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PROGRESS REPORT ON THE "AUTOMATED STRENGTH-AEROELASTIC DESIGN OF AEROSPACE STRUCTURES" PROGRAM

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INTRODUCTION

This paper describes an ongoing program whose goal is to develop an automated procedure that can assist in the preliminary design of aircraft and space structures. As Figure 1 indicates, the program is sponsored by the Air Force Wright Aeronautical Laboratories with Northrop Corporation, Aircraft Division, as the prime contractor and Universal Analytics, Inc., a subcontractor.

The paper is entitled a "Progress Report" because it reports on an ongoing effort. The presentation will be limited to a discussion of the approach and capabilities that are to be included in the final procedures. An exception is that the Executive System is defined and tested to an extent sufficient to permit specific results to be included in the presentation.

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PERFORMANCE PERIOD:	JULY 1983 - MARCH 1988

Figure 1

MOTIVATION

The motivation for this program comes from a number of sources (Figure 2). First, there is a need for a procedure of this type that integrates the disciplines which drive structural design concepts with powerful optimization techniques. Existing procedures that approach this capability are deficient in their analysis techniques and their optimization methods and/or are not in the public domain. Additional motivating factors are to exploit the rapid advances that have been made in automated design algorithms, computer hardware and computer software. For instance, in the automated design area, recent research has shown the similarity of optimum criterion methods and mathematical programming approaches and has shown how approximate analyses can replace most of the detailed analyses formerly required in a design task (Ref. 1). It is hardly necessary to mention the revolutionary progress being made in computer hardware and, with modern data base concepts and structured programming, in software techniques.

- EXISTING PROCEDURES ARE CONSIDERED OUTDATED AND INADEQUATE
- IMPROVED UNDERSTANDING OF AUTOMATED DESIGN
- IMPROVED HARDWARE
- IMPROVED DATA HANDLING
- IMPROVED LANGUAGE - FORTRAN 77

Figure 2

REQUIREMENTS

In developing the procedure, a number of basic requirements must be kept in mind (Figure 3). For instance, for the program to be useful, it must include analysis techniques from the technical disciplines that impact the preliminary design of aerospace structures. The procedure must also be efficient in its use of computer resources in order that its stated capabilities be affordable. It must also be recognized that a large array of related analysis procedures already exists in the environment this new procedure will enter. This program should, to the extent practicable, be compatible with these existing procedures. Finally, difficulties associated with the introduction of a new procedure must be minimized by providing well written and ample documentation.

- INTERDISCIPLINARY
- EFFICIENT
- COMPATIBLE
- UNDERSTANDABLE

Figure 3

PROGRAM TASKS

The program is divided into six interrelated tasks (Figure 4). In the recently completed Design System Definition task, architecture of the procedure was defined and basic design issues were resolved. The current effort is focused on the development of the unique executive system and data base manager that will be used. The Module Development task, which is also under way, will integrate the engineering analysis techniques into the procedure. A "Pilot System," which will contain the key features of the final system, will be delivered in late 1985. Design studies will refine the procedure and apply it to practical design problems drawn from ongoing development activities. Under the User Guidelines task, comprehensive documentation of the procedure's structure, capabilities and input requirements will be developed. Results from applying the procedure and recommendations for its use will also be given.

PHASE	
I	DESIGN SYSTEM DEFINITION
II	EXECUTIVE/DATA BASE CODING
III	MODULE DEVELOPMENT
IV	PILOT SYSTEM
V	DESIGN STUDIES
VI	USER GUIDELINES

Figure 4

SYSTEM ARCHITECTURE

The basic components of the system are identified in Figure 5. The Executive System is the heart of the software and directs program execution, data base control and system input and output. A new programming language entitled MAPOL (Matrix Analysis Problem Oriented Language) has been developed to drive the procedure. The Data Base System is a combination of a relational data base system (Ref. 2) which handles basic engineering data and a separate matrix handler to efficiently store and retrieve the matrix information using sophisticated packed formats. The functional modules perform the engineering tasks and are literally modularized for ease of program enhancement and modification. A utilities library will contain all basic matrix manipulation procedures and assorted miscellaneous operations such as search and sort routines. This will serve to eliminate redundant coding and help ensure its reliability.

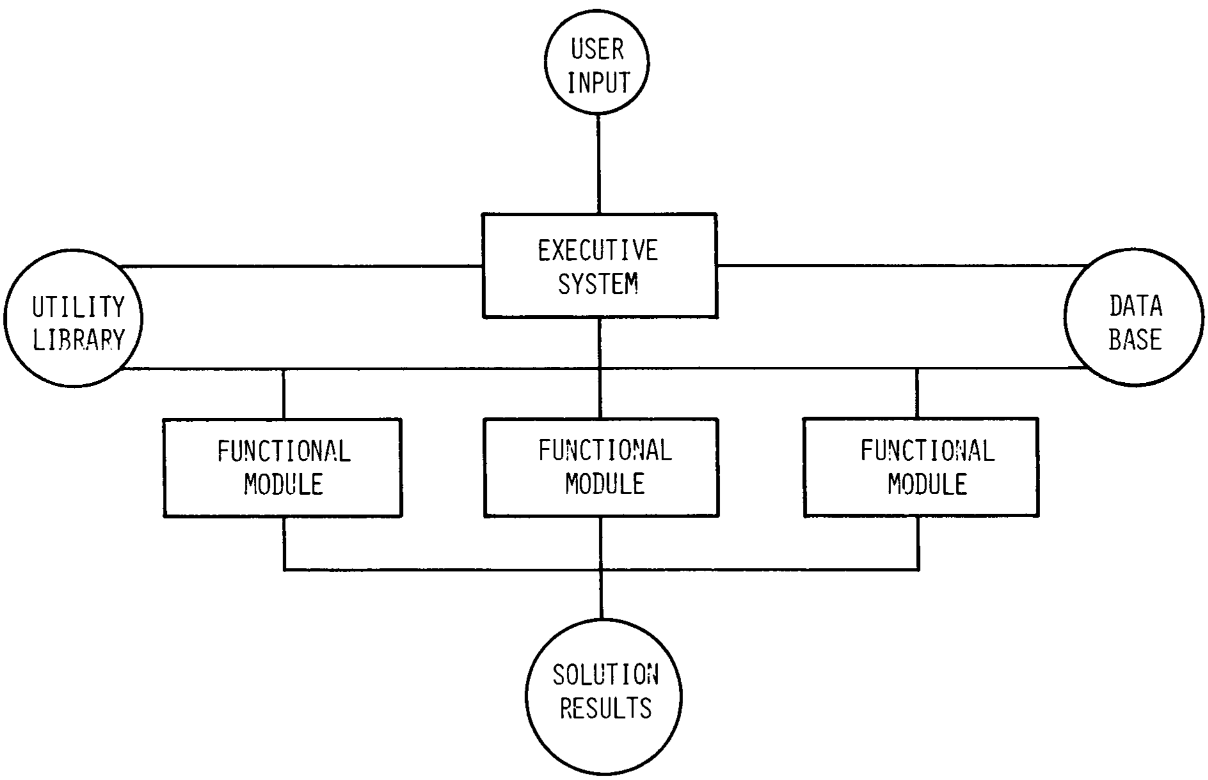

Figure 5

EXECUTIVE SYSTEM

The Executive System is the heart of the software and performs four primary functions, as shown in Figure 6. Module sequence control is facilitated by a problem-oriented language called MAPOL. The actual execution of modules within the system will be performed by a "pseudo-machine," similar to the execution monitor concept of NASTRAN. This model is extremely flexible and powerful. Data management is a critical part of a large-scale analysis system both in terms of function and performance. The need to locally modify data while performing design optimization is ideally addressed by a relational data base system such as the RIM (Ref. 3) system. However, the need for the efficient manipulation of very large matrices requires that sophisticated packed formats, along with appropriate algorithms, be available. Therefore, the concept of a "partitioned data base" has been defined to satisfy both needs. The User-Interface includes simple, easy-to-use input data entry. Accurate, informative and user-friendly messages will be issued by the software instead of the often obscure programmer-oriented jargon often encountered. Solution results will be user-selectable and will be printed in a clear, easy to read manner. The allocation of computer resources and interfaces with the operating system of the procedure's host computer are also handled by the executive.

- MODULE SEQUENCE CONTROL
- DATA MANAGEMENT CONTROL
- USER-INTERFACE CONTROL
- COMPUTER RESOURCE ALLOCATION

Figure 6

THE MAPOL LANGUAGE

The execution of the procedure is directed by a sophisticated control language which can be most readily described as being an updating of the DMAP language used in NASTRAN (Ref. 4). Figure 7 provides a list of features of the language. The language recognizes scalars, vectors, matrices and relations and has a number of intrinsic procedures to deal with each. A user can also construct special purpose procedures and structured programming features such as IF-THEN-ELSE, DO-WHILE and DO-UNTIL are available. With these features, the user has considerable flexibility and power in directing the sequence of the program's execution. The language also simplifies the coding task by substituting the higher level capability of MAPOL for detailed FORTRAN programming.

- SPECIAL DATA TYPES FOR MATRICES AND RELATIONS
- PERMITS USER WRITTEN PROCEDURES
- CONTAINS STRUCTURED PROGRAMMING FEATURES
- INCLUDES A UTILITY LIBRARY
- CAN OPERATE DIRECTLY ON THE DATA BASE

Figure 7

MAPOL EXAMPLE

Figure 8 provides a simple application of the MAPOL language in order to clearly illustrate some of its features. The program reads in three matrices and operates on them in one of three different ways depending on whether the parameter ALPHA is negative, zero or positive. The input matrices are printed after they are input while the output matrix and two scalar parameters are printed at the completion of the task.

```
PROGRAM MATRIX
MATRIX A, B, C, X;
REAL ALPHA, BETA;
CALL INPUT;
CALL PRINT (A, B, C);
IF (ALPHA < Ø) THEN
    X : = A * B + C;
ELSE
    IF (ALPHA = Ø) THEN
        X : = TRANS (BETA * A + B);
    ELSE
        X : = A * A * INV (C);
    ENDIF
ENDIF
CALL PRINT (ALPHA, BETA, X);
END;
```

Figure 8

ENGINEERING MODULES

The scope of the engineering capabilities of the procedure is indicated by Figure 9, which lists the six distinct disciplines that are to be included to provide comprehensive preliminary design. In most cases, proven engineering software can serve as a resource for the various technologies. Candidate engineering analysis tools include NASTRAN, USSAERO (Ref. 5), Doublet Lattice (Ref. 6), and ADS (Ref. 7). The sensitivity module, which will provide gradient information, requires significant new coding while the other modules will be significantly altered to interact with the data base and the utilities library. The controls response analysis module is included in recognition of the increasingly important interactions between the control system and the structural response in the design of aerospace structures.

- STRUCTURAL ANALYSIS
- AERODYNAMIC LOADS
- AEROELASTIC STABILITY
- SENSITIVITY ANALYSIS
- OPTIMIZATION TECHNIQUES
- CONTROL RESPONSE ANALYSIS

Figure 9

MILESTONES

An indication of the scope of the project is given in Figure 10. The entire project is slated to last for almost five years. As the figure indicates, much of this time is to be spent in testing and debugging the procedure, the rationale being that the eventual success of the procedure rests heavily on making it as reliable and fully tested as practicable. Other milestones include the recently completed design of the system architecture and the implementation of this architecture by early next year. A pilot system, which will incorporate the major design capabilities of the procedure, will be delivered in early 1986. The final system delivery is scheduled for September 1987 with a training workshop for interested government and industry personnel slated for early 1988.

PROGRAM GO-AHEAD	JULY 1983
SYSTEM ARCHITECTURE DESIGNED	JANUARY 1984
DATABASE AND EXECUTIVE SYSTEM CODED	JANUARY 1985
PILOT SYSTEM DELIVERY	JANUARY 1986
FINAL SYSTEM DELIVERY	SEPTEMBER 1987
TRAINING WORKSHOP	JANUARY 1988

Figure 10

CONCLUSIONS

Because this presentation is a progress report, it is not possible to present conclusions in the usual sense. Instead, some summarizing comments on how the various attributes of the system will meet the goals set for the project will be offered. Firstly, by using proven engineering software as a basis for the project, a reliable and interdisciplinary procedure will be developed. The use of a control language for module sequencing and execution permits efficient development of the procedure and gives the user significant flexibility in altering or enhancing the procedure. The data base system will provide reliable and efficient access to the large amounts of interrelated data required in an enterprise of this sort. In addition, the data base will allow interfacing with existing pre- and post-processors in an almost trivial manner. Altogether, the procedure promises to be of considerable utility to preliminary structural design teams.

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