N89-12907

COMPONENT SPECIFIC MODELING*

R.J. Maffeo, R.L. McKnight, M.T. Tipton, and G. Weber
General Electric Company

INTRODUCTION

The overall objective of this program is to develop and verify a series of interdisciplinary modeling and analysis techniques that have been specialized to address three specific 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 are integrated to provide an accurate, efficient, and unified approach to analyzing combustor burner liners, hollow air-cooled turbine blades, and air-cooled turbine vanes. For these components, the methods developed predict temperature, deformation, stress, and strain histories throughout a complete flight mission.

The base program for the component specific modeling effort is illustrated in Figure (1). Nine separate tasks were arranged into two parallel activities. The component specific structural modeling activity in Figure (2), was directed towards the development of the analytical techniques and methodology required in the analysis of complex hot section components. The component specific thermomechanical load mission modeling effort illustrated in Figure (3), provides for the development of approximate numerical models for engine cycle, aerodynamic, and heat transfer analyses of hot section components.

THERMODYNAMIC AND THERMOMECHANICAL MODELS

The Thermodynamic Engine Model (TDEM) and the Thermomechanical Load (TDLM) Model have been reported on extensively at previous HOST conferences. They have been installed on the NASA Lewis CRAY for over a year where they have been exercised by both GE and NASA personnel. Figures 4, 5 and 6 show representative pieces of input and output of these models. Figure 4 shows the input to the TDEM defining a specific mission. Figure 5 shows the output of the TDEM giving the engine parameters for a mission. This is then the input to the TDLM. Figure 6 shows a snapshot of a portion of the output of the TDLM for a combustor nugget showing the result of running the TDEM and TDLM to be local structural temperature and pressure loading on a component.

COMBUSTOR STRUCTURAL ANALYSIS

The emphasis in Phase I of this program has been on automating the COSMO procedure for the combustor liner. The COSMO procedure continues with the output

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of the TDLM being structured as a data file for use in the combustor component specific model. Figure 7 defines the recipe which generates the combustor structural model. Figure 8 is a snapshot of a typical run of the combustor model when it was in the checkout phase as a free-standing code. As indicated, the model contains a default set of recipe parameters, only changes to this list need be given. After the recipe parameters have been set, only 5 parameters need be specified to generate a 3D sector model of a combustor to perform a hot streak analysis. The first parameter (shown as the number of exhaust nozzles) is required to divide the 360° combustor into the proper number of sectors. The next parameter (shown as the no. of circumferential elements) is used by the analyst to split up the circumferential sector into a number of slices, NS, for the 3D elements. Next, depending on the number of slices selected, the analyst can bias these slices by specifying NS-1 percents (program calculates final bias to total 100%). In this case the biasing selected, starting at the hot streak, was 5%, 15%, and 30% with the final slice being 50%. This is all the information that is required to generate a 3D finite element model consisting of 20-noded isoparametric elements. In this case the model consists of 648 elements, 3192 nodes and has 768 element faces with pressure loading. Figures 9 and 10 are graphical depictions of this 3D model. The combustor then maps the temperatures and pressures from the TDLM onto this model and generates data files for the structural analysis.

COSMO SYSTEM

Figure 11 shows a flow chart of the overall COSMO system including the action positions of the adaptive controls developed in this program. This system includes a bandwidth optimizer which is necessary to make the automatic remeshing/mesh refinement activity possible. For the combustor, the following adaptive controls have been incorporated into the system (the numbers are consistent with Figure 11).

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

The first four adaptive controls are a function of the structural code being used. For this system the code and the controls are those developed under, "3D Inelastic Analysis Methods for Hot Section Structures." The other adaptive controls are keyed from a decision grid as indicated in Figure 12. The gradients in normalized stress, total strain, plastic strain, and creep strain will be used to rank requirements.

REFERENCES

1. McKnight, R.L., "Component Specific Modeling - First Annual Status Report," NASA CR-174765, 1983.

2. McKnight, R.L., "Component Specific Modeling - Second Annual Status Report," NASA CR-174925, 1985.

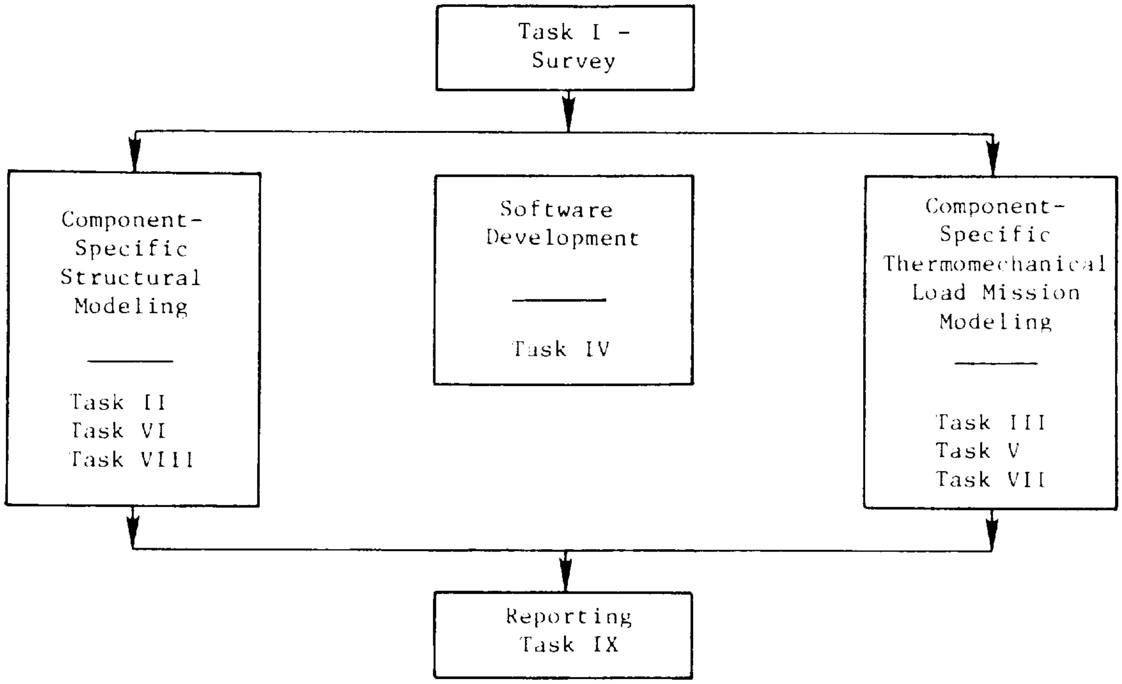

Figure 1. Component Specific Modeling Base Program.

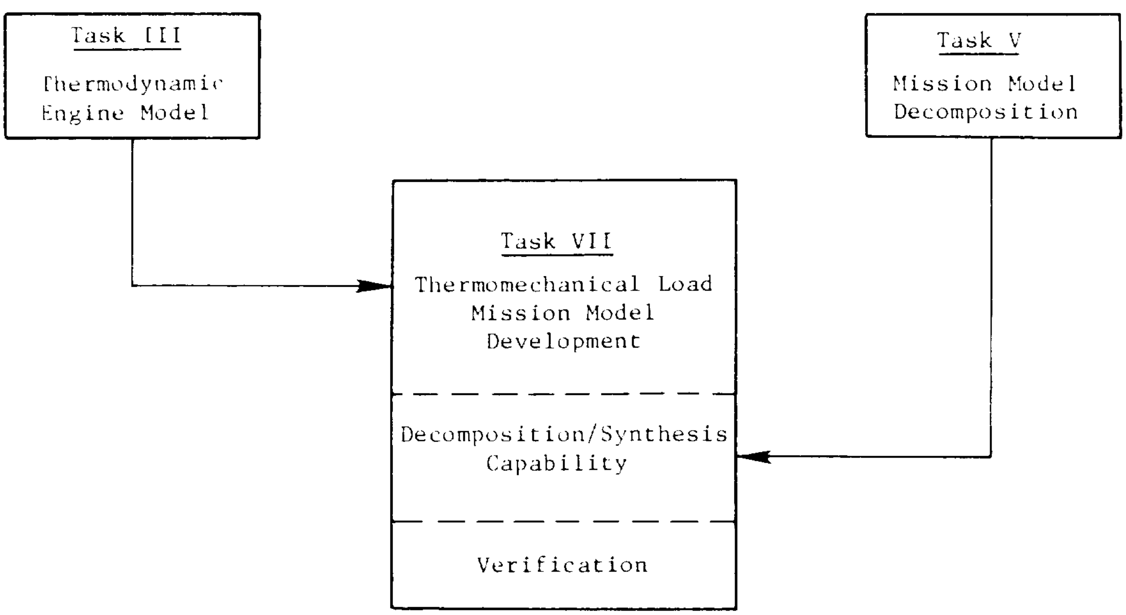

Figure 2. Component Specific Thermomechanical Load Mission Modeling.

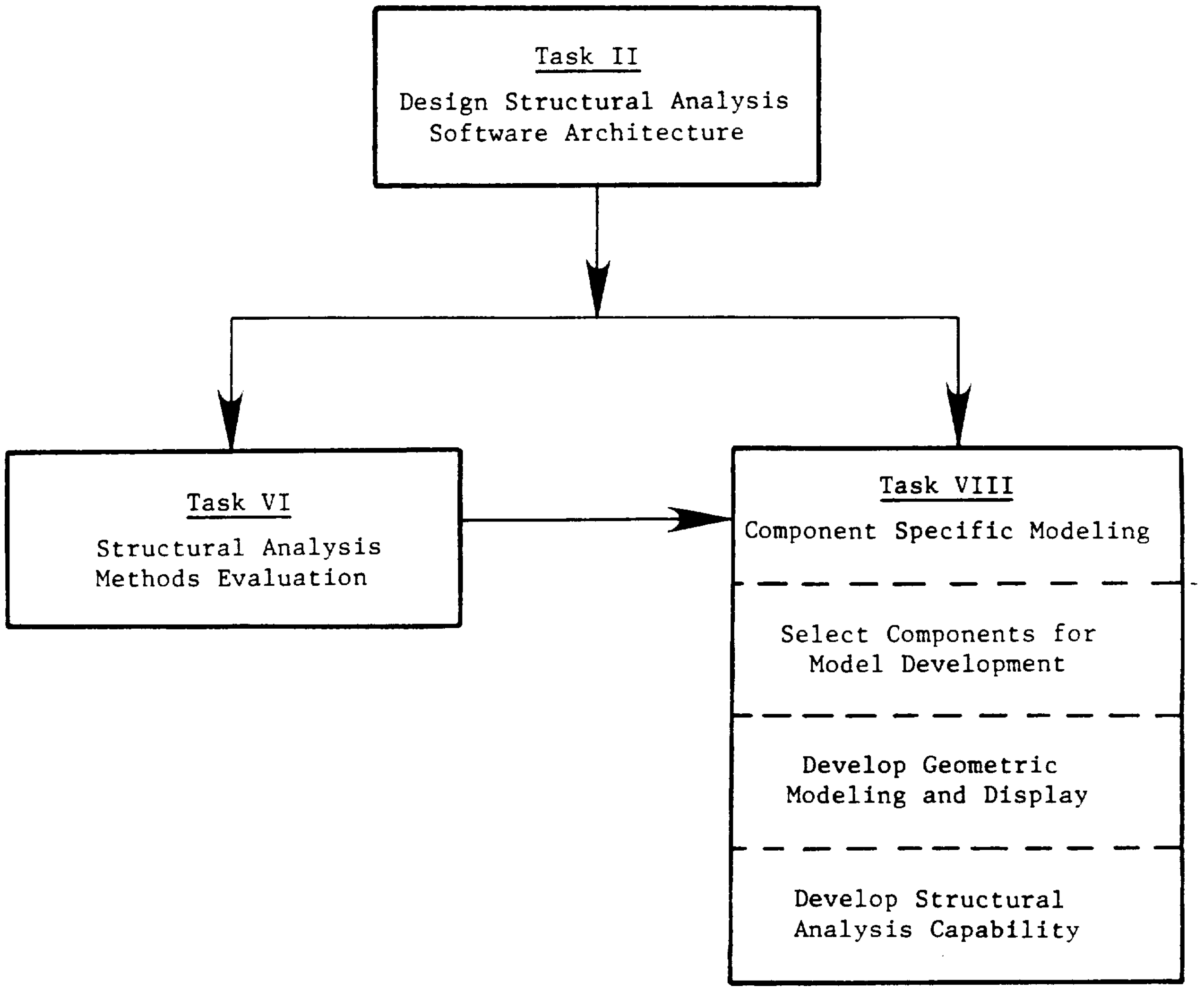

Figure 3. Component Specific Structural Modeling.

Case No.	Mach No.	Alt	Amb T Code	ΔTo	Power Code	Fan Speed	Bleed Code		No. Offset Instr	Special Ref. Case	Flt Phase
197	Ø.ØØ	Ø.	1Ø	Ø.	41	Ø.	-1.	-1.	Ø	197	ST
151	Ø.ØØ	Ø.	1Ø	Ø.	37	Ø.	-1.	-1.	Ø	Ø	GI1
152	Ø.ØØ	Ø.	1Ø	Ø.	22	373Ø.	-1.	-1.	Ø	Ø	TO1
153	.243	2ØØØ.	1Ø	Ø.	22	3743.	-1.	-1.	Ø	Ø	TO2
154	.243	2ØØØ.	1Ø	Ø.	22	3634.	-1.	-1.	Ø	Ø	CL1
155	.45	1ØØØØ.	1Ø	7.Ø	22	3634.	-1.	-1.	Ø	Ø	CL2
156	.58	11ØØØ.	1Ø	7.Ø	22	3618.	-1.	-1.	Ø	Ø	CL3
157	.82	33ØØØ.	1Ø	11.Ø	22	3724.	-1.	-1.	Ø	Ø	CL4
158	.82	33ØØØ.	1Ø	11.Ø	22	3466.	-1.	-1.	Ø	Ø	CRU
159	.82	33ØØØ.	1Ø	11.Ø	38	Ø.	-1.	-1.	Ø	Ø	D1
16Ø	.61	11ØØØ.	1Ø	7.Ø	38	Ø.	-1.	-1.	Ø	Ø	D2
161	.61	11ØØØ.	1Ø	7.Ø	37	Ø.	-1.	-1.	Ø	Ø	D3
162	.42	6ØØØ.	1Ø	2.Ø	37	Ø.	-1.	-1.	Ø	Ø	D4
163	.42	6ØØØ.	1Ø	2.Ø	22	2798.	-1.	-1.	Ø	Ø	APPR
164	.24	Ø.	1Ø	Ø.Ø	22	2798.	-1.	-1.	Ø	Ø	LDG
165	.18	Ø.	1Ø	Ø.Ø	38	Ø.	-1.	-1.	Ø	Ø	FI
166	.18	Ø.	1Ø	Ø.Ø	39	2968.	-1.	-1.	Ø	Ø	TR1
167	Ø.ØØ	Ø.	1Ø	Ø.Ø	39	2834.	-1.	-1.	Ø	Ø	TR2

Figure 4. Inputs to Thermodynamic Engine Model.

DATE - 07/16/85

* ENGINE PERFORMANCE DATA BY MISSION PHASE *

PHASE #	CASE #	P2	P25	P3	P4		P49	P5	P8	FNIN1	DTAMB	PHASE
				** E N G I N E	P A R A M E T E R **							
1	197	14.696	14.696	14.696	14.696	0.	14.696	14.696	0.018	0.	0.	ST
2	151	14.696	15.531	73.295	69.860	0.	20.820	15.048	15.031	4538.261	0.	GI1
3	151	14.696	15.531	73.295	69.860	0.	20.820	15.048	15.031	4538.261	0.	GI1
4	152	14.696	32.353	422.356	402.822	0.	91.073	23.769	23.456	48907.753	0.	TO1
5	153	14.238	31.569	413.413	394.295	0.	89.075	23.105	22.796	37628.904	0.	TO2
6	154	14.237	30.207	388.387	370.358	0.	83.604	22.011	21.727	35094.032	0.	CL1
7	155	11.613	24.987	321.570	306.667	0.	69.312	17.822	17.580	24750.564	7.000	CL2
8	156	12.205	25.735	327.605	312.364	0.	70.500	18.211	17.966	22581.097	7.000	CL3
9	157	5.910	13.987	187.264	178.717	0.	40.557	10.415	10.275	11977.777	11.000	CL4
10	158	5.910	12.634	160.416	153.003	0.	34.522	8.872	8.752	9849.775	11.000	CRU
11	158	5.910	12.634	160.416	153.003	0.	34.522	8.872	8.752	9849.775	11.000	CRU
12	159	5.910	5.820	14.195	13.596	0.	5.152	3.878	3.876	-1602.839	11.000	D1
13	160	12.494	12.425	32.608	31.167	0.	12.205	9.855	9.850	-2438.477	7.000	D2
14	161	12.494	13.434	60.439	57.424	0.	15.634	10.153	10.136	-1434.762	7.000	D3
15	162	13.297	14.110	64.982	61.827	0.	17.506	12.153	12.137	-18.451	2.000	D4
16	163	13.296	19.957	205.245	195.282	0.	43.655	14.847	14.731	11991.389	2.000	APP
17	164	15.296	22.579	238.419	226.933	0.	51.135	17.924	17.793	16294.929	0.	LDG
18	165	15.032	15.290	42.036	40.353	0.	17.187	14.821	14.815	207.969	0.	FI
19	165	15.032	15.290	42.036	40.353	0.	17.187	14.821	14.815	207.969	0.	FI
20	166	15.033	23.122	261.537	249.111	0.	55.912	18.394	18.240	-11588.640	0.	TR1
21	167	14.697	21.554	234.321	223.144	0.	50.301	17.691	17.561	-4309.143	0.	TR2
22	151	14.696	15.531	73.295	69.860	0.	20.820	15.048	15.031	4538.261	0.	GI1
23	151	14.696	15.531	73.295	69.860	0.	20.820	15.048	15.031	4538.261	0.	GI1
24	197	14.696	14.696	14.696	14.696	0.	14.696	14.696	0.018	0.	0.	ST

Figure 5. Outputs From Thermodynamic Engine Model.

Pts 0.034 ➞ 1.15 are Sufficient to Illustrate data

X	Y	T_H	T_A	ΔT_H	ΔT_A	ΔP
0.034	0.030	520.182	520.182	0.161	0.161	0.
0.094	0.030	521.284	521.284	0.263	0.263	0.
0.158	0.030	522.834	522.834	0.391	0.391	0.
0.208	0.030	523.901	523.901	0.463	0.463	0.
0.254	0.030	524.487	524.487	0.485	0.485	0.
0.288	0.030	524.935	524.935	0.499	0.499	0.
0.340	0.030	525.658	525.520	0.516	0.505	0.
0.404	0.030	526.519	526.002	0.523	0.489	0.
0.438	0.030	528.827	526.967	0.639	0.521	0.
0.584	0.040	530.446	527.690	0.735	0.562	0.
0.654	0.040	531.376	528.276	0.790	0.597	0.
0.764	0.040	531.686	528.758	1.032	0.800	0.
0.854	0.040	530.928	527.690	1.144	0.841	0.
0.934	0.044	529.826	527.311	1.310	1.014	0.
1.040	0.044	528.586	526.967	1.481	1.238	0.
1.074	0.040	527.828	526.726	1.461	1.284	0.
1.114	0.030	527.656	526.485	1.541	1.340	0.
1.150	0.030	527.518	526.381	1.613	1.405	0.

Figure 6. Outputs From Combustor Thermodynamic Loads Model.

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

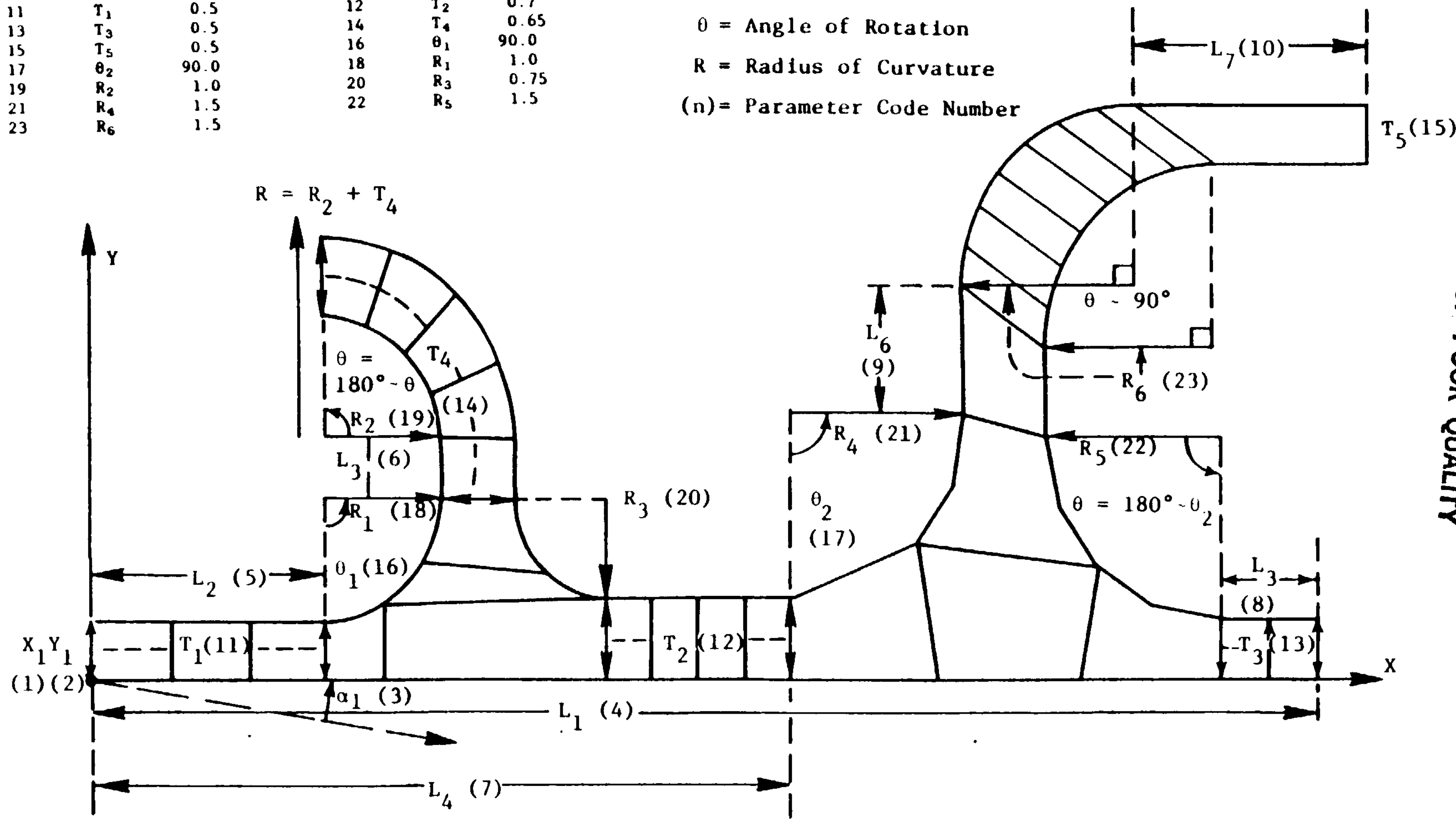

Figure 7. Combustor Liner Parameters.

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      NUGGET RECIPE    VERS.11 8/29/85

DO YOU HAVE A PARAMETER FILE 21? (0/1)
*

          CODE       VALUE                    CODE      VALUE
            1        0.                         2       0.
            3        0.                         4       1.16700
            5        0.19200                    6       0.04500
            7        0.81000                    8       0.06800
            9        0.10000                   10       0.20000
           11        0.06000                   12       0.08000
           13        0.06000                   14       0.06800
           15        0.06800                   16     110.00000
           17       90.00000                   18       0.06000
           19        0.06300                   20       0.12000
           21        0.12500                   22       0.08300
           23        0.09500

  ENTER PARAMETER CHANGES (ENTRY CODE, NEW VALUE)
      WHEN DONE ENTER     0 0

*0 0

          CODE       VALUE                    CODE      VALUE
            1        0.                         2       0.
            3        0.                         4       1.16700
            5        0.19200                    6       0.04500
            7        0.81000                    8       0.06800
            9        0.10000                   10       0.20000
           11        0.06000                   12       0.08000
           13        0.06000                   14       0.06800
           15        0.06800                   16     110.00000
           17       90.00000                   18       0.06000
           19        0.06300                   20       0.12000
           21        0.12500                   22       0.08300
           23        0.09500

 DO YOU WANT TO CHANGE PARAMETERS? (0/1)
*
READING FILE NUGCON
READING DONE
                 27 ELEMENTS READ

ENTER ENGINE TEMPERATURE AND PRESSURE FILE NAME
*/GM/NUGINF
READING FILE /GM/NUGINF                    ,
READING DONE
                 35 CENTROIDS READ


ENTER THE NUMBER OF EXHAUST NOZZLES
  AND THE NO. OF CIRCUMFIRENTIAL ELEMENTS
  BETWEEN T-AVE AND T-HOT (MAX NO.=10)
*3 4

ENTER THE  3 CIRCUMFIRENTIAL BIASING PARAMETERS
 -- ENTER AS PERCENTS, THE SUM BEING LESS THAN 100% --
*5 15 30

********   3192 NODES IN 3-D MODEL      *******
********    648 ELEMENTS IN 3-D MODEL   *******
********    768 FACES WITH PRESSURES    *******

 *** 2-D NODE    FILE IS TEMP FILE 20 ***
 *** PARAMETER   FILE IS TEMP FILE 21 ***
 *** 3-D  UIF    FILE IS TEMP FILE 26 ***

*
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FIGURE 8. TYPICAL PROGRAM RUN

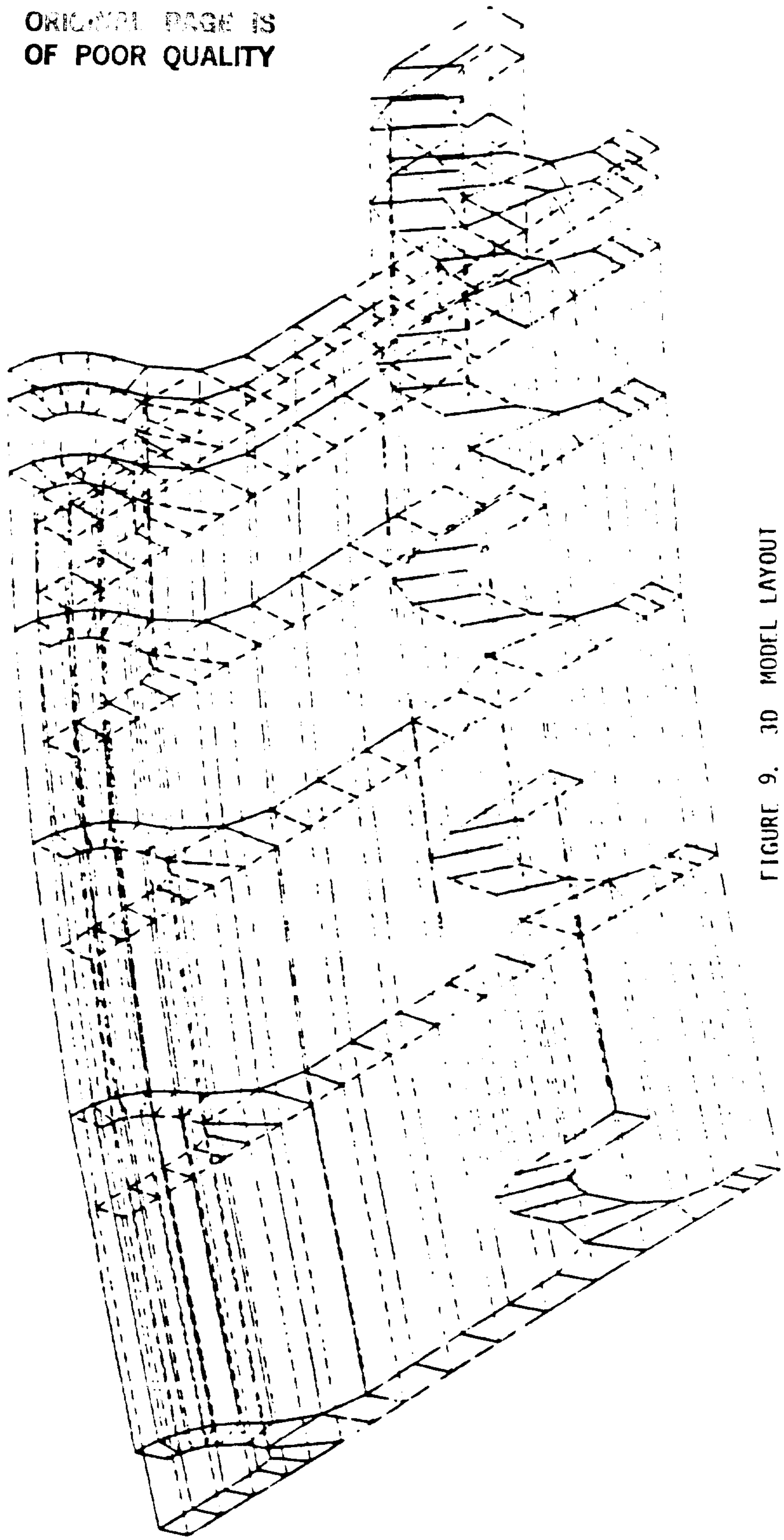
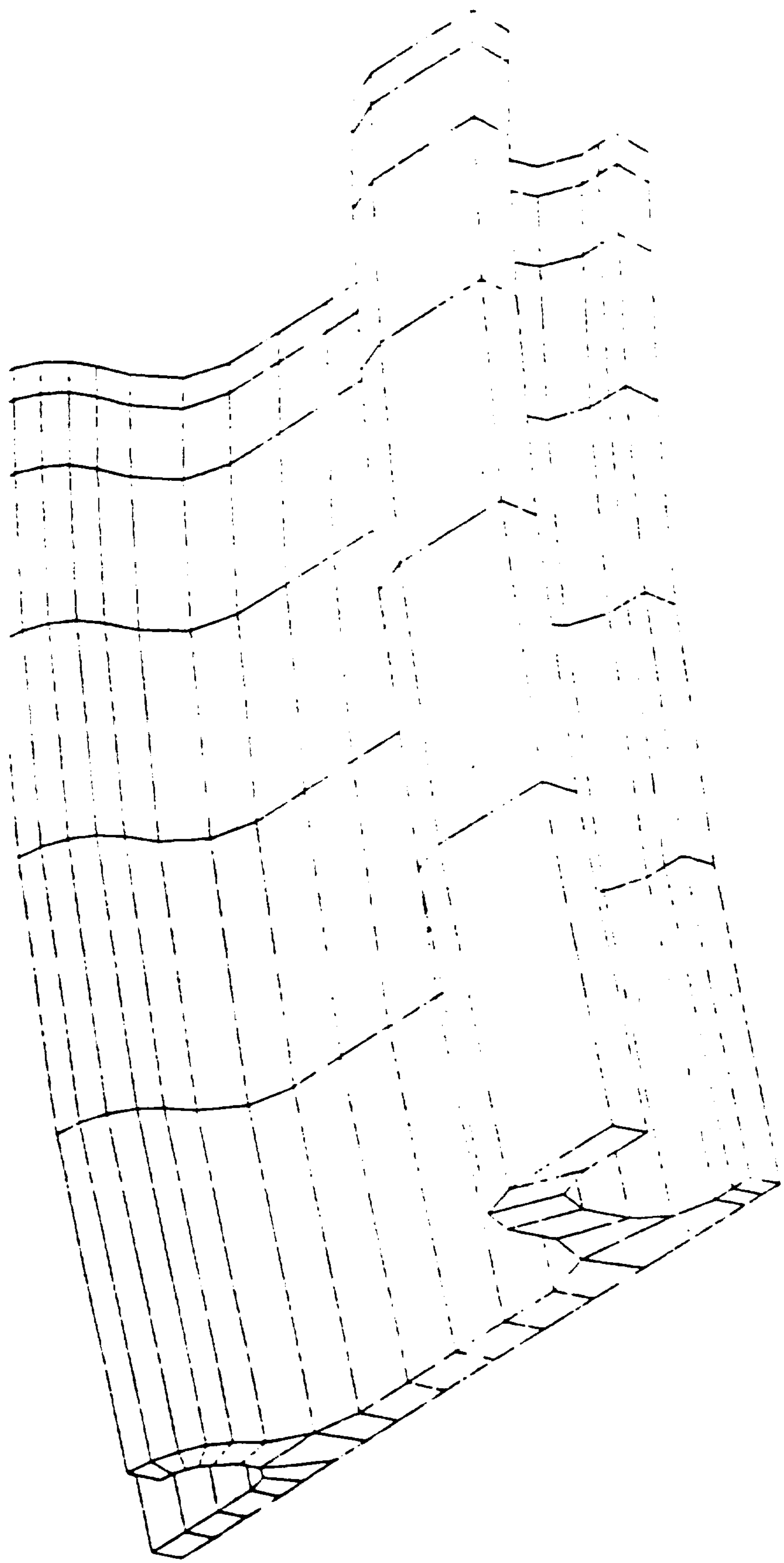


FIGURE 9. 3D MODEL LAYOUT



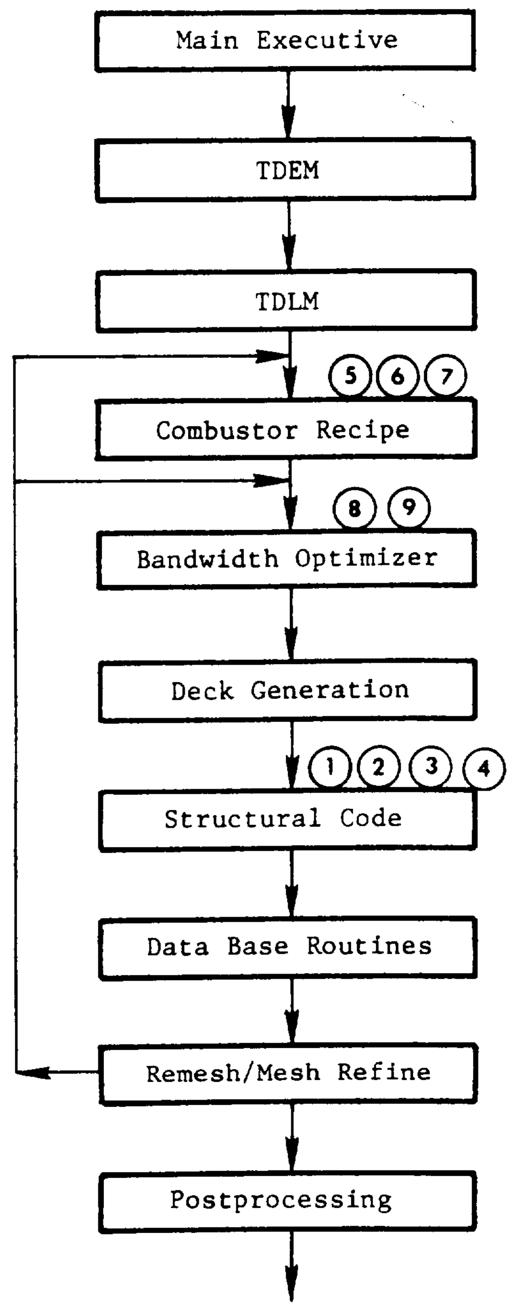


Figure 11. System Flow Chart Showing Adaptive Control Positions.

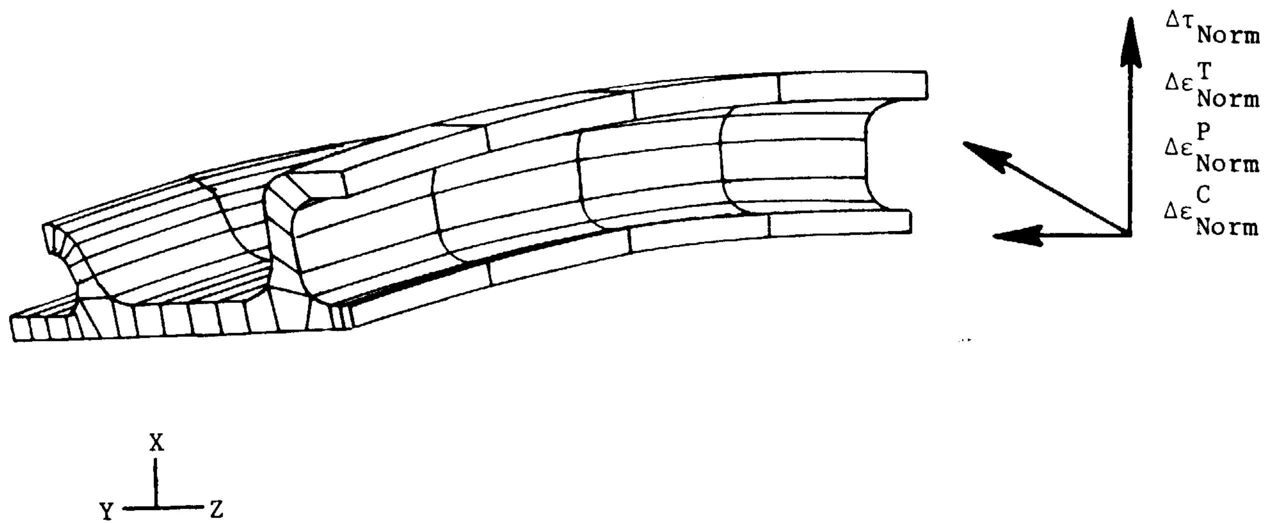


Figure 12. Combustor Nugget Decision Grid.