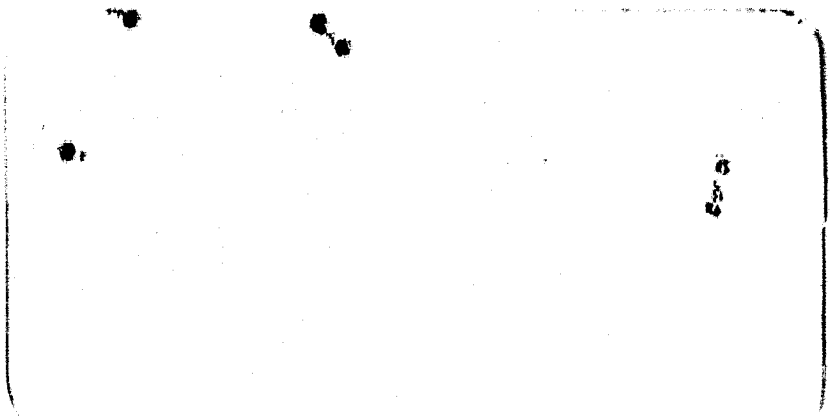

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ECONOMIC EVALUATION OF COMPUTERIZED STRUCTURAL ANALYSIS

Final Report

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Economic Evaluation of Computerized Structural Analysis

I. Introduction

This completed effort involved a technical and economic study of the capabilities of computer programs in the area of structural analysis. The applicability of the programs to NASA projects and to other users was studied. The applications in other industries was explored including both research and development and applied areas. The costs of several alternative analysis programs were compared.

A literature search for computer programs to do computerized structural analysis was completed. The literature search covered applicable technical literature including journals, trade publications and books.

In addition to the literature search, several commercial companies that have developed computerized structural analysis programs were contacted and their technical brochures reviewed.

II. Structural Analysis Discussion

A. Computer-Aided Engineering (CAE) can be defined as a group of computer based tools to help the engineer in doing his analysis. Preprocessors help in generating the structural model by accessing a data base for dimensional material, and loading information. Mesh generators layout the model details and the data file for the analysis program. When the analysis has been completed post-processors condense the results into an

interpretative format such as stress contours, modal shapes, and deformed geometry. The engineer, with these results, can refine the model or design and start another cycle in the analysis.

B. Structural Analysis Computation Kernels

The computational kernels in structural analysis are the solution of linear simultaneous equations, the extraction of eigenvalues and eigenvectors, and matrix multiplication. In static analysis, solution of equations is the majority of the computation. Whereas in dynamic analysis, the main kernel is the eigensolution. Matrix multiplication of small matrices is present in the element formulation and stress recovery.

Now we will present a summary of some of the available computer programs for doing structural analysis.

III. Structural Analysis Programs

A. SDRC I-DEAS

Discussions were held with General Electric CAE International Inc. on the SDRC I-DEAS program. Although the program is highly integrated relative to the state-of-the-art, it does not handle rotating structures except in very limited applications using the SYSTAN system analysis module. Although, they do not have a special purpose rotating structures package, they have done some limited in-house work on rotating machinery. Their system runs best on a large VAX and also can be run on Apollo and IBM machines. Their program SDRC costs about $170K plus $50K/year for support and enhancements. The program, however, does not provide the unique rotating structures emphasis that is available with STARS. The programs were developed by

Structural Dynamics Research Corporation and are marketed and distributed by GE CAE International Inc. There are 400 companies performing their experimental modal analysis with MODAL-Plus, and it appears to be the leading software program in the study of experimental modal analysis.

B. MSC/NASTRAN

Discussions were also held with Mac Neal-Schwendler Corporation on the MSC/NASTRAN program. Their program handles rotating structures. The program is extremely large with about 500,000 lines of FORTRAN source code. The program is only available on a lease basis. The cost is a function of the performance of the computer so the cost varies depending on whether it is run on a Cray-1, Apollo, or VAX 11780, for example. On a VAX 11780 the lease price is $1,800/month plus an initial fee of $3,000. This includes technical support and updates. The lessee gets the object executable version and not the source code. The program is batch. The agreement also applies to multiusers and is not restricted by the terminals.

C. SCADA

Another company contacted was American Computers and Engineers who distribute SCADA. This general purpose program will handle rotating structures. The program is sold and not leased. It is sold in the executable version only. For a VAX 11780, a large number of different modules are available. The total package cost is $12,700 and there is a minimum purchase of $7,000 for a VAX. This includes one year of upgrade and support at no extra cost. In order to obtain continuous updates of the programs, there is a 25% per year or 8% per quarter service

agreement which is a percent of the then current price of the software. This agreement entitles the user to receive all enhancements at no extra charge. If the service agreement is not taken, then future enhancements may be obtained at a negotiated price. Multiple licenses are available.

100% first CPU

30% second similar CPU

10% third similar CPU

The licenses are per CPU not per user. If one wants a license for a different version, like MSDOS for example, then the multiple license is 50%. There are about 200 users of the SCADA program.

To do rotating structures, requires the following modules MJEN, SCADA/A, SCADA/G, and SCADA/R.

D. SUPERSAP

SUPERSAP is supplied by Algor Interactive Systems, Inc. It has been used in a number of applications. The Harbor Branch Foundation which conducts oceanographic research for National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF) used SUPERSAP to design components of mini-submarines. Other users have had SUPERSAP help in the design of the world's largest inflatable form concrete dome; a telescopic camera that will go into geo-synchronous orbit on a weather satellite; and the first inflatable crown back-up roll system to be build in the United States.

SUPERSAP consists of

pre-processing - creating the analytical model

processing - analyzing the model

post processing - evaluating the results

It is available for all models of DEC VAX, Prime computers--50 series, NCR Tower 1632, Pixel computers--80 and 100 series, IBM PC/XT, and many UNIX computers with FORTRAN 77.

The program is also available via Algor's time-sharing service or as a turnkey system based on a Digital VAX or Pixel.

E. NISA/DISPLAY

Another large program is NISA/DISPLAY. NISA stands for Numerically Integrated Elements for Systems Analysis. This is a general purpose program for analyzing problems in civil, mechanical, offshore engineering environments, and in automotive and aerospace industries. NISA and all the pre-and post-processing programs have been implemented on the following mainframes:

Amdahl

Burroughs

CDC

Cray

Hitachi

Honeywell

IBM

Univac

Also implemented on the following mini computers:

Alpha-Micro

Apollo

Data General

Gould Sel

Harris

HP 1000

HP A600, A70, A900

HP 9000

Perkin Elmer

Prime

VAX

One can license the entire NIS A/D program or selected modules. The price is the same for 1 to 100 NISA installations on the same brand of computer system at one site. For each different computer system at one site, the only additional charge is the cost of an annual maintenance contract.

The price range to lease is $500-$2,000 per month. For a personal computer, the purchase cost is $1,000 to $5,000. And for a mini computer, it is $5,000 to $30,000. Finally, for a supermini and mainframe, the cost is $10,000 to $60,000. All prices are for unlimited use.

F. STAAD-III

STAAD-III stands for Structural Analysis And Design. This is a STRUDL-look-alike that accepts English commands in format-free input and can be run interactively or in batch.

STAAD-III is widely available on the following major time-sharing networks:

Cybernet Services

United Information Services (UIS)

University Computing Company (UCC)

Boeing Computer Service (BCS)

Martin Marietta Data Systems

Staad-III is also available to buy for in-house use. Currently it runs on

IBM 370, 43XX, 30XX

Prime 50-series

HP-1000

VAX 730, 750, 780

It is also available for some micro computers.

G. MICAS

MICAS stands for Mini Computer Analysis System. It is developed specifically for minicomputer use. It is "virtualized" and has a capacity limited only by available disk space. The program is interactive. The program is distributed by Rand Associates, Inc.

H. GTSTRUDL

GTSTRUDL stands for Georgia Tech STRUctural Design Language. It was originally developed in 1966-70 by MIT for IBM computers. Today is is one of the most widely used structural engineering computer programs. In 1975-77, GTSTRUDL was developed by Georgia Tech from the original IBM version of STRUDL. GTSTRUDL does general purpose structural analysis and design, as well as structural data base processing. It is used by governmental agencies, industrial organizations including A/E firms, construction firms, power industry firms, utilities, and manufacturing companies for example.

GTSTRUDL is available from Boeing Computer Services for the following computers:

IBM 30XX and 43XX

DEC VAX Family

Data General MV Family

GTSTRUDL is also available from Georgia Tech for the following computers:

DEC VAX

DG Eclipse MV/Family

CDC Cyber

GTSTRUDL is certified to be in full conformance with the United States Nuclear Regulatory Commission quality assurance software verification procedures.

This program is extremely powerful considering its small size. It's special features are:

interactive

user friendly

modularity

versatility

handles rotating structures

This program has many applications in such fields as aerospace, mechanical and civil engineering. To complete this summary of structural analysis programs, we will discuss STARS.

I. STARS

STARS stands for Structural Analysis RoutineS. It is an interactive, graphics oriented, finite-element computer program for analyzing the static, stability, free-vibration, and dynamic responses of damped and undamped structures, including rotating systems.

The original is written in FORTRAN for the VAX 11 computers.

The program now consists of about 12,000 programmed instructions. This program has the following features:

user friendly

data preparation is extremely simple

highly interactive

handles rotating structures

fast and accurate numerical schemes

IV. Summary and Recommendations

This report summarizes a short study to present an overview of the computerized structural analyses programs available today. Many other additional detailed features of these programs would be very helpful to NASA and other users. This additional information would help reduce costs, manpower, and scheduling delays for major structural analysis projects. It is recommended that this work be expanded in the future so that these economic benefits would be fully realized.