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COMPARISON OF SEVERAL NASTRAN ANALYTICAL TECHNIQUES FOR LARGE STRUCTURES

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SUMMARY

In order to plan for the finite element structural analysis of future aircraft at Northrop, five static analysis techniques using the MacNeal-Schwendler Corporation version of NASTRAN are evaluated. The structure is analyzed as:

1. A single model with a symmetric loading condition.

2. A single model with symmetric/unsymmetric loading conditions.

3. Three substructures in three phases using tape storage with a symmetric loading condition.

4. Three superelements using data base storage with a symmetric loading condition.

5. Three superelements using data base storage with cyclic symmetry for symmetric/unsymmetric loading conditions.

The superelement techniques prove superior to the single model approaches by reducing computer time for redesign work by as much as 70 percent.

Job control errors are also substantially reduced by using the NASTRAN data base in place of the tapes necessary in substructuring. The evaluation indicates that the superelement methods are more productive than the single model and substructure methods when a large amount of computer resources for a stress analysis are required.

INTRODUCTION

Before scheduling a large project using finite element analysis, the specific solution methods chosen must be thoroughly tested. This is true not only for the analysis flow, which in the case of NASTRAN is the Direct Matrix Abstraction Program (DMAP), but also for internal software restrictions and data center hardware constraints.

Too often the analysis method selected is based upon small prototype testing. This, coupled with an incomplete understanding of both the finite element program being used and the peculiarities of the computer system in a large solution environment, frequently leads to:

(a) Deadlines consistently missed.

(b) Complaints against the finite element program being used.

(c) The computer system "crashing" during excessively long computer residency.

(d) Computer runs terminated due to insufficient core or data base space.

An effort was started in 1977 within the NASTRAN group at Northrop to evaluate these problem areas prior to selecting a method of analysis for a new aircraft project. A small prototype model (Figure 1) and an actual production model containing 9500 degrees of freedom (Figure 2) were selected for evaluating the MSC superelement capability. The results are compared here with previous results using a single model and substructure approaches. Five criteria for this comparison are:

(1) NASTRAN software behavior.

(2) Hardware limitations.

(3) CPU time for a preliminary analysis.

(4) CPU time for a redesign analysis.

(5) Total calendar time.

TESTING PROCEDURE

Realistic evaluation of the MSC/NASTRAN superelement analysis method is made using a finite element model of the T-38 structure (wing, center and forward fuselages only). A comparison of the program response and the computer system billing for this model was possible using results from previous single structure and substructure analyses.

Five different analyses over a one year period were made, then rerun with a redesigned wing simulating a realistic production situation (Figure 3).

TESTS

(1-1a) Single Structure Analysis With One Set of Boundary Conditions

Rigid Format 24 was used without any alters. Because this model, as with all others, was symmetric about the x-axis, only the left hand side was idealized.

Only symmetric loads were used for this analysis which required one set of boundary conditions along the x-axis. A redesigned wing was run from a cold start.

(2-2a) Single Structure Analysis With Two Sets of Boundary Conditions

Rigid Format 24 with RF alter 24$13 allowed two sets of boundary conditions to be stored. The redesigned wing was run as a cold start.

(3-3a) Substructure Analysis With One Set of Boundary Conditions

Rigid Format 24 with RF alter 24$37 allows only one set of boundary conditions. Therefore, only a symmetric load case was run. DMAP's have been written to work with two sets of boundary conditions by Sodha, Reference 1. However, due to anticipation of the superelement cyclic symmetry capability, no attempt was made to duplicate this effort. The redesign was limited to and required only reanalysis of the wing.

(4-4a) Superelement Analysis With One Set of Boundary Conditions

Rigid Format 48 was used in Version 38, but was replaced with DMAP1 in Version 46. As in the substructure analysis, symmetric loads were used and the redesign test required only reanalysis of the wing and the residual structure.

(5-5a) Superelement Analysis Using Cyclic Symmetry

DMAP1C, Version 46, was used to allow the left hand side to be duplicated into a right hand side, Reference 2. Symmetric and unsymmetric loadings were then applied. Redesign of the wing necessitated only the reanalysis of that particular structure.

TEST RESULTS

Figures 4 and 5 show that the superelement/substructure methods for a large analysis are comparable to the single structure if only one solution is required. However, the first analysis is usually not sufficient and requires many iterations before a satisfactory solution is obtained. Under these circumstances the substructure/superelement method proves itself far superior, requiring only one-third of the CPU time for a reanalysis using a new wing. Not only does this reduce the billing time, but even more important, this increases the chances that the job will run before the computer malfunctions.

The superelement method uses a disk pack data base which reduces the multitude of Job Control Language (JCL) cards necessary to run the substructure analysis. This, in turn, reduces chances of making errors when a large group of engineers works on the same project. No NASTRAN errors were encountered when using the superelement method; only a minor problem was found in the estimation of space needed on the data base.

CONCLUSIONS

The superelement method will substantially lower computer run times for a large finite element analysis. This will decrease the job execution wall-clock time, which will decrease the chances that the computer system will malfunction before an analysis is finished. For structures which require a large amount of computer resources and long execution time, the calendar time to finish an analysis will also be reduced.

Simplification in Job Control Language, use of disk pack storage, and future resource commitment to the superelement method strongly recommend this technique to replace the single structure and substructure methods for any future project.

REFERENCES

1. Sodha, R.: Substructure Analysis in MSC NASTRAN of Symmetric Structures Subject to Asymmetric Loading. British Aircraft Corporation, Warton Aerodrome, Tornado Unified Analysis Project Report, 25 January 1977.

2. Joseph, Jerrard A: Cyclic Symmetry in MSC/NASTRAN. MSC/NASTRAN Application Manual, November 1972.

FIGURE 1 - NORTHROP T-38 FINITE ELEMENT MODEL

PROTOTYPE - 36 DEGREES OF FREEDOM

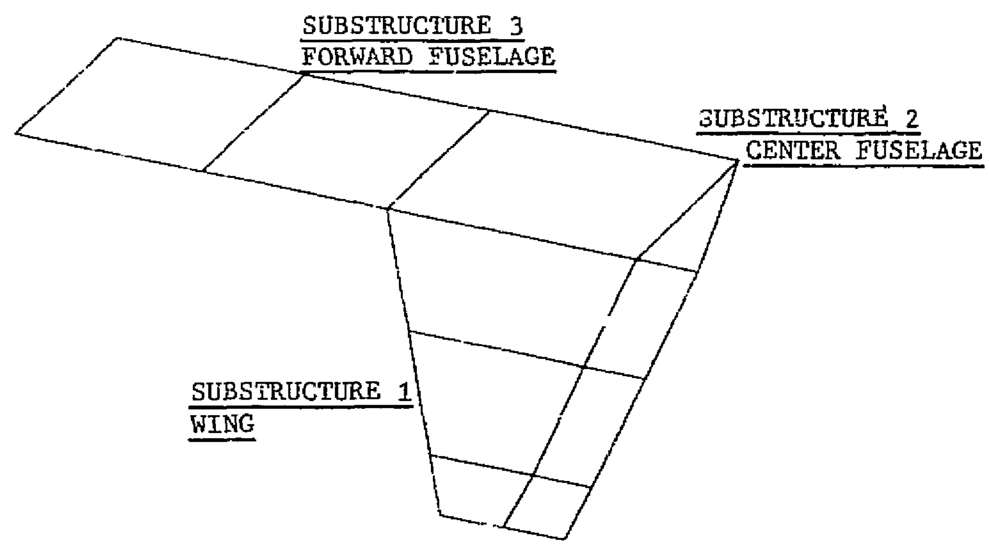

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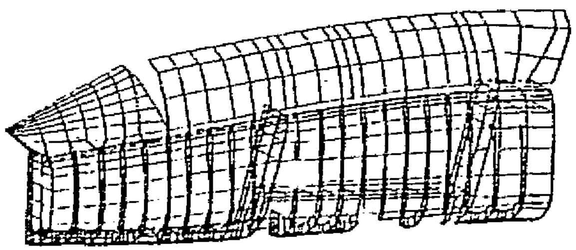
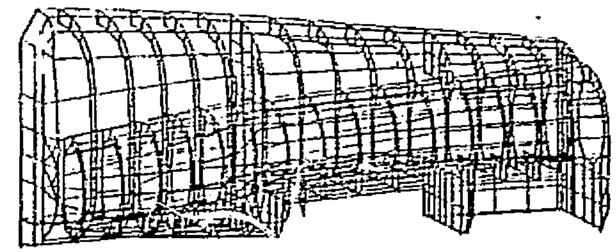
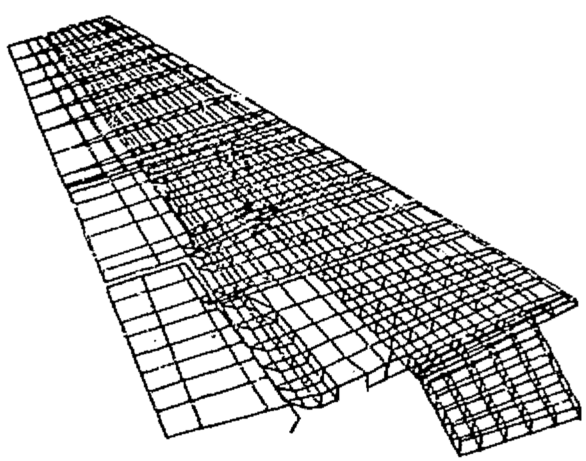
FIGURE 2 - NORTHROP T-38 FINITE ELEMENT MODEL
PRODUCTION MODEL - 9500 DEGREES OF FREEDOM



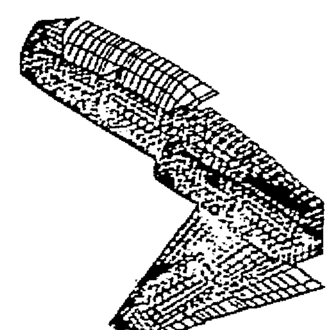
SUBSTRUCTURE 3
FORWARD FUSELAGE
(3000 dof)



SUBSTRUCTURE 2
CENTER FUSELAGE
(2500 dof)



SUBSTRUCTURE 1
WING
(4000 dof)



COMBINED STRUCTURE
(9500 dof)

FIGURE 3 - NASTRAN MODEL TEST SCHEDULE

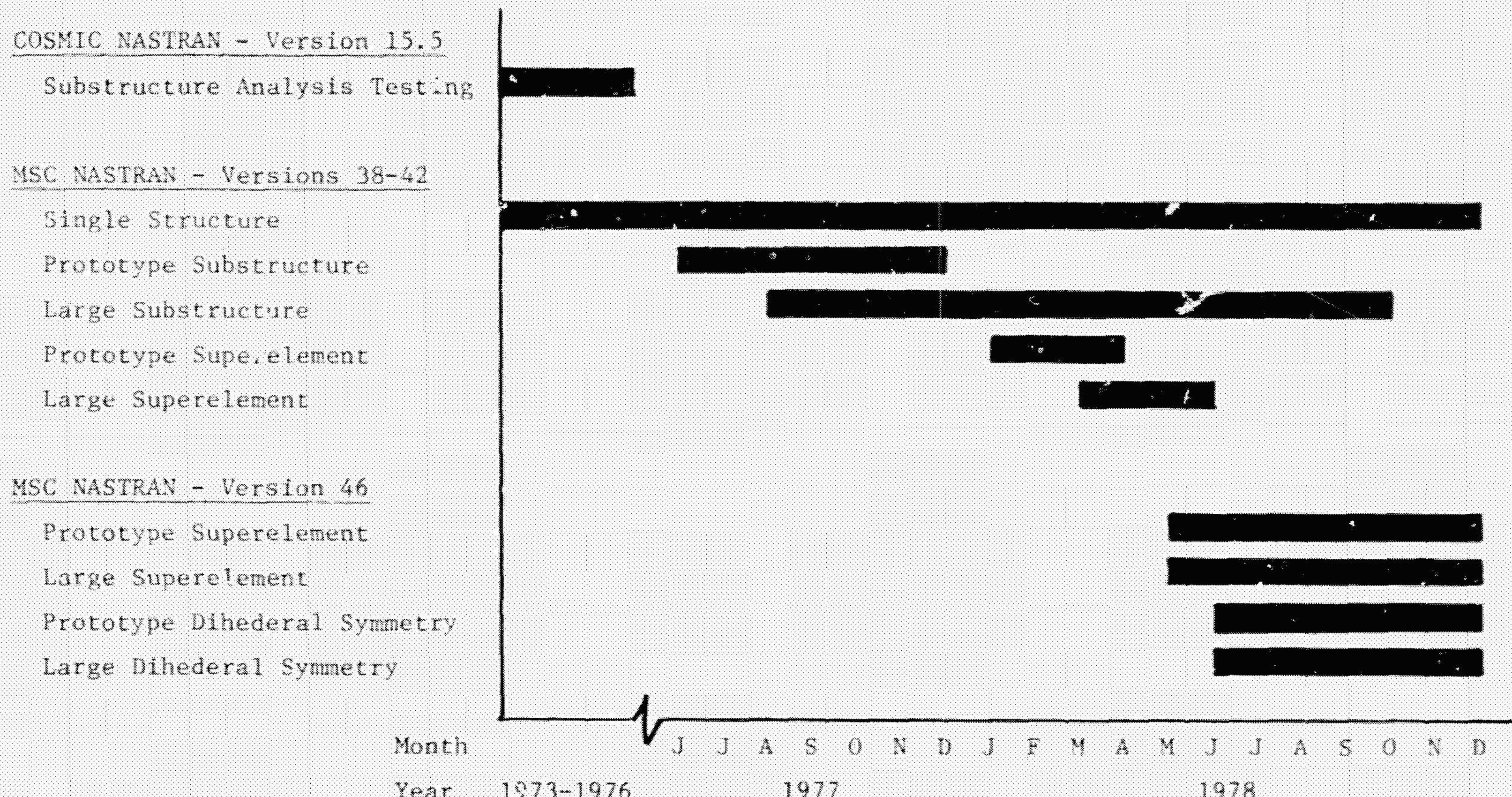


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FIGURE 4 - T-38 NASTRAN ANALYSIS USING FIVE DIFFERENT METHODS

9500 ANALYSIS DEGREES OF FREEDOM

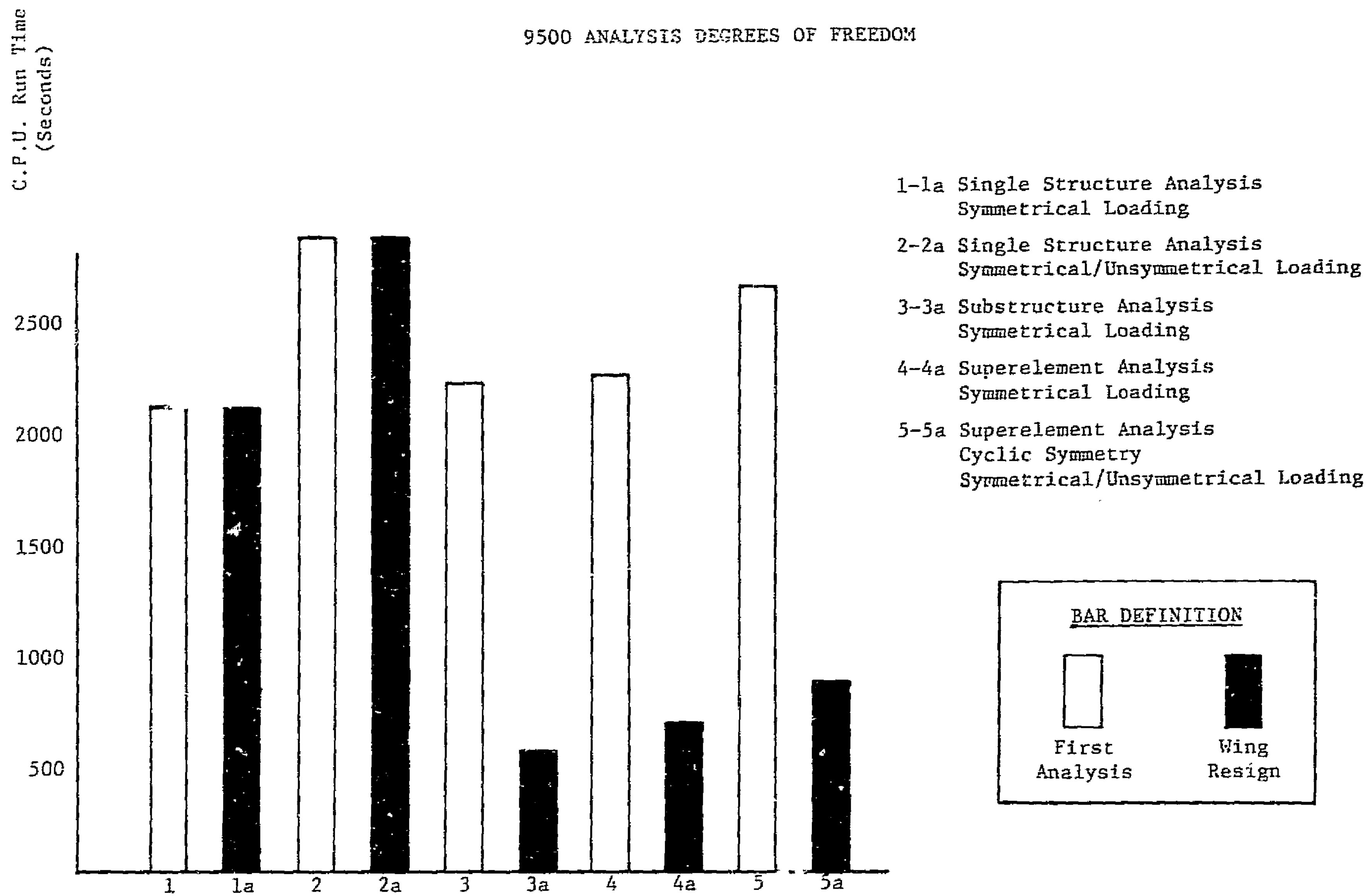

FIGURE 5 - COMPARISON OF NASTRAN COMPUTER RUNS FOR T-38

	1-1a	2-2a	3-3a		4-4a		5-5a	
	Single Structure (L.H. Side)	Single Structure (Both Sides)	Substructure (L.H. Side)		Superelement (L.H. Side)		Superelement Cyclic Symmetry (Both Sides)	
MATRIX SIZE	KAA	KAA	KAA	KOO	KAA	KOO	KAA	KOO
Substructure I	9575	9575	30	3944	30	3938	104	3914
II			156	2500	138	2497	606	2373
III			126	3031	114	3039	504	2899
Total Size			312	9475	282	9474	1214	9186
EMG (Sec.)								
Substructure I	281	296	33		35		33	
II			131		133		140	
III			129		130		138	
Total Time			293		298		311	
EMA (Sec.)								
Substructure I	90	90	39		40		34	
II			39		35		31	
III			26		24		26	
Total Time			104		99		91	
Decomp (Sec.)								
Substructure I	317	689	137		139		93	
II			86		85		51	
III			78		77		50	
Total Time			301		301		194	
FBS (Sec.)								
Substructure I			66		59		221	
II	--	--	152		129		283	
III			132		98		347	
Total Time			350		286		851	
Total Elapsed CPU (Sec.)	1588	2190	1682		1700		2025	
Redesign CPU (Sec.)	1588	2190	413		518		662	
Restart Storage	Tape	Tape	Tape		2470 Trks		3183 Trks	

Computer Used: IBM 370/168 - MVS

Disk Pack: 3330 - Mod. II

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