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COMPONENT SPECIFIC MODELING

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The overall objective of this program was to develop and verify a series of interdisciplinary modeling and analysis techniques specialized to address hot section components. These techniques incorporate data as well as theoretical methods from many diverse areas including cycle and performance analysis, heat transfer analysis, linear and nonlinear stress analysis, and mission analysis. Building on the proven techniques already available in these fields, the new methods developed through this contract were integrated into a system which provides an accurate, efficient, and unified approach to analyzing hot section structures. The methods developed under this contract predict temperatures, deformation, stress and strain histories throughout a complete flight mission.

The Component Specific Modeling program is shown in Figure 1. Nine separate tasks were performed in two parallel activities. The component specific thermomechanical load mission modeling activities are shown in Figure 2. The products of these activities were the develoOment of computer simulation models for the engine mission cycle, the engine thermodynamic performance, and the component thermal prediction. The Component Specific Structural Modeling activities are shown in Figure 3. The product of these activities were the development of a computer system controlled through an executing module which directs the work of the component specific thermomechanical load mission modeling software, the component geometric modeling software, and the component structural analysis software to perform a component specific nonlinear analysis.

The results of this program have exceeded original expectations. As a productivity enhancer, this system has demonstrated the ability to compress the time span of a hot section component mission analysis from months to less than a day. Along with this time compression comes increased accuracy from the advanced modeling and analysis techniques. As a result of this, more analytical design studies can be performed, reducing the chances for field surprises and the amount of component testing required.

THERMODYNAMIC AND THERMOMECHANICAL MODELS

The Thermodynamic Engine Model (TDEM) is the subsystem of computer software which translates a list of mission flight points and delta times into time profiles of major engine performance parameters. Its present data base contains CF6-50C2 engine performance data. In order to adapt this system to a different engine requires only the restocking of this data base with the appropriate engine performance data.

The Thermodynamic Loads Model (TDLM) is the subsystem of computer software which works with the output of the TDEM to produce the mission cycle loading on the individual hot section components. There are separate segments for the combustor, the turbine blade, and the turbine vane. These segments translate the major engine performance parameter profiles from the TDEM into profiles of the local thermodynamic loads (pressures, temperatures, RPM) for each component. The formulas which perform this mapping in the TDLM models were developed for the specific engine components. To adapt these models to a different engine would require evaluating these formulas for their simulation capability and making any necessary changes.

COMPONENT SPECIFIC STRUCTURAL MODELING

The heart of the Component Specific Structural Modeling is geometric modeling and mesh generation using the recipe concept. This idea has proved its worth as a productivity enhancer. A generic geometry pattern is determined for each component. A recipe is developed for this basic geometry in terms of point coordinates, lengths, thicknesses, angles, and radii. These recipe parameters are encoded in computer software as variable input parameters. A set of default numerical values are stored for these parameters. The user need only input values for those parameters which are to have different values. These recipe parameters then uniquely define a generic component with the defined dimensions. The software logic then works with these parameters to develop a finite element model of this geometry consisting of 20-noded isoparametric elements. The user specifies the number and distribution of these elements through input control parameters. Figure 4 shows the generic geometry and recipe for a combustor liner panel.

The subsystem which performs the three-dimensional nonlinear finite element analysis of the hot section component model was that developed in the NASA HOST program, "3D Inelastic Analysis Methods for Hot Section Structures." This software performs incremental nonlinear finite element analysis of complex 3D structures under cyclic thermomechanical loading with temperature dependent material properties and material response behavior. The nonlinear analysis considers both time independent and time dependent material behavior. Among the constitutive models available is the Haisler-Allen classical model which performs plasticity analysis with isotropic material response, kinematic material response, or a combination of isotropic and kinematic material response. This is combined with a classical creep analysis formulation. A major advance in the ability to perform time-dependent analyses is a dynamic time incrementing strategy incorporated in this software.

COSMO SYSTEM

The COSMO system consists of an executive module which controls the TDEM, TDLM, the geometric modeler, the structural analysis code, the file structure/data base, and certain ancillary modules. These ancillary modules consist of a bandwidth optimizer module, a deck generation module, a remeshing/mesh refinement module and a postprocessing module. The executive directs the running of each module, controls the flow of data among modules and contains the self-adaptive control logic. Figure 5 is a flow chart of the COSMO system showing the data flow and the action positions of the adaptive controls. The modular design of the system allows each subsystem to be viewed as a plug-in module. They can be abstracted and run alone or replaces with alternate systems.

CONCLUSIONS

The ideas, techniques, and computer software developed in the Component Specific Modeling Program have proven to be extremely valuable in advancing the productivity and design-analysis capability for hot section structures. This software in conjunction with modern supercomputers is able to reduce a design task which previously required man-months of effort over a time period of months to a one man, less than a day effort. The ideas are amenable to further generalization/specialization and extension to all areas of the engine structure. These techniques will have their major payoff in the next generation of aerospace propulsion systems with their increasingly larger number of parametric variations.

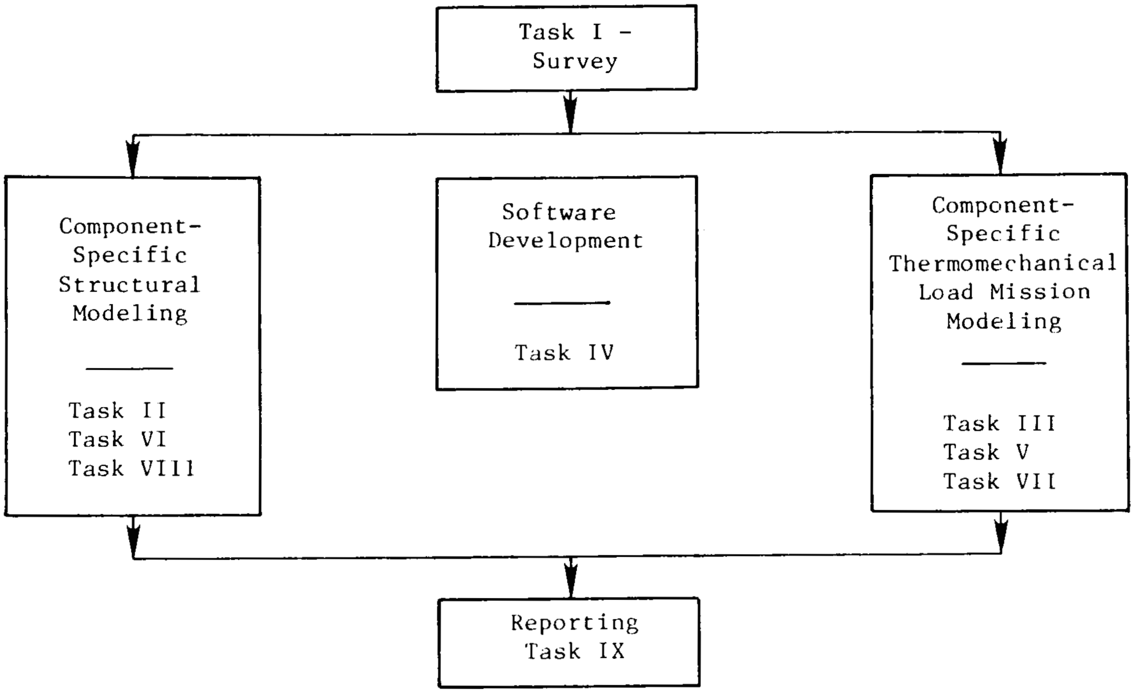


Figure 1. Component Specific Modeling Base Program.

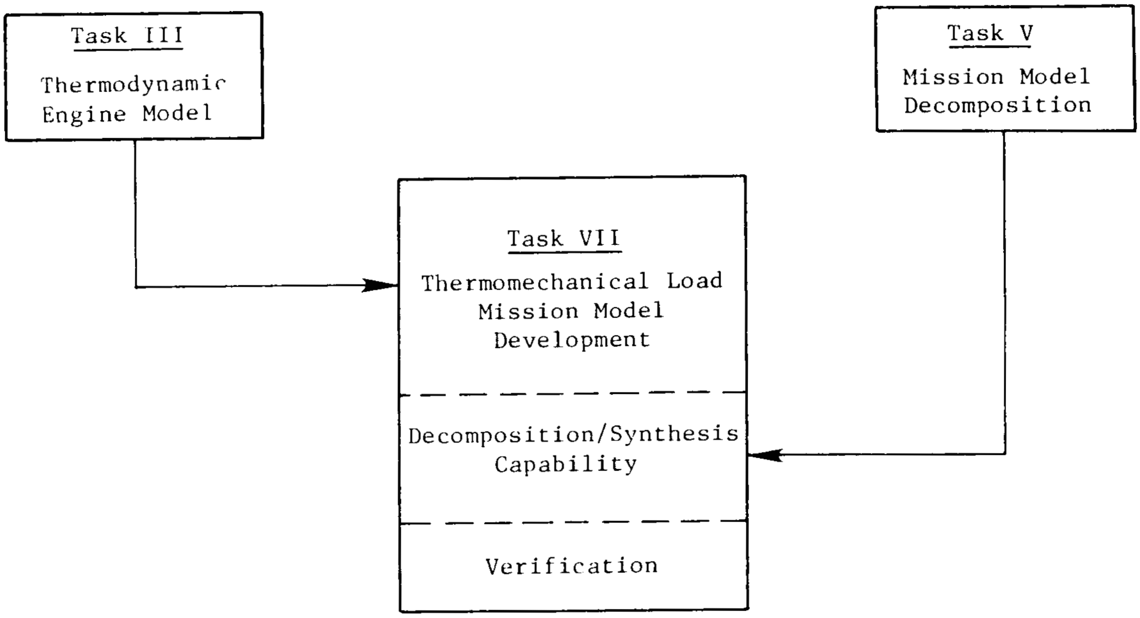


Figure 2. Component Specific Thermomechanical Load Mission Modeling.

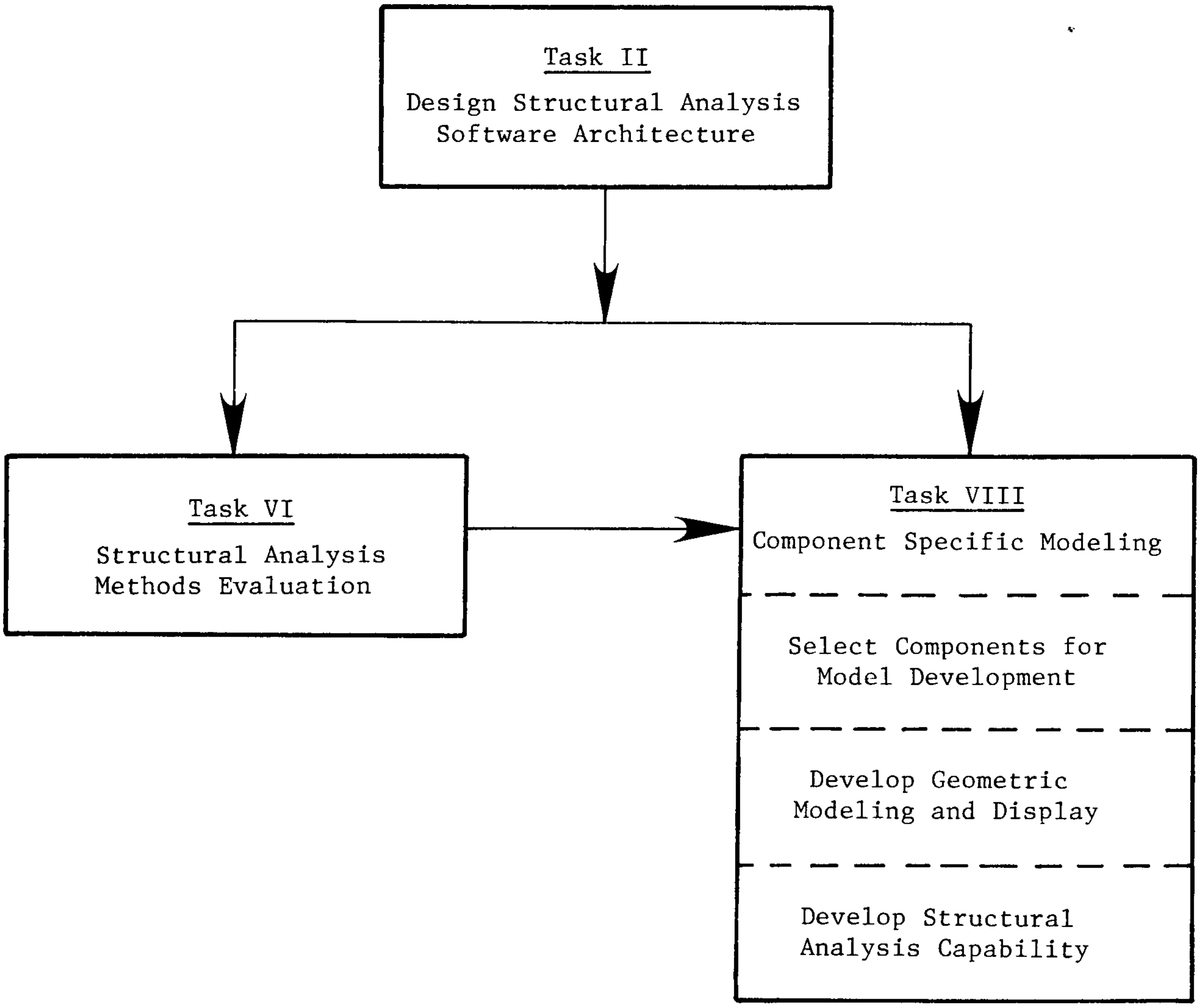


Figure 3. Component Specific Structural Modeling.

Combustor Liner Parameter List

Code	Name	Default	Code	Name	Default
1	X_1	0.0	2	Y_1	0.0
3	α_1	0.0	4	L_1	10.5
5	L_2	2.0	6	L_3	0.5
7	L_4	6.0	8	L_5	0.8
9	L_6	1.0	10	L_7	2.0
11	T_1	0.5	12	T_2	0.7
13	T_3	0.5	14	T_4	0.65
15	T_5	0.5	16	θ_1	90.0
17	θ_2	90.0	18	R_1	1.0
19	R_2	1.0	20	R_3	0.75
21	R_4	1.5	22	R_5	1.5
23	R_6	1.5			

X = Coordinate
Y = Coordinate
α = Angle wrt, x - Axis
L = Length
T = Thickness
θ = Angle of Rotation
R = Radius of Curvature
(n)= Parameter Code Number

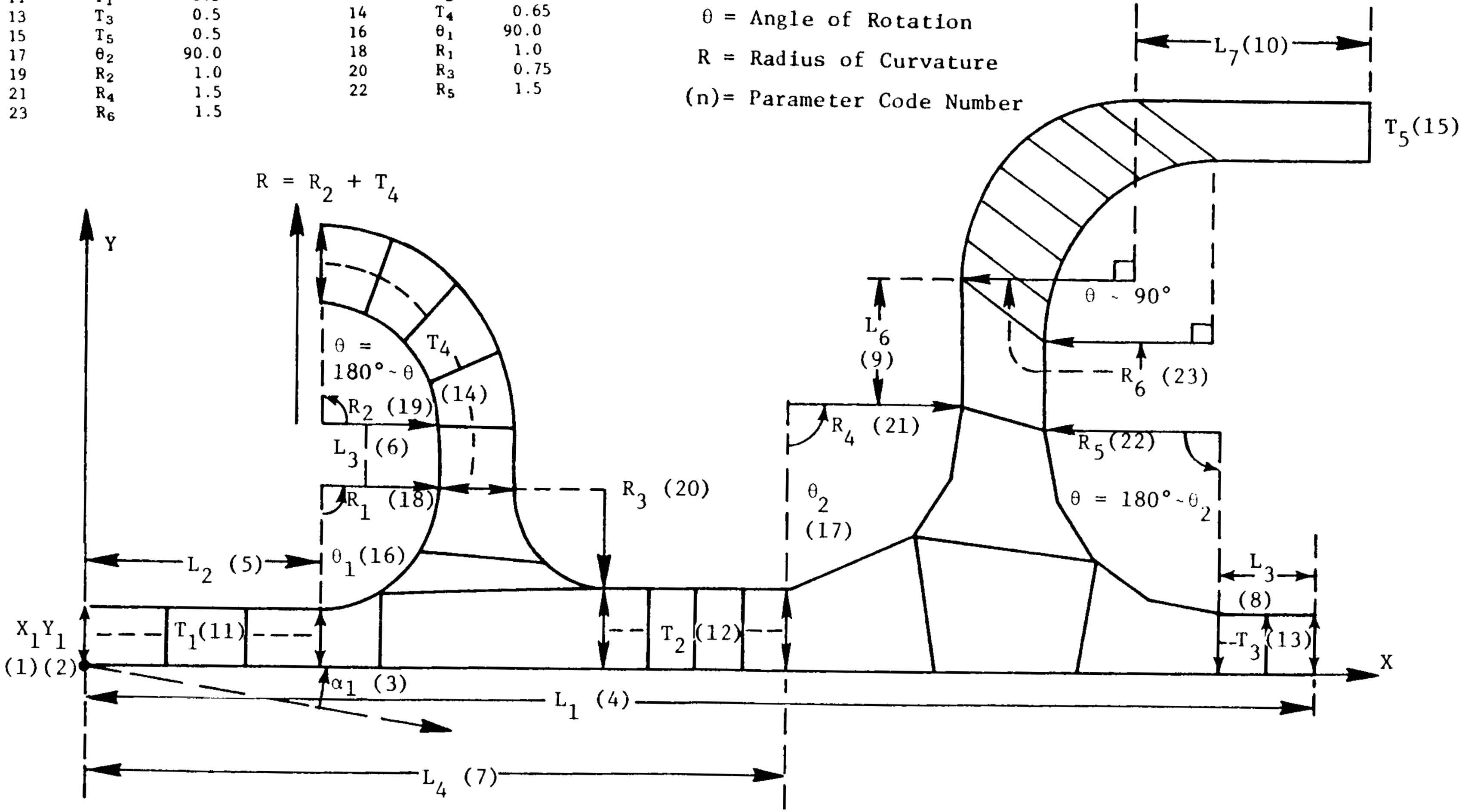
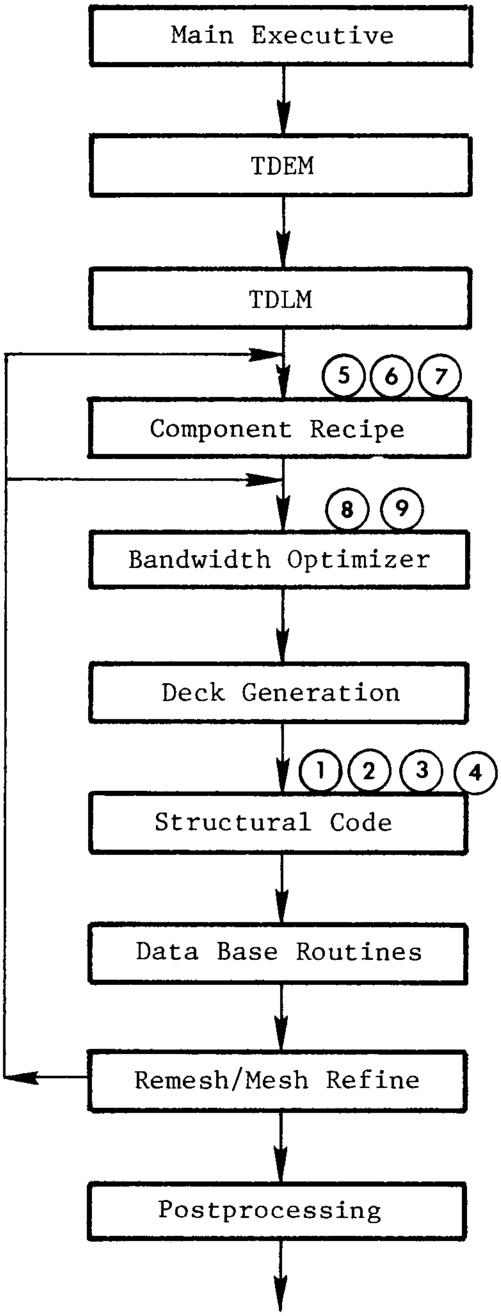


Figure 4. Combustor Liner Parameters.



1. TIME INCREMENT
2. LOAD INCREMENT
3. PLASTICITY TOLERANCES
4. CREEP TOLERANCES
5. NUMBER OF MASTER REGION ELEMENTS
6. NUMBER OF SLICES
7. POSITION OF SLICES
8. ROW REFINEMENT
9. ELEMENT REFINEMENT

Figure 5. System Flow Chart Showing Adaptive Control Positions.