ABSTRACT

The development of MacNeal-Schwendler Corporation NASTRAN on minicomputers offers users another alternative for engineering computer processing. This paper describes the ongoing distribution of the McDonnell Aircraft Company (MCAIR) NASTRAN system. The latest addition to this distributed processing transformation is VAX/NASTRAN with DECNET communications. A Digital Equipment VAX 11/780 computer dedicated to NASTRAN with DECNET communications was tested. The test description and results are presented.

BACKGROUND

McDonnell Aircraft Company, a division of the McDonnell Douglas Corporation, has developed an integrated computer aided design and manufacturing (CAD/CAM) system based on computer graphics. This integration has evolved over the past twenty-one years. The 1971 release of Computer Aided Design Drafting (CADD) with three-dimensional capability opened the way to NASTRAN pre- and post-processing. In 1973 pre-processing capability was released, and post-processing was added in 1974. Also in 1974 a new project was formed and given overall responsibility for development and integration of CAD systems. Figure 1 shows the activities included in the Computer Aided Technology, or CAT, project. The structural analysis disciplines include strength, weights, structural dynamics and external loads.

INTRODUCTION

MCAIR's NASTRAN system includes MSC/NASTRAN and Computer Graphics Structural Analysis (CGSA). CGSA is the portion of CAD/CAM for pre- and post-processing NASTRAN data. Any discussions of the distribution of MCAIR's NASTRAN processing must include an introduction to CGSA.

The NASTRAN models are created in CGSA. Flexibility data in the form of reduced stiffness matrices are passed to the Structural Dynamics and External Loads Departments. Revised stiffness requirements and external loads are returned and incorporated in the NASTRAN model. Similarly, data from the Weights Department is generated, shared, and revised. These data transfers are described in Figure 2.

All structural requirements are incorporated into the CGSA model. By using CGSA the stress analyst can define, store, and edit all required data for the NASTRAN solution. The finite elements supported within CGSA include the ROD, BAR, SHEAR, QUAD4, and TRIA3. This list is expanded or modified as requirements and technology change.

The procedure for definition of a NASTRAN model normally begins in the CADD module. Loft data is obtained and reduced to required point definition. The analyst then transfers to CGSA, converts the required points to Grid Points, and connects the Grid Points with structural finite elements. These elements are defined by light pen detection of the defining grids and selection of mechanical properties. Automatic element generation with a parametric cubic patch is also available. External loads, boundary conditions, and control statements are then added and filed with the model.

Data review within CGSA is accomplished by interactive display and hardcopy of the properties. A few of these options are shown in Figures 3 thru 6, including loads, reactions, areas, thicknesses, and material properties.

The structural model is typically stored in several files. The content of each file is determined by the analyst. A wing model might include a file containing the upper skin; the lower skin in a second file; and ribs and spars in a third. Thus the data is grouped for ease of modeling, editing, display, and output presentation. The files may be broken into sub sections and recombined at any time during pre- or post-processing. When the input data is complete, the analyst selects the input files, a file to receive the answers, and submits the NASTRAN batch job. When this batch job executes, a pre-processor retrieves the input files and creates a NASTRAN card-image input deck. NASTRAN then solves the problem and writes the output to the user-defined answers file. The NASTRAN submittal procedure is outlined in Figure 7.

The post-processing is accomplished using CGSA. The analyst retrieves an input file and selects an output file. Some of the output display options available are shown in Figures 8 thru 10.

HARDWARE AND COMMUNICATION EVOLUTION

Prior to 1978 IBM 2250 refresh terminals were connected to various IBM mainframes. Communication was accomplished over 50,000 bit/second (or 50 k-baud) cables. This central system configuration, as shown in Figure 11, is being phased out. There are presently 9 IBM 2250 terminals in use at St. Louis.

In 1978 a distributed system began replacing the original central configuration. The Distributed Graphics System (DGS) is also described in Figure 11. The model data, vector generation, and other functions requiring extensive computations or memory remain on the mainframe. User commands are fielded by a Digital Equipment Corporation (DEC) PDP 11/70 minicomputer. The IBM 2250 terminals are replaced by Evans and Sutherland Picture System 2 terminals. The microprocessor with each pair of new terminals is used to provide instantaneous translation, rotation and scaling. Communications over a 50 k-baud cable are handled by the 11/70 and DEC PDP 11/34 minicomputers. The St. Louis facility presently includes 68 terminals, 14 PDP 11/70's, 3 PDP 11/34's, and one IBM 3033 mainframe.

The DGS system has improved response and cost by tailoring hardware to the requirements. This process is being continued by two developments. The first of these is the total off-loading of CGSA to the PDP 11/70. The second is the migration of NASTRAN processing to the DEC VAX 11/780 minicomputer. Figure 12 shows a system configuration involving these new developments.

TEST OF VAX/NASTRAN AND DECNET

The proposed dedicated VAX/NASTRAN system was tested in St. Louis. A VAX 11/780 was available on off-shifts and weekends. The test problems were the only load on the system. This allowed comprehensive testing of VAX/NASTRAN in the proposed dedicated environment.

The VAX 11/780 used in the testing had less real memory and disk storage than the proposed production system. However it did contain several important features including the VMS 2.0 operating system and floating point processor. A comparison of the test and production machines is given in Figure 13.

DECNET was installed between the test VAX and PDP 11/70 CAD minicomputer. These were connected by splitting an existing telephone line, giving a communication rate of 4800 baud. The operating system on the PDP 11/70 was RSX-11M Version 3. The test was designed to answer the following questions:

1) Can VAX/NASTRAN fill the processing requirements?
2) Are DECNET and CGSA compatible?
3) Will DECNET fill the communications requirements?
4) Is this system reliable?
5) Are maintenance and overhead minimal?

The following results answered each of these questions with a "yes".

DECNET PERFORMANCE AND TEST RESULTS

In the production configuration the VAX will be controlled by the user procedure of job submittal. Job submittal will involve the file selection and control of various options such as checkpoint, restart, and data base operations. These instructions were assembled into DECNET commands.

A typical job involved instructions to transfer the NASTRAN input deck to the VAX, add the job to the NASTRAN queue, and return the answers file to the PDP 11/70. DECNET contains simple instructions for each of these steps. The data was transferred correctly and the VAX required no operator intervention.

Another advantage offered by DECNET is the networking capability. As new PDP 11/70's or VAX 11/780's are added, the network can easily be expanded. Minimal software changes are required. If communication hardware goes down DECNET can route data by other paths. Finally a network supervisor can interrogate and optimize data transfer.

The final concern was the amount of PDP 11/70 work space, or "pool", DECNET required. DGS, CGSA, and the plotters already require substantial work space. The test indicated that DECNET required approximately 2200 bytes. This is within the remaining work space.

VAX/NASTRAN PERFORMANCE AND TEST RESULTS

Approximately thirty representative NASTRAN problems were assembled from various production projects. These problems use nine NASTRAN procedures. The problem size varied from 100 to 26,000 degrees of freedom. VAX/NASTRAN results could be compared with existing solutions to each of these problems.

A comparison of the test and production VAX configurations is shown in Figure 13. The test VAX had insufficient disk space to solve the largest problem (26,000 degrees of freedom). Therefore the production configuration contains increased disk space.

Several static, Rigid Format 24, problems were solved. They contained no checkpointing, one load condition and one boundary condition. The grid point sequencing was optimized by Rigid Format Alter 74. The problems averaged three degrees of freedom per grid point. All answers agreed with previous solutions. VAX CPU and elapsed time are plotted versus problem complexity in Figure 14.

Fifteen other problems were solved. These validated results from other NASTRAN procedures. They also explored the VAX/NASTRAN large problem capacity. Results of these problems are presented in Figures 15 and 16. A test problem using Direct Transient Response (RF 9) did not converge on the VAX. MacNeal-Schwendler believes this was caused by the decreased precision on the VAX versus the CDC. No other precision problems were encountered.

The NASTRAN testing confirmed previous findings of high reliability, versatility, and performance on the VAX 11/780. The machine can be used in a slaved environment with minimal operator intervention. DECNET allows the stress analyst to control the VAX for normal operations.

CONCLUSIONS

The tests clearly showed that all major components required to integrate VAX/NASTRAN into MCAIR's Distributed Graphics System are available and reliable. The resulting system requires minimal software conversion. The flexibility allows matching the computing power to the computing needs.

ACKNOWLEDGMENTS

The successful completion of this project hinged on the excellent cooperation received from:

MacNeal-Schwendler Corporation

Digital Equipment Corporation

McDonnell Douglas Automation Company

McDonnell Douglas Astronautics Company

C.A.T. ORGANIZATION CHART

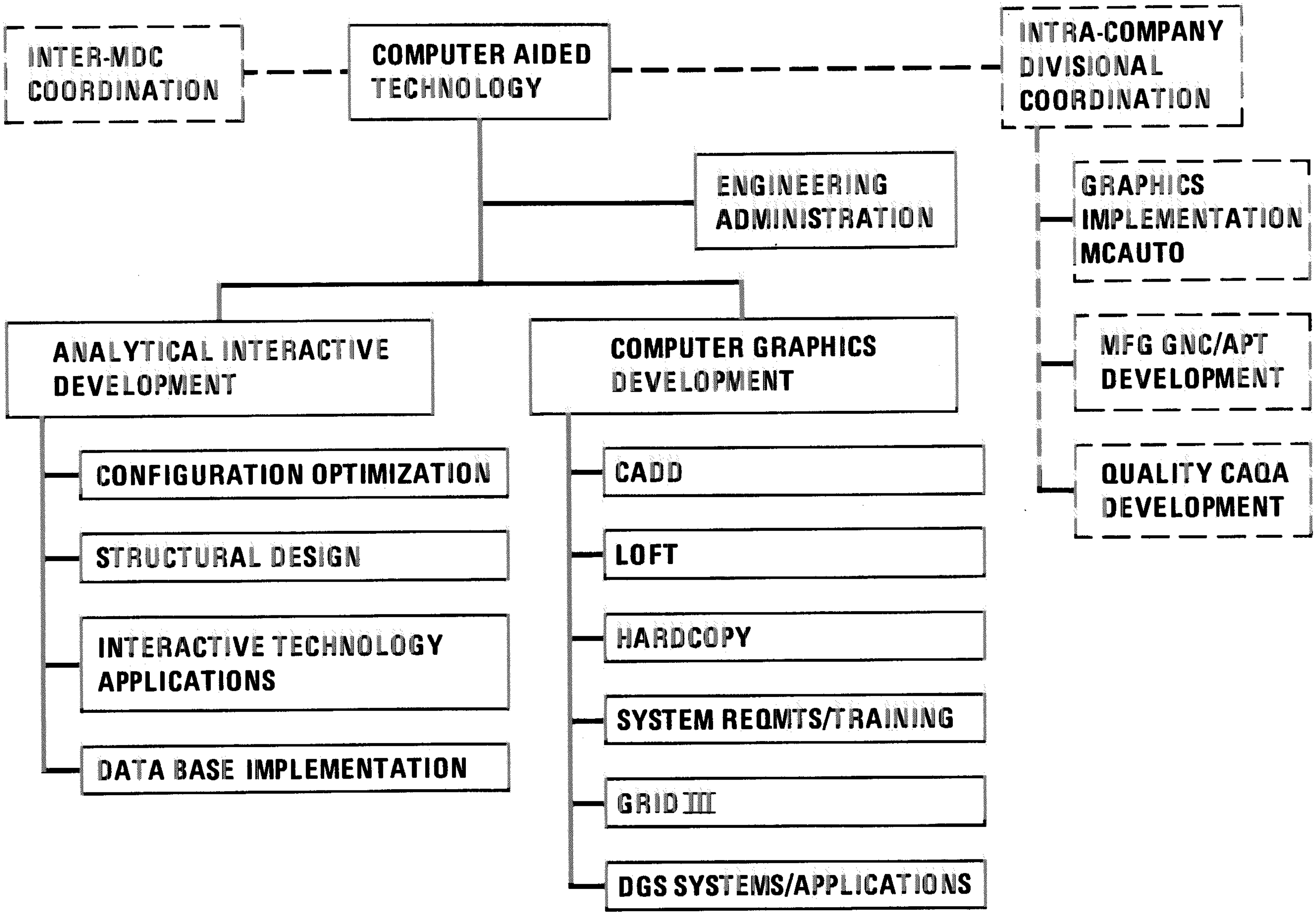

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FIGURE 1

CGSA ACTIVITIES

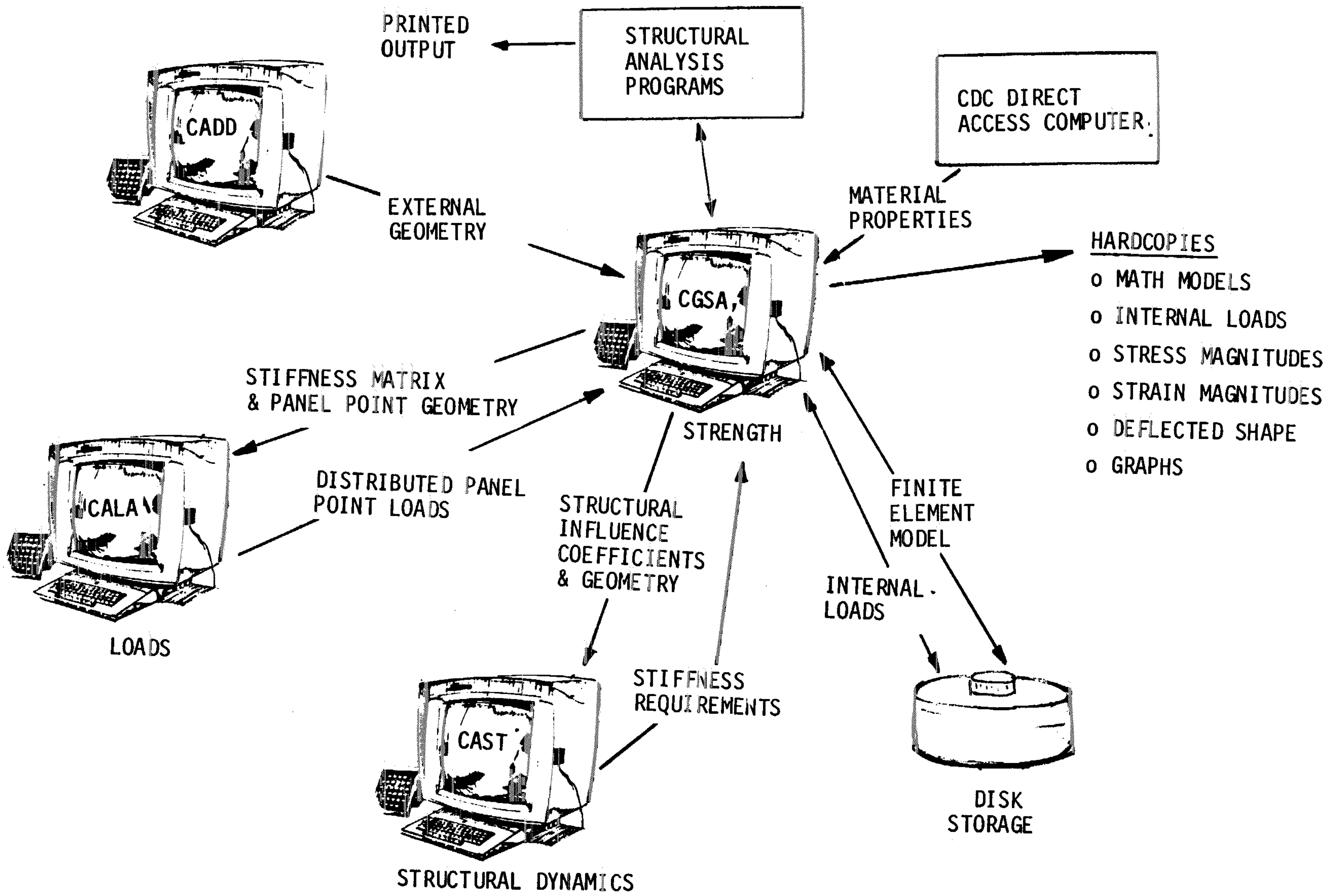


FIGURE 2

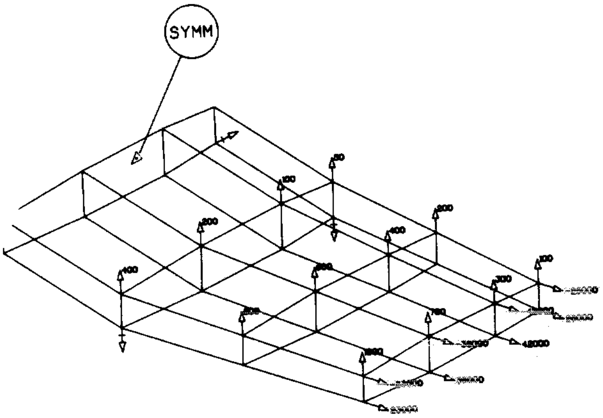


FIGURE 3 LOAD MAGNITUDES CONDITION 1

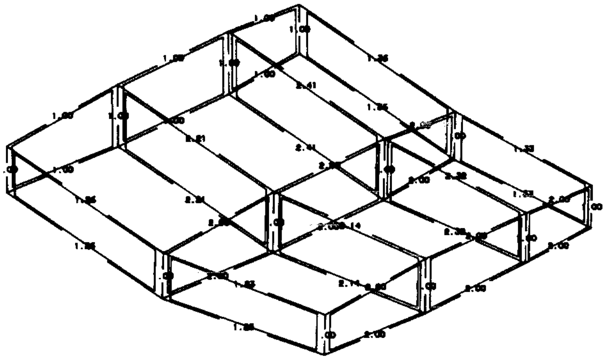


FIGURE 4 BAR AREAS

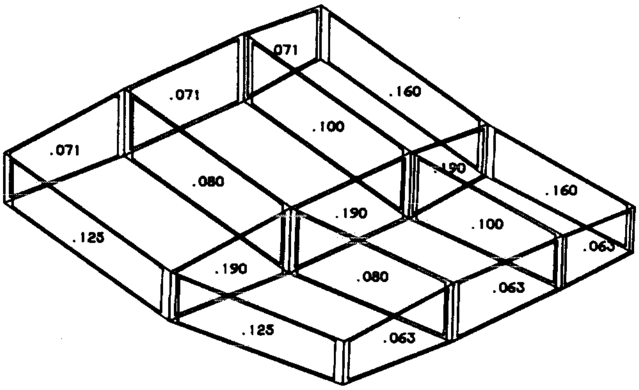


FIGURE 5 SHEAR PANEL THICKNESS

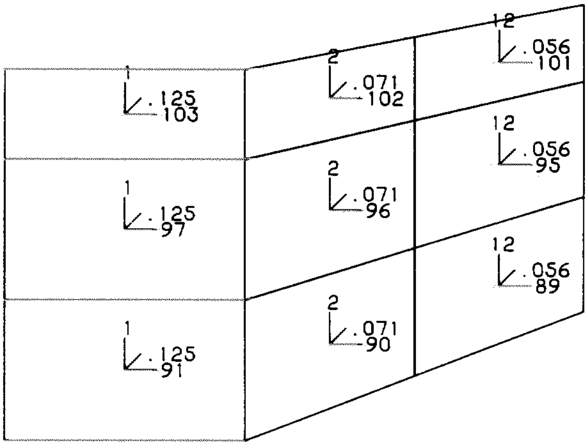


FIGURE 6 QUAD 4 LABEL, THICKNESS, AND MATERIAL ID

AUTOMATED NASTRAN SUBMITTAL

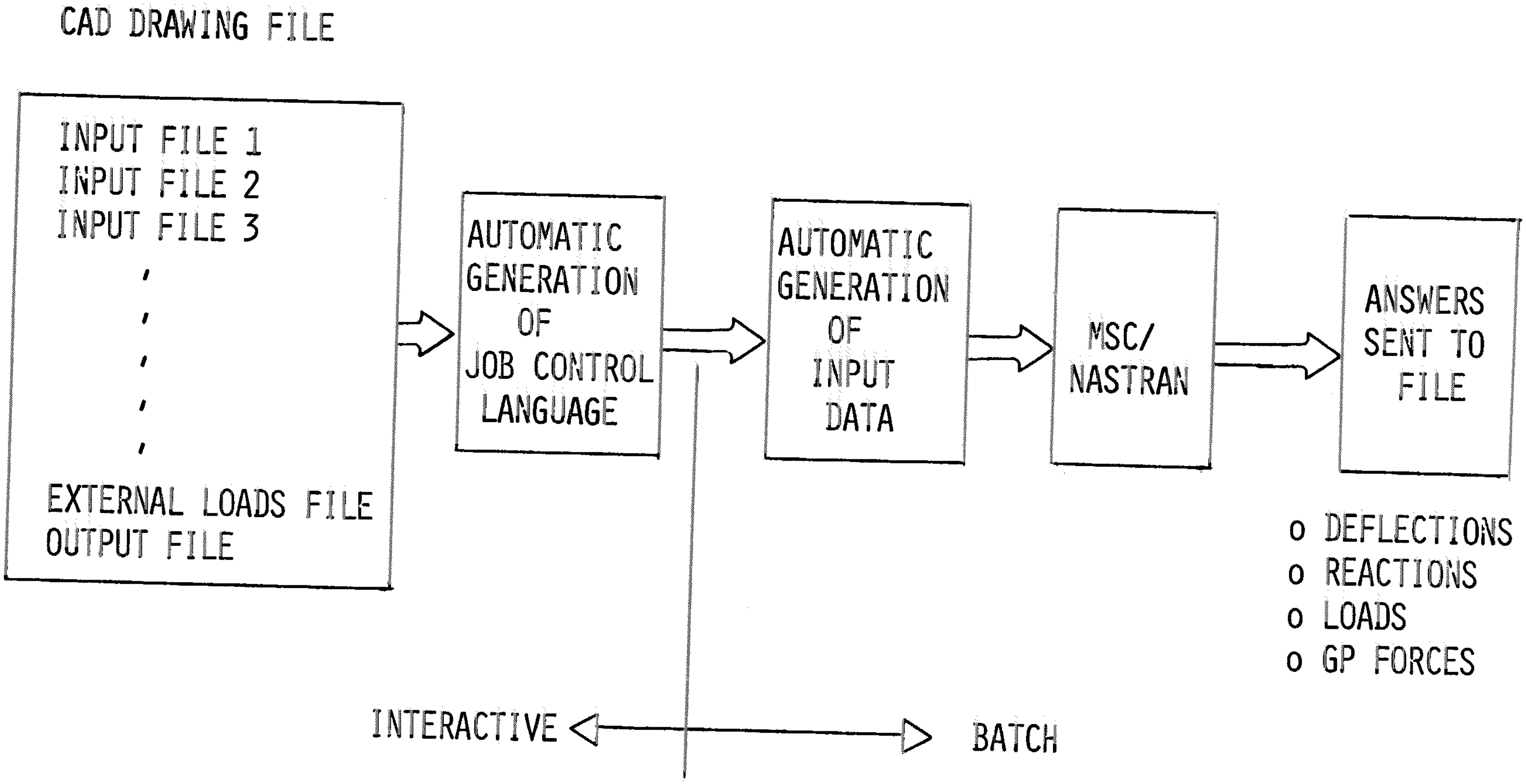
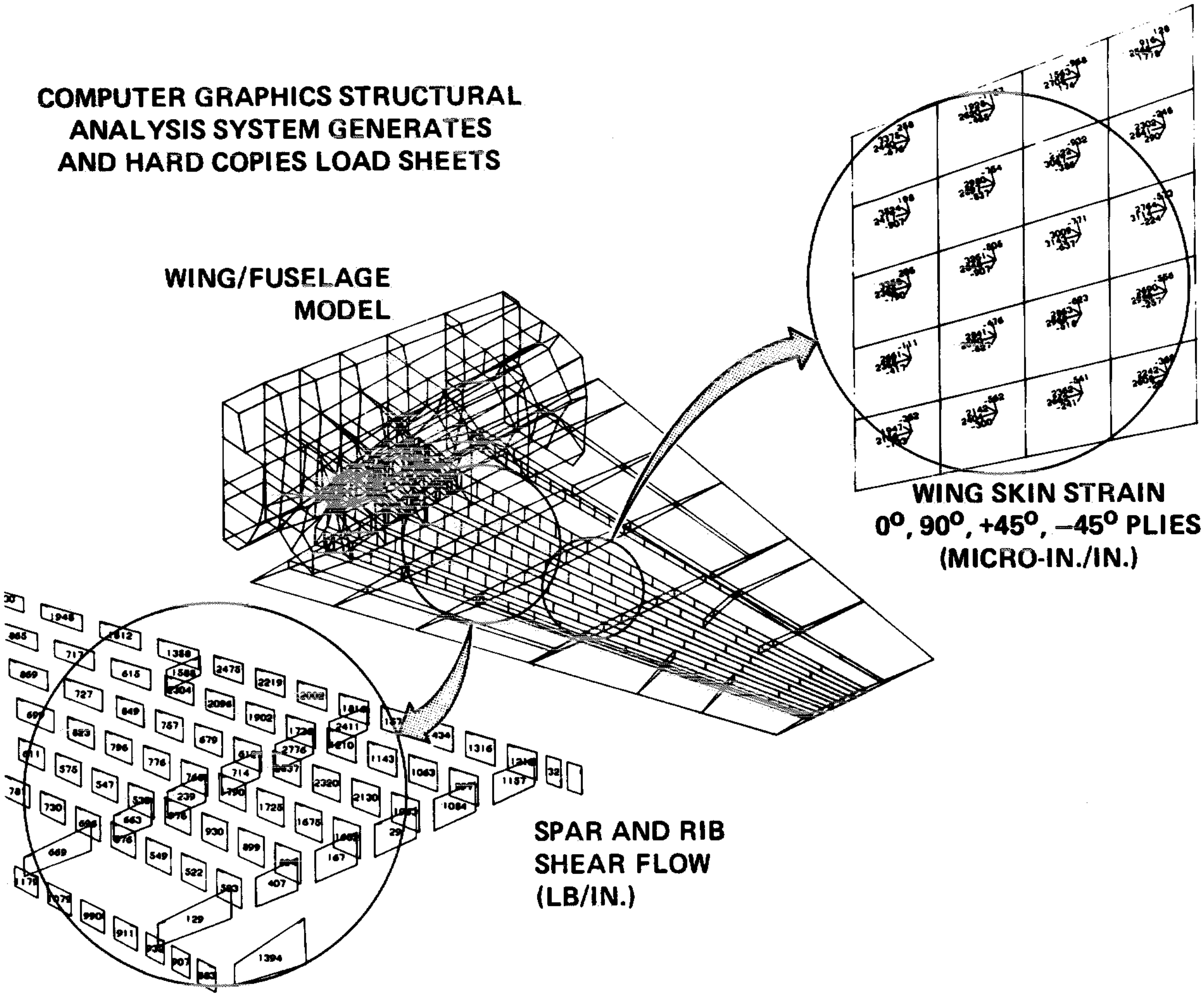


FIGURE 7



COMPUTER GRAPHICS STRUCTURAL ANALYSIS SYSTEM GENERATES AND HARD COPIES LOAD SHEETS

WING/FUSELAGE MODEL

WING SKIN STRAIN
0°, 90°, +45°, −45° PLIES
(MICRO-IN./IN.)

SPAR AND RIB
SHEAR FLOW
(LB/IN.)

FIGURE 8 CGSA DATA REDUCTION

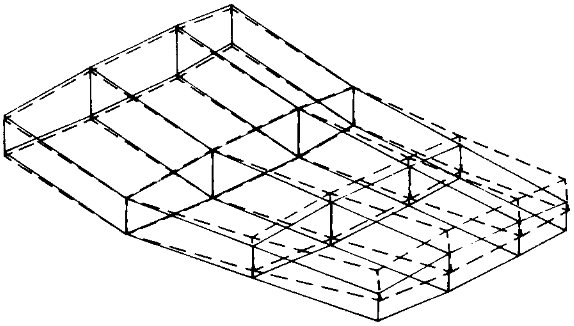


FIGURE 9 DEFLECTED SHAPE SCALED UP BY 5.0

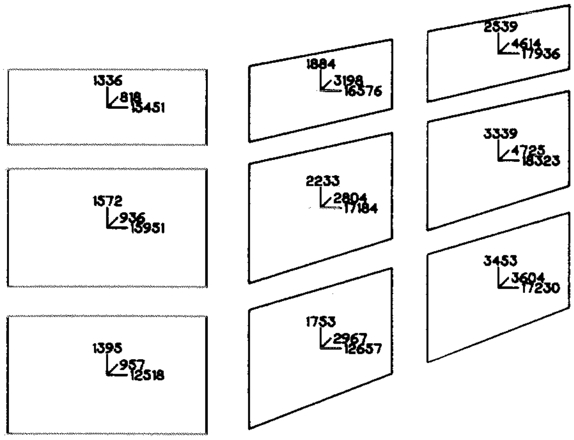


FIGURE 10 LOWER COVER MEMBRANE STRESS (PSI)

CENTRAL SYSTEM vs DGS COMPARISON

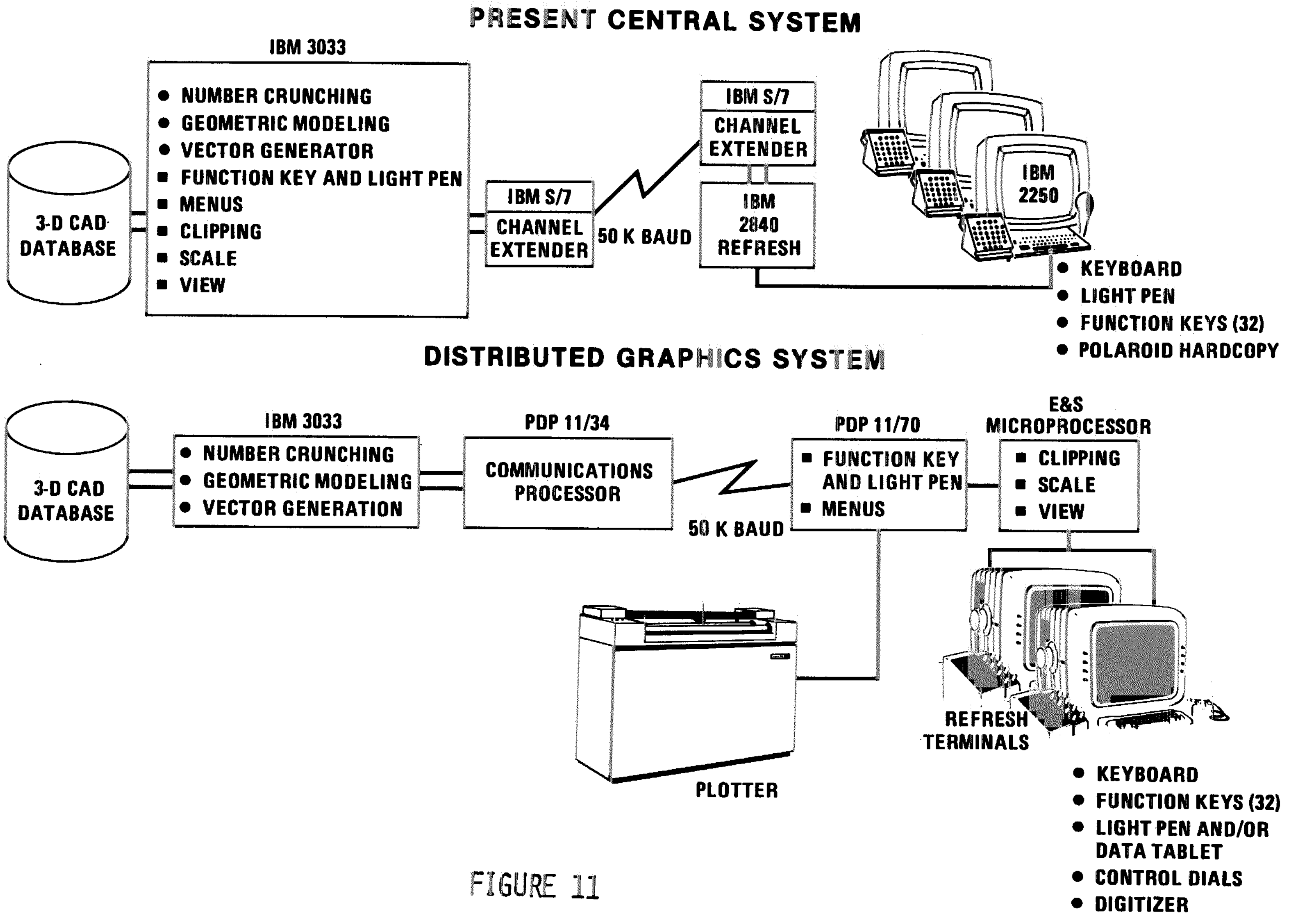


FIGURE 11

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DISTRIBUTED GRAPHICS WITH DEDICATED VAX/NASTRAN

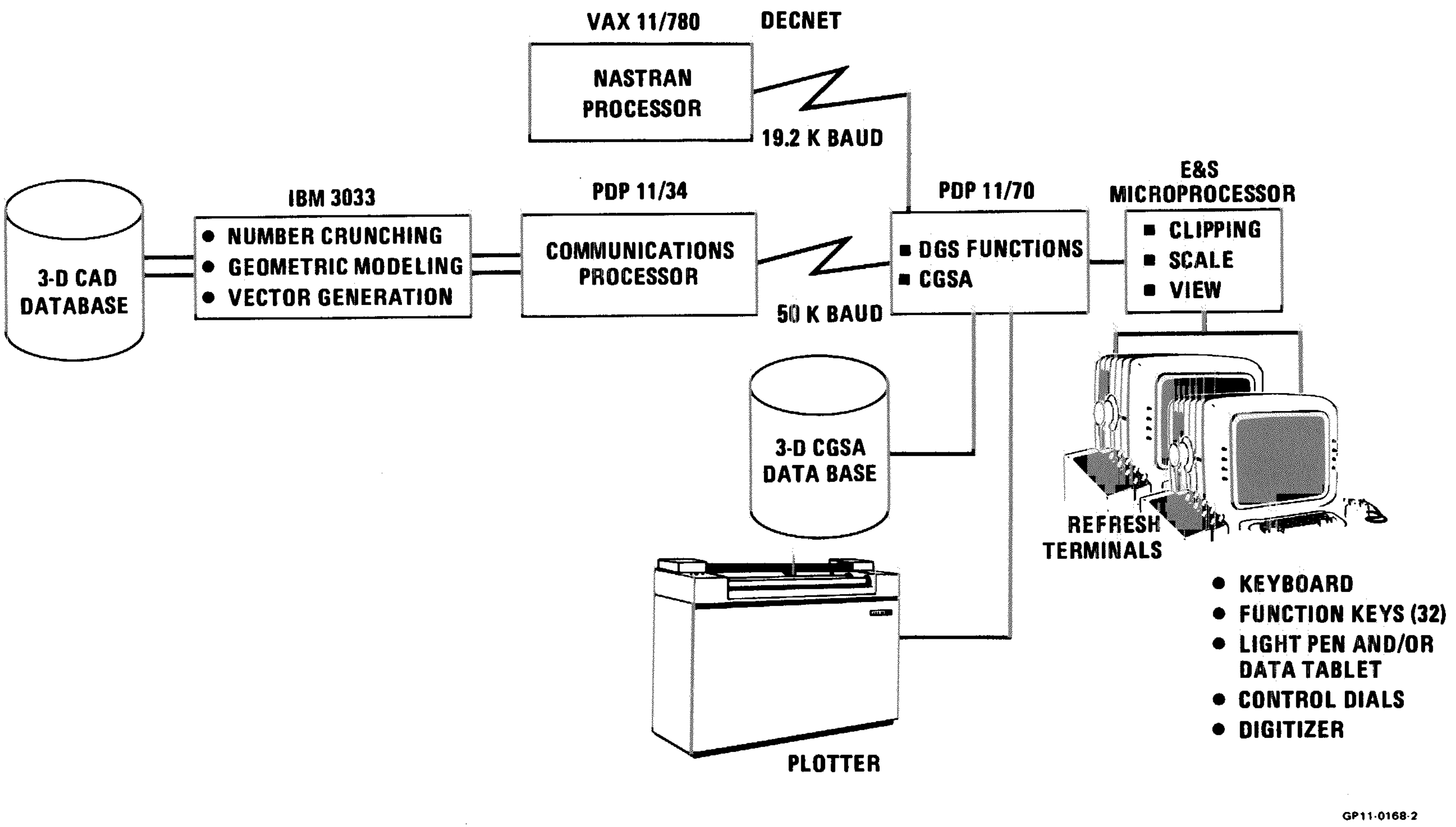

FIGURE 12

VAX 11/780 CONFIGURATION

TEST		PRODUCTION	
1	VAX 11/780 WITH 1.5 MEGABYTE MEMORY	1	VAX 11/780 WITH 3 MEGABYTE MEMORY
1	FLOATING POINT PROCESSOR	1	FLOATING POINT PROCESSOR
2	RP06 DISK DRIVES (TOTAL CAPACITY = 338 MEGABYTES)	4	RM05 DISK DRIVES (TOTAL CAPACITY = 1024 MEGABYTES)
1	DISK CONTROLLER	2	DISK CONTROLLERS
1	TAPE DRIVE	1	TAPE DRIVE
1	COMMUNICATION LINE (4.8 K BAUD) DECNET AND HARDWARE	3	COMMUNICATION LINES (19.2 K BAUD) DECNET AND HARDWARE
1	600 LINE/MINUTE PRINTER	1	900 LINE/MINUTE PRINTER
		1	285 LINE/MINUTE PRINTER

FIGURE 13

DEDICATED VAX/NASTRAN PERFORMANCE
RF 24 SINGLE LOAD AND BOUNDARY CONDITION
OPTIMIZED GRID POINT SEQUENCING

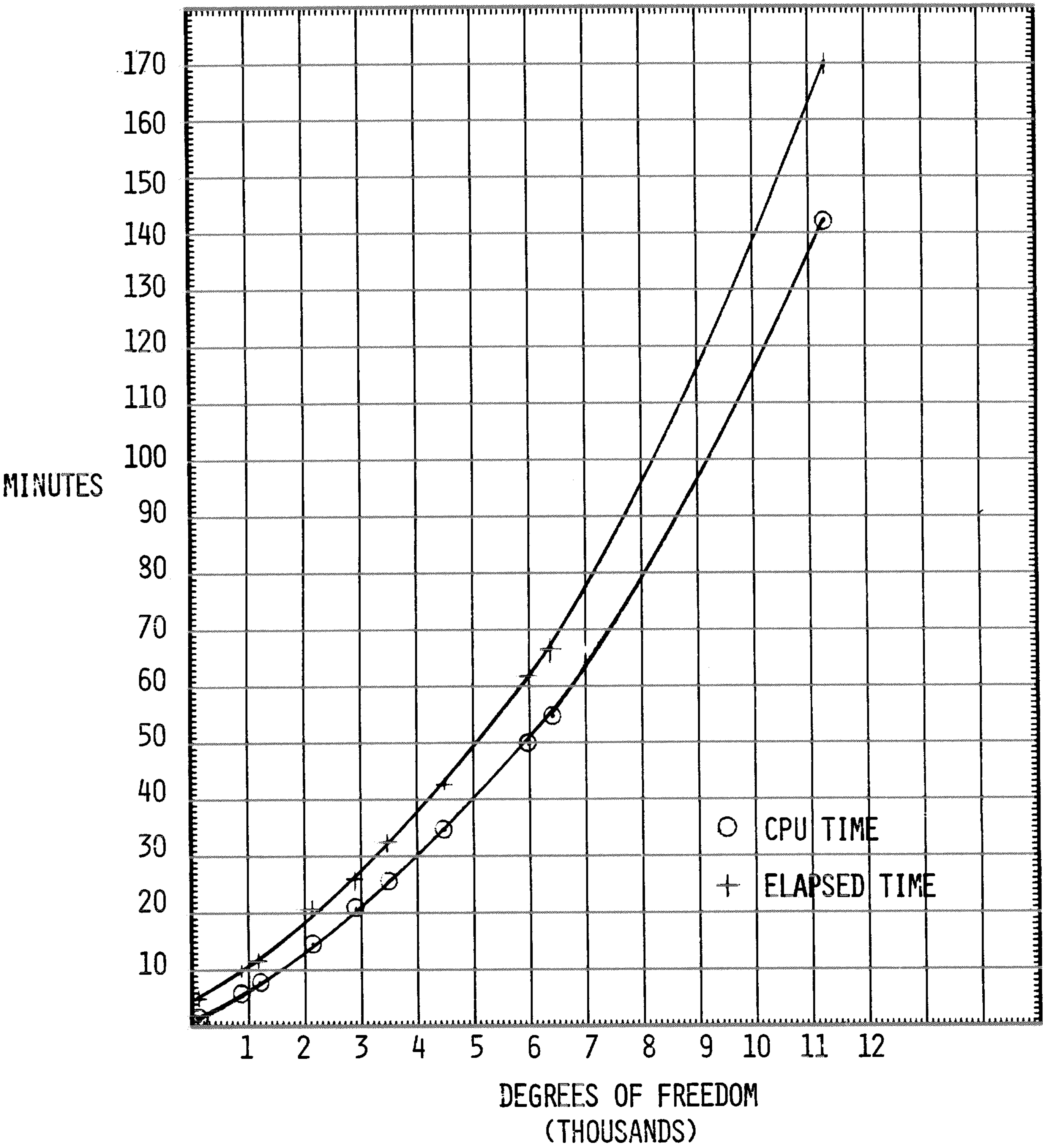

FIGURE 14

ADDITIONAL TEST PROBLEMS

DESCRIPTION	DEGREES OF FREEDOM	VAX SOLUTION TIME (MINUTES)	
		CPU	ELAPSED
DMAP1 WITH GENERAL ELEMENT	438	7	12
DYNAMICS (RF 25)	93	3	6
DMAP4, 19 ITERATIONS	189	18	22
RF 24 (UNSYM. LOADING)	5961	53	67
RF 24 (UNSYM. LOADING, CHECKPOINT)	11308	229	276
RF 24 (RESTART, NEW LOADS ONLY)	11308	54	81
DMAPIC	11906	444	533
DMAPIC (RESTART, NEW LOADS ONLY)	11906	98	138
DMAPIA WITH CYCLIC SYMMETRY	25849	530*	600*

* PROJECTED. TEST SITE DISC SPACE LIMITATION ALLOWED ONLY 70% COMPLETION.

FIGURE 15

ADDITIONAL TEST PROBLEMS (CONTINUED)

DESCRIPTION	DEGREES OF FREEDOM	VAX SOLUTION TIME (MINUTES)	
		CPU	ELAPSED
RF 24 (UNSYM. LOADING)	11308	198	229
RF 24 (RESTART OF SYM. LOADS RUN)	11308	24	37
RF 5 (BUCKLING)	2244	14	17
RF 25 (DYNAMICS)	366	3	6
RF 11 (MODAL FREQUENCY RESPONSE)	132	3	5

FIGURE 16