COMPUTATIONAL STRUCTURAL MECHANICS
FOR ENGINE STRUCTURES

1. Investigate Unique Advantages of Parallel and Multi Processors For:
   - Reformulating/Solving Structural Mechanics
   - Formulating/Solving Multidisciplinary Mechanics

2. 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
- LIFE PRED., STRUCT. INTEGRITY COMPOSITE MECH., CONTACT MECH., ETC.

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.
STRUCTURES DIVISION
STRUCTURAL MECHANICS BRANCH

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.
ENGINE STRUCTURES COMPUTATIONAL SIMULATOR (ESCS)

ESMOS S
GEOMETRIC MODELS
DYNAMIC REMESHING
I/O EXPEDITERS

3D TITAN
THERMAL LOADS

COSMO
COMPLEX STRUCTURES
GLOBAL ASSEMBLERS/SOLVERS
GLOBAL CONVERGENCE
CRITICAL LOCATION
DATA RECOVERERS

ESCS
NEW FINITE ELEMENTS
NONLINEAR CONSTITUTIVE RELATIONSHIPS
MATHEMATICAL MODELS
DEDICATED ALGORITHMS
LOCAL CONVERGENCE

TRIM

STAT
GEOMETRIC NONLINEARITIES
AERO LOADS
TAILORING ALGORITHMS
ACOUSTICS
Flutter

STAEBL
OPTIMIZERS
GRADIENT EVALUATORS
CONTRAIN GENERATORS
SUB-OPTIMIZERS
IMPACT MODULES
FORCED VIBRATION MODULES

DURABILITY
INTEGRITY
STABILITY
PERFORMANCE
ECONOMY
RETIRED FOR CAUSE
DISTORTION CONTROL
INSPECTION INTERVAL

QUALITY OF POOR QUALITY
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.
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.
ENGINE STRUCTURES COMPUTATIONAL SIMULATOR

ENGINE

FINITE ELEMENT MODEL

BLADE

ROTOR SECTOR

ROTOR STAGE
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.
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.
MINOST 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

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

0 REDUCED DEVELOPMENT TIME AND COSTS
0 FEWER DEVELOPMENT ENGINE BUILDS
0 LONGER LIFE COMPONENTS
0 REDUCED LIFE CYCLE COSTS ON COMPONENTS
0 REDUCED COMPONENT AND ENGINE WEIGHT
0 IMPROVED ENGINEERING PRODUCTIVITY
0 INCREASED PERFORMANCE