STRUCTURES DIVISION
STRUCTURAL MECHANICS BRANCH

COMPUTATIONAL STRUCTURAL MECHANICS
ENGINE STRUCTURES COMPUTATIONAL SIMULATOR

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NASA WORKSHOP ON COMPUTATIONAL STRUCTURAL MECHANICS
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COMPUTATIONAL STRUCTURAL MECHANICS
FOR ENGINE STRUCTURES

0 Investigate Unique Advantages of Parallel and Multi
Processors For:

- Reformulating/Solving Structural Mechanics
- Formulating/Solving Multidisciplinary Mechanics

0 Develop "Integrated" Structural System Computational
Simulators For:

- Predicting Structural Performance
- Evaluating Newly Developed Methods
- Identifying/Prioritizing Improved/Missing
  Methods Needed
THE COMPUTATIONAL STRUCTURAL MECHANICS (CSM) PROGRAM AT LEWIS ENCOMPASSES
(1) FUNDAMENTAL ASPECTS FOR FORMULATING AND SOLVING STRUCTURAL MECHANICS PROBLEMS
AND (2) DEVELOPMENT OF INTEGRATED SOFTWARE SYSTEMS TO COMPUTATIONALLY SIMULATE THE
PERFORMANCE/DURABILITY/LIFE OF ENGINE STRUCTURES.
COMPUTATIONAL STRUCTURAL MECHANICS

**FY 86**
- High Temperature Structures
- Rotating System Dynamics
- Advanced Computer Technology

**FY 88**
- Computational Testbed
- Integrated Engine Structural Analysis

**FY 90-92**
- Engine Structures Performance/Integrity Simulator (ESPIS)
- Highly Parallelized Analysis
- Full Engine Structural Mission Analysis

**KEY PROGRAM ELEMENTS**
- Structural Analysis Methods
- Advanced Computer Technology
- Computational Testbed/ESCS
THE GENERAL CONTENT OF THE CSM LEWIS PROGRAM PLAN IS SUMMARIZED IN THE ACCOMPANYING BLOCK DIAGRAM. THE LONG-RANGE OBJECTIVE OF THE PROGRAM IS THE FULL ENGINE STRUCTURAL SIMULATION.
COMPUTATIONAL STRUCTURAL MECHANICS

IDENTIFIED METHODOLOGY - IMPROVED/MISSING

- BOUNDARY ELEMENTS FOR 3-D INELASTIC ANALYSIS
- BOUNDARY ELEMENTS FOR HOT FLUID/STRUCTURE INTERACTION
- EFFICIENT HYBRID ELEMENTS
- ADAPTIVE TRANSITIONAL FINITE ELEMENTS
- COMPUTATIONAL COMPOSITE MECHANICS
- COMPUTATIONAL CONTACT MECHANICS
- COUPLE COMPUTATIONAL SIMULATION WITH OPTIMIZATION
AN IMPORTANT PART OF THE CSM FOR ENGINE STRUCTURES PROGRAM IS THE IDENTIFICATION OF METHODOLOGY WHICH NEEDS IMPROVEMENT AND/OR IS MISSING. THIS METHODOLOGY INCLUDES SEVERAL KEY ELEMENTS AS LISTED IN THE ACCOMPANYING CHART.
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COMPUTATIONAL STRUCTURAL MECHANICS
IDENTIFIED METHODOLOGY - ALTERNATE

0 PROBABILISTIC/STOCHASTIC:
  - VARIATIONAL PRINCIPLES FOR PROBABILISTIC FINITE ELEMENT
  - PROBABILISTIC STRUCTURAL ANALYSIS METHODS
  - PROBABILISTIC FRACTURE MECHANICS

0 ALTERNATE FORMULATIONS:
  - MULTI-PARALLEL PROCESSORS FOR MULTI-DISCIPLINE MECHANICS PROBLEMS
  - SPECIALTY FUNCTIONS FOR SINGULAR MECHANICS PROBLEMS
  - COUPLED CONSTITUTIVE RELATIONSHIPS
  - DEDICATED EXPERT SYSTEMS
ANOTHER IMPORTANT PART OF THE CSM PROGRAM IS TO IDENTIFY ALTERNATE METHODOLOGY FOR COMPUTATIONAL SIMULATION SUCH AS (1) PROBABILISTIC FOR QUANTIFYING THE ACERTAINTIES WITH ALL VARIABLES/PARAMETERS OF STRUCTURAL ANALYSIS/DESIGN AND (2) ALTERNATE METHODS/APPROACHES FOR FORMULATING STRUCTURAL MECHANICS PROBLEMS.
A MAJOR PART OF THE LEWIS CSM PROGRAM IS THE DEVELOPMENT OF ENGINE STRUCTURES
COMPUTATIONAL SIMULATOR (ESCS). ESCS INTEGRATES DISCIPLINE SPECIFIC METHODOLOGY
AND COMPUTER CODES DEVELOPED UNDER RESEARCH AND TECHNOLOGY PROGRAMS.
SIMULATOR ARCHITECTURE OF THE SOFTWARE SYSTEM

INTERFACES
- FEM TRANSLATOR
- COSMO TRANSLATOR
- ESMOSS TRANSLATOR

LOADING MODULE
- COSMO

MODELING MODULE
- ESMOSS
- CSM PLOT
- GRAPH3D

STRUCTURAL ANALYSIS MODULE
- 3-D INELASTIC ANAL**
- NA-TRAN
- MHOST
- STAEBL
- BEST3D

USER → EXPERT SYSTEM ** → EXECUTIVE MODULE (REXX) * → COMM INT. LINK

DEDICATED DATABASE MANAGEMENT MODULE
- (REXX/PORTRAN)

DEDICATED DATABASE STRUCTURE

PERM RECORDS *
- AEROGEOMETRY
- DISCRETE GEOMETRY
- MATERIAL PROPERTIES
- TEMPERATURES
- PRESSURES
- OTHER THERMAL PARAMETERS
- COMBUSTOR LAYER GEO FILE
- TURBINE BLADE G10 FILE
- DEFAULT MISSION FILES
- MISC (MISSION CRAY JCL )

TEMP RECORDS *
- GEOMETRY-%
- GEOMETRY-DISCRETE
- MISSION MATERIAL PROPERTIES
- MISSION TEMPERATURES
- MISSION PRESSURES
- OTHER THERMAL PARAMETERS
- DEFAULT MISSION FILES
- OPERATING SYSTEM UTILITY FILES
- MISC (MISSION CRAY JCL )

ARCHIVE **

* - PRELIMINARY VERSION AVAILABLE
** - TO BE INSTALLED

OF POOR QUALITY
ESCS is modular with an expert system driven executive module. It includes interfacing modules, a database and its manager. A schematic of the ESCS present status configuration is shown in the accompanying chart.
ESCS IS CONFIGURED TO COMPUTATIONALLY SIMULATE THE STRUCTURAL PERFORMANCE OF ENGINE STRUCTURES: (1) SUBCOMPONENTS, (2) COMPONENTS, (3) SUBASSEMBLIES, (4) ASSEMBLIES AND (5) INTEGRATED SYSTEMS FOR MISSION SPECIFIED REQUIREMENTS.
THE LOADS ON THE BLADES (TEMPERATURES, PressURES AND RotATING SPEEDS) ARE
determined by an engine loads module (COSMO in the ESCS schematic). THIS MODULE IS
based on engine thermodynamics. THE TEMPERATURES AND PressURES ARE PREDICTED ON
the surface at user selected span stations. THE ACCOMPANYING CHART IS A TYPICAL
example for temperatures. THE BLADE HAS BEEN UNFOLDED FOR 3-D PLOTTING
PRESENTATION.
NASPAT 1.7
TEMPERATURE AND PRESSURE LOAD FROM COSMO
MISSION TIME INC = 0.13 + 01 SUBCASE 1
THE PRESSURE IS SIMILARLY REPRESENTED IN A 3-D PLOT.
THE STRUCTURAL RESPONSE CAN BE PREDICTED THROUGHOUT THE MISSION. REPRESENTATIVE RESULTS FOR BLADE-TIP RADIAL DISPLACEMENT ARE SHOWN GRAPHICALLY AT IDENTIFIABLE STAGES DURING THE FLIGHT.
MIDOST AS A MODULE IN THE ENGINE STRUCTURES COMPUTATIONAL SIMULATOR (CSM)

(RADIAL DISPLACEMENT OF LEADING EDGE TIP UNDER PRESSURE AND THERMAL LOADING)

1 - Engine Start
2, 3 - Ground Idle
4, 5 - Take Off
6-9 - Climb
10, 11 - Cruise
12-15 - Descend
16 - Approach
17 - Land
18, 19 - Flight Idle
20, 21 - Thrust Reverse
22, 23 - Ground Idle
24 - Engine Turn-Off

RADIAL DISPLACEMENT (Inch)

ELAPSED FLIGHT TIME (sec)
The long range objective of the ESCS is to provide a computational simulation that parallels and replaces, in part, the current development methods which make extensive use of experimental procedures.
POTENTIAL BENEFITS TO AEROSPACE INDUSTRY

- Reduced development time and costs
- Fewer development engine builds
- Longer life components
- Reduced life cycle costs on components
- Reduced component and engine weight
- Improved engineering productivity
- Increased performance
THE ANTICIPATED BENEFITS OF ECS ARE SUMMARIZED, QUALITATIVELY, IN THE LAST CHART.