COMBUSTION HOT SECTION TECHNOLOGY

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The overall objective of the Turbine Engine Hot Section Technology Combustion Project is to develop and verify improved and more accurate analysis methods for increasing the ability to design with confidence the combustion system for advanced aircraft turbine engines. The analysis methods developed will be generically applicable to combustion systems and not restricted to one specific engine or manufacturer.

This projects approach is to first assess and evaluate existing combustor aerothermal analysis models by means of a contracted effort initiated during FY '82. This evaluation effort will quantify known models strengths and deficiencies. A balanced contract and in-house program will then be conducted to support, focus, and accelerate the development of new methods to more accurately predict the physical phenomena occurring within the combustor. This balanced program will include both analytical and experimental research efforts in the areas of aerothermal modeling and liner cyclic life.

It is expected that the combustor model development effort will generate improved understanding in the areas of: high pressure flame radiation characteristics, model numerical methods and solution schemes, complex geometrical boundary conditions, fuel spray - flow field interactions, combustion kinetics, flow and mixing of dilution jets, turbulence and heat transfer, and soot and carbon formation. The primary in-house effort in this area will be the determination of high pressure flame radiation characteristics in a full annular combustor. This experiment will be conducted in the NASA LeRC High Pressure Facility with the results compiled into a comprehensive flame radiation and liner heat flux model.

In the area of liner cyclic life, HOST will develop a test apparatus to economically determine combustor thermal strains and cyclic life. This test apparatus will be run in-house at NASA LeRC and will be the test vehicle for many of the advanced high temperature instruments developed under HOST sponsorship. The fundamental data generated in this project will be used to assess and develop current analytical liner life programs.

OBJECTIVE

TO DEVELOP IMPROVED ANALYTICAL MODELS OF THE INTERNAL COMBUSTOR FLOW FIELD AND LINER HEAT TRANSFER AS A MEANS TO SHORTEN COMBUSTOR DEVELOPMENT TIME AND INCREASE TURBINE ENGINE HOT SECTION LIFE.

TURBINE ENGINE HOT SECTION TECHNOLOGY

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APPROACH

- UTILIZE EXISTING MODELS - DETERMINE THEIR DEFICIENCIES
- CONDUCT SUPPORTING RESEARCH TO IMPROVE PHYSICAL MODELS
- REFINE MODELS TO IMPROVE NUMERICS AND NUMERICAL DIFFUSION
- INTEGRATE NEW AND IMPROVED ROUTINES INTO EXISTING MODELS AND VERIFY THEIR IMPROVED PREDICTIVE CAPABILITY

TURBINE ENGINE HOT SECTION TECHNOLOGY

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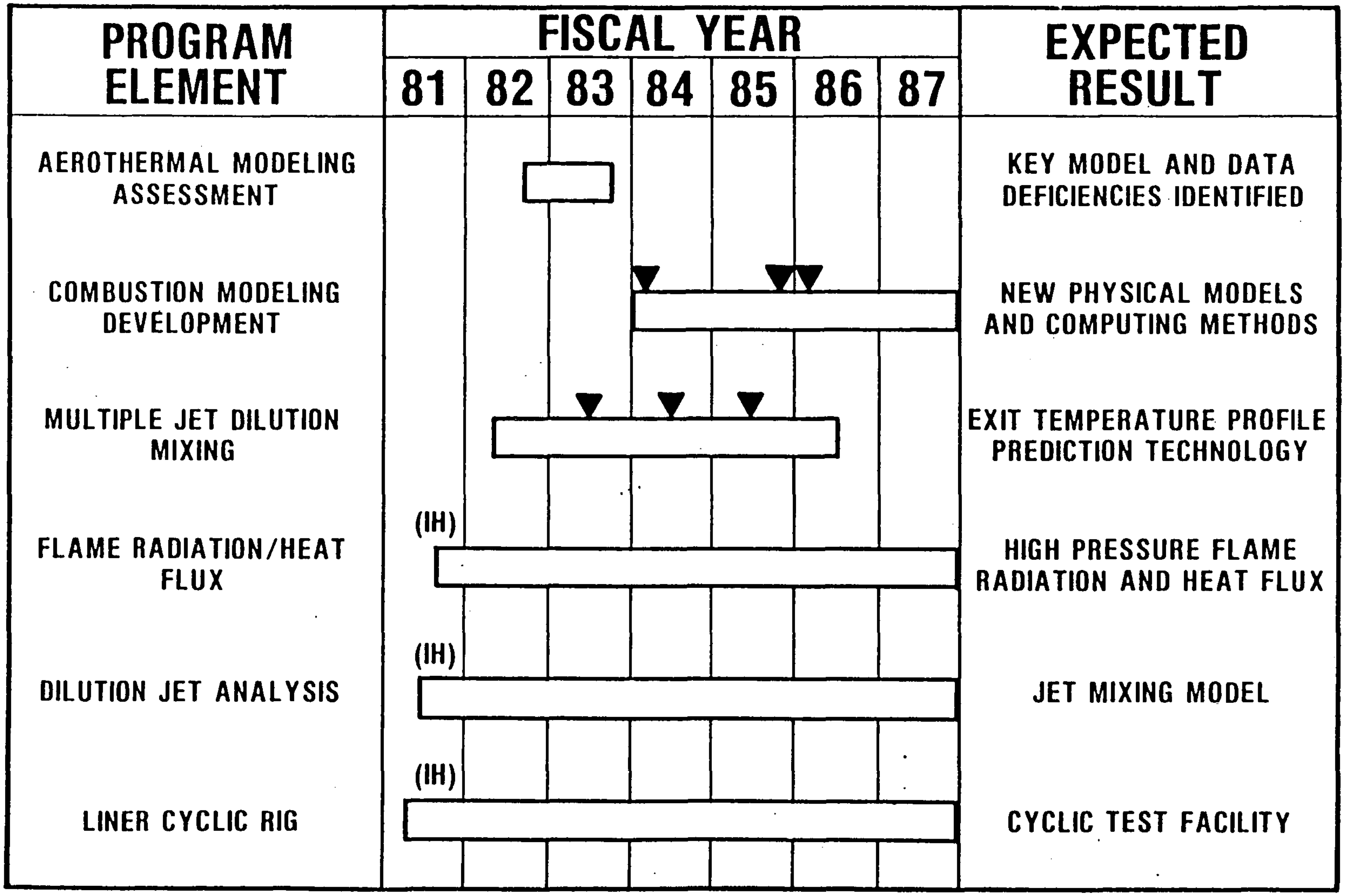
COMBUSTION



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OBJECTIVE:

ASSESS THE CURRENT STATE-OF-THE-ART AND IDENTIFY THE DEFICIENCIES IN CURRENT AEROTHERMAL MODELS FOR GAS-TURBINE COMBUSTORS

AEROTHERMAL MODELING PROGRAM

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PROGRAM APPROACH OUTLINE

TASK 1

1.1 MODEL DEFINITION

1.2 DATA BASE GENERATION

1.3 BENCHMARK TEST CASE DEFINITION

TASK 2

2.1 MODEL EXECUTION

2.2 MODEL ASSESSMENT

2.3 PROGRAM PLAN FOR MODEL IMPROVEMENT

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SUBTASK 1.1 - MODEL DEFINITION

DESCRIBE COMPUTER PROGRAMS TO BE USED FOR MODEL ASSESSMENT

- COMBUSTOR PERFORMANCE MODEL (2-D AND 3-D)
- NEAR-WALL MODEL

DESCRIBE PHYSICAL SUBMODELS TO BE ASSESSED

- TURBULENCE MODELS
- GASEOUS COMBUSTION MODELS
- SPRAY COMBUSTION MODELS
- SOOT FORMATION/OXIDATION MODEL
- RADIATION MODELS

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SUBTASK 1.2 - DATA BASE GENERATION

CLASSIFY AND REVIEW AVAILABLE DATA BASE

- o COMPLEXITY OF FLOW FIELD
  - o PARABOLIC FLOW
  - o STREAMLINE CURVATURE
  - o RECIRCULATING FLOWS W/O SWIRL
  - o SWIRLING FLOWS WITH AND W/O RECIRCULATION
- o PHYSICAL/CHEMICAL PROCESSES
  - o NON REACTING FLOWS
  - o REACTING FLOWS
    - o GASEOUS COMBUSTION
    - o SPRAY COMBUSTION
- o IDEALIZED FLOW ELEMENTS AND PRACTICAL COMBUSTORS

- TURBULENCE MODEL
  - FLOW OVER A FLAT PLATE: $\bar{U}$, $\overline{U'^2}$, $\overline{U'V'}$, K
  - TWO STREAM MIXING LAYER WITHOUT RECIRCULATION: $\bar{U}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{W'^2}$, $\overline{U'V'}$
  - MIXING OF UNCONFINED COAXIAL JETS: $\bar{U}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{U'V'}$
  - DEVELOPING PIPE FLOW: $\bar{U}$, $\bar{V}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{U'V'}$
  - FLOW IN A CURVED DUCT: $\bar{U}$, $\bar{V}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{W'^2}$, $\overline{U'V'}$
  - FLOW OVER A PLANE STEP: $\bar{U}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{U'V'}$
  - MIXING OF CONFINED COAXIAL JETS WITH RECIRCULATION: $\bar{U}$, $\bar{V}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{W'^2}$, $\overline{U'V'}$
  - MIXING OF UNCONFINED COAXIAL SWIRLING JETS W/O RECIRCULATION: $\bar{U}$, $\bar{V}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{W'^2}$, $\overline{U'V'}$, $\overline{U'V'}$, $\overline{V'W'}$
  - SWIRLING FLOW IN A PIPE EXPANSION WITH RECIRCULATION: $\bar{U}$, $\bar{V}$, $\overline{U'^2}$, $\overline{V'^2}$, $\overline{W'^2}$, $\overline{U'V'}$, $\overline{U'W'}$, $\overline{V'W'}$

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BENCHMARK TEST CASE DEFINITION (CONT'D)

- GASEOUS COMBUSTION MODEL
  - 1-D LAMINAR FLAT FLAME: FUEL, O_2, CO, CO_2, H_2O, H_2, T
  - 2-D LAMINAR DIFFUSION FLAME WITH RECIRCULATION: CH_4, CO_2, CO, H_2, H_2O, O_2, N_2, VELOCITY T
  - 2-D TURBULENT PREMIXED FLAME WITH RECIRCULATION: VELOCITY, CO, CO_2, C_3H_8, H_2O, O_2, N_2, T
  - 2-D TURBULENT DIFFUSION FLAME W/O RECIRCULATION: VELOCITY, T, CH_4, H_2, CO_2, CO, H_2O, O_2, N_2
  - 2-D TURBULENT DIFFUSION FLAME WITH RECIRCULATION: MIXTURE FRACTION O_2, N_2, CH_4, CO, CO_2, H_2O, T
  - 2-D TURBULENT, SWIRLING DIFFUSION FLAME WITH RECIRCULATION: CO_2, CO, H_2, VELOCITY, T

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BENCHMARK TEST CASE DEFINITION (CONT'D)

- SPRAY COMBUSTION MODEL
  - 2-D TURBULENT EVAPORATING SPRAY W/O RECIRCULATION: DROP SIZE DISTRIBUTION, T, MIXTURE FRACTION, GAS VELOCITY
  - 2-D TURBULENT REACTING SPRAY W/O RECIRCULATION: T, CO, CO_2, O_2, N_2, H_2, H_2O, GAS VELOCITY
  - 2-D TURBULENT REACTING SPRAY WITH RECIRCULATION: DROP NUMBER DENSITY, T, O_2, CO, CO_2, C_XH_Y, GAS VELOCITY
  - 2-D TURBULENT SWIRLING REACTING SPRAY WITH RECIRCULATION: DROPLET VELOCITY AND SIZE DISTRIBUTION, T, CO, CO_2, O_2, C_XH_Y, GAS VELOCITY

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BENCHMARK TEST CASE DEFINITION (CONT'D)

- SOOT FORMATION/OXIDATION MODEL:
  - 2-D LAMINAR DIFFUSION CH_4-FLAME W/O RECIRCULATION: SMOKE CONCENTRATION
  - 2-D TURBULENT DIFFUSION CH_4, C_3H_8 FLAME W/O RECIRCULATION: SMOKE CONCENTRATION AND RADIATION
- GAS-TURBINE COMBUSTORS - GARRETT IN-HOUSE DATA:
  - COMBUSTOR DESIGN CRITERIA VALIDATION PROGRAM: VELOCITY, CO, CO_2, C_XH_Y, RADIATION
  - UPRATE T-76 COMBUSTOR: PRIMARY ZONE: T, CO, C_XH_Y
  - TPE331-15 COMBUSTOR: LINER WALL TEMPERATURES

SUMMARY AND FUTURE WORK

- SUMMARY
  - DATA BASE FOR TURBULENCE AND GASEOUS COMBUSTION MODELS FAIRLY ADEQUATE
  - DATA BASE FOR SPRAY MODELS LESS SATISFACTORY STATE
  - DATA BASE FOR SOOT AND RADIATION MODELS RATHER INADEQUATE
- FUTURE WORK
  - COMPUTATIONS OF THE BENCHMARK CASES WITH AEROTHERMAL MODEL
  - IDENTIFY MODEL DEFICIENCIES
  - PREPARE PROGRAM PLAN FOR MODEL IMPROVEMENT.

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