEL VALIDATION



CONTOUR PLOT - GROSS WING MODEL
LOWER SKIN

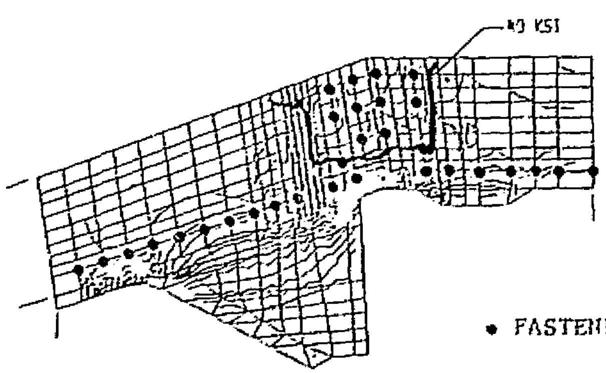


CORRELATION FACTORS (%)			
	GAGE		
	203	204	205
K_G	1.160	.947	1.466
K_M	1.203	.925	1.439
Δ%	3.6	2.4	1.9

$K_G = \frac{\epsilon_{GAGE}}{\epsilon_{GAGE\ 206}}$

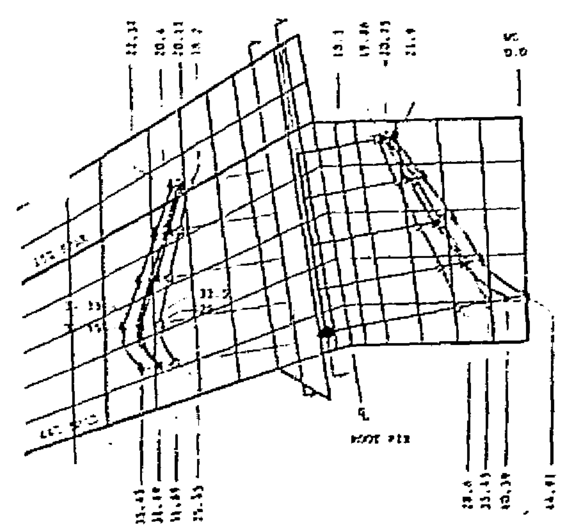
$K_M = \frac{\epsilon_M}{\epsilon_{M\ PANEL\ 221002}}$

LOCAL MODEL VALIDATION
STRESS GRADIENTS

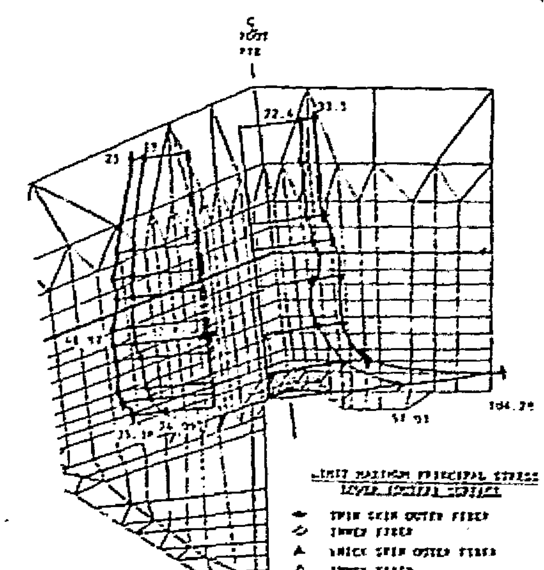


• FASTENERS

CONTOUR PLOT - LOCAL MODEL



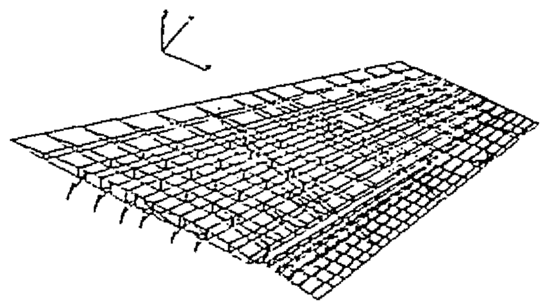
GROSS MODEL CHORDWISE STRESS DISTRIBUTION
Fig. 8



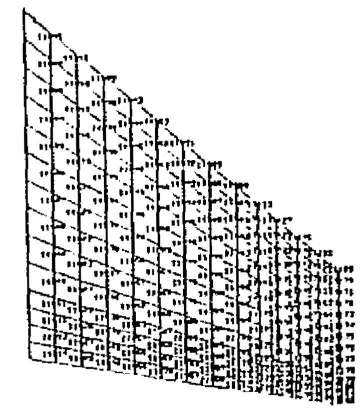
LOCAL MODEL STRESS DISTRIBUTION

NASTRAN FLUTTER ANALYSIS

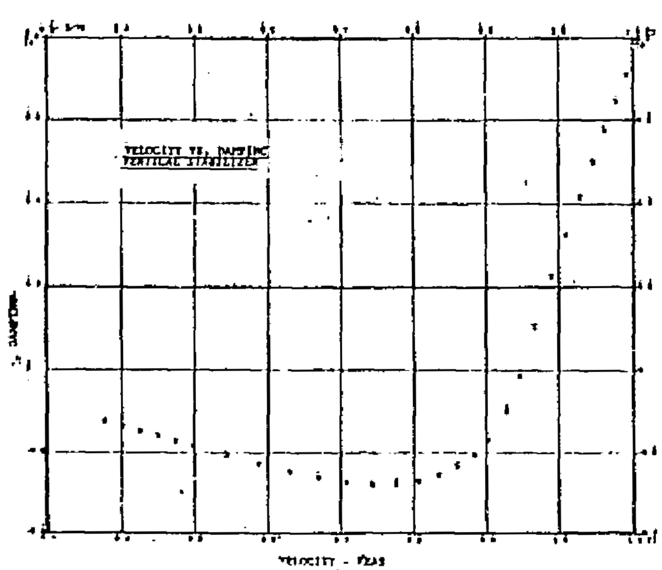
VERTICAL STABILIZER & RUDDER



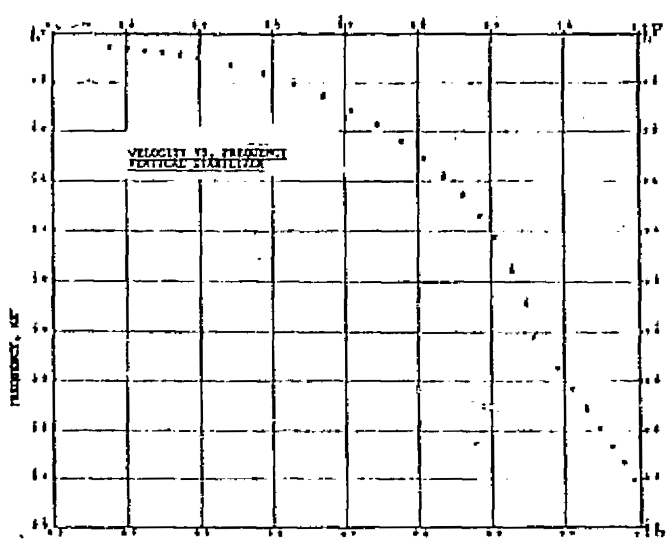
NASTRAN STRUCTURAL MODEL



AERODYNAMIC ELEMENTS



V-g PLOT

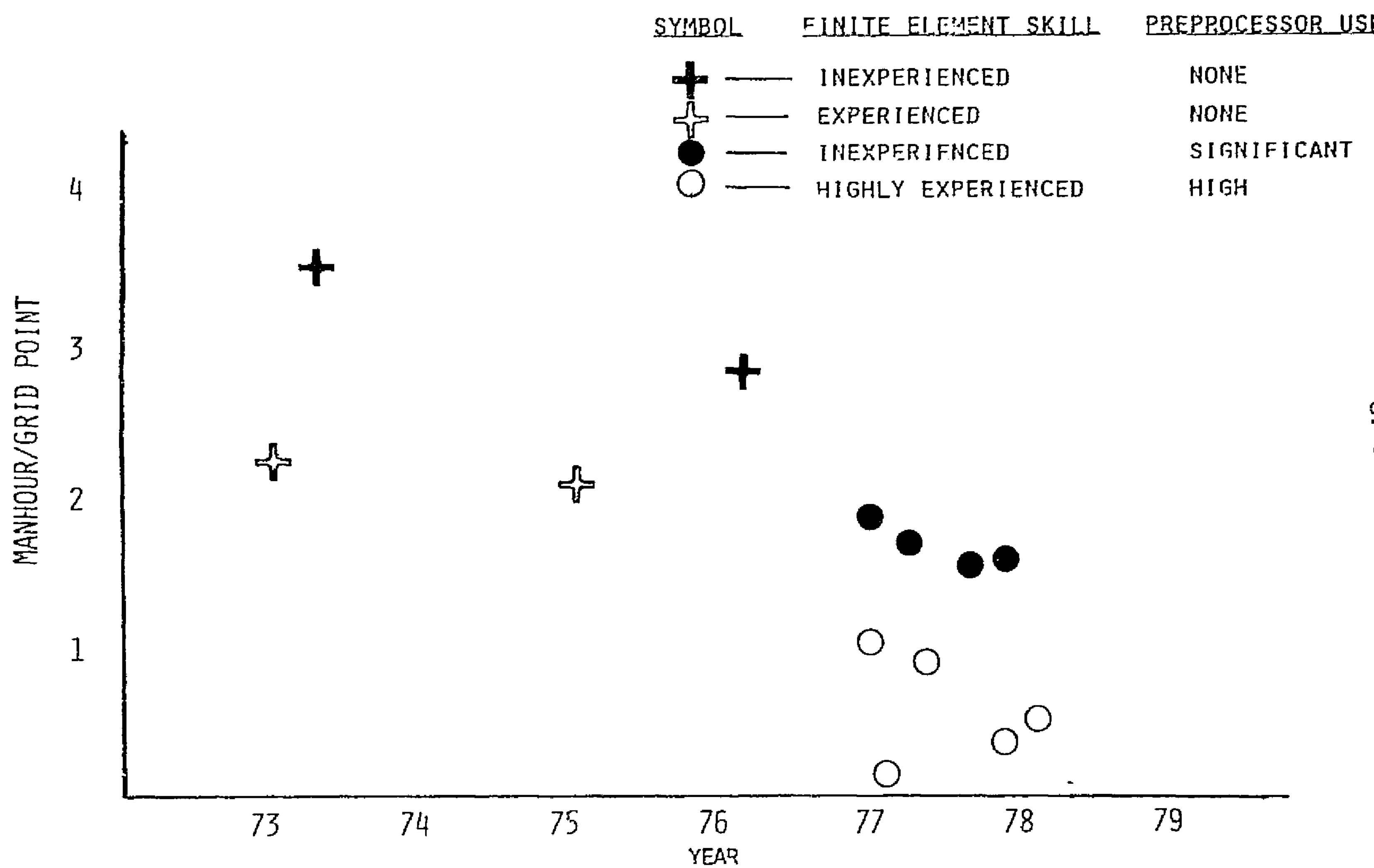


FREQUENCY PLOT

Fig. 9

NASTRAN EFFICIENCY

IMPROVEMENTS



NASTRAN MODEL GENERATION TIME

Fig. 10

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