FATIGUE AND FRACTURE - OVERVIEW

G. R. Halford
National Aeronautics and Space Administration
Lewis Research Center

We are pleased to report that all of the planned contractual and grant research programs in the fatigue and fracture discipline of the HOST Project are now in place. Many are producing important new results. These results and detailed aspects of the individual efforts will be conveyed by the responsible technical principal investigators in Session IVa scheduled for the last afternoon of this workshop. At this point I would like to give a brief overview of the status of the fatigue and fracture programs.

The programs involve the development of appropriate analytic material behavioral models for cyclic stress-strain-temperature-time/cyclic crack initiation, and cyclic crack propagation. It was convenient to divide the research efforts into two camps, depending upon the nominally isotropic or anisotropic mechanical response of the materials. Five industrial contracts with three different research organizations, three university grants, and two in-house programs round out the overall effort.

Figures 1 to 6 provide a block flow diagram of the activities within the various programs. I will address these figures one by one, but the reader is encouraged to study the individual contributions for more specific details.

I do want to emphasize the underlying thrust of these programs: the development and verification of WORKABLE engineering methods for the calculation, in advance of service, of the local cyclic stress-strain response at the critical life governing location in hot section components, and the resultant cyclic crack initiation and crack growth lifetimes.
FATIGUE & FRACTURE ... IT'S ROLE IN HOST

GOAL: DEVELOP AND VERIFY ANALYTIC ENGINEERING MODELS THAT CAN BE USED ON A ROUTINE DESIGN BASIS FOR THE PREDICTION OF CYCLIC STRESS-STRAIN-TEMPERATURE-TIME RESPONSE (i.e., CONSTITUTIVE RESPONSE) AND FATIGUE CRACK INITIATION AND PROPAGATION LIFETIMES OF TURBINE ENGINE HOT SECTION COMPONENTS MADE OF ISOTROPIC OR ANISOTROPIC ALLOYS

PROGRAM INTEGRATION

PROGRAM ELEMENTS:

- CONSTITUTIVE MODELLING - ISOTROPIC — (48 mos)
- LIFE PREDICTION - ISOTROPIC — (60 mos)
- CRACK PROPAGATION - ISOTROPIC — (48 mos)
- LIFE PREDICTION & CONSTITUTIVE MODELLING - ANISOTROPIC — (60 mos)
- IN-HOUSE ACTIVITIES — (60 mos)

Figure 1

CONSTITUTIVE MODELLING—ISOTROPIC MATERIAL

SOUTHWEST RESEARCH, LINDHOLM; AND GENERAL ELECTRIC, LAFLEN

SCREEN CONSTITUTIVE MODELS
EVALUATE BEST MODELS
IMPLEMENT IN FE CODE
EVALUATE MULTIAXIAL MODES
BENCHMARK NOTCH EXPERIMENTS
DEMONSTRATION OF MODEL
PROPERTY EVALUATION PROCEDURES
REFINEMENT OF MODEL
ALTERNATE MATERIAL

Figure 2
LIFE PREDICTION - ISOTROPIC MATERIAL
PRATT AND WHITNEY, MORENO

SCREEN LIFE-PREDICTION METHODS
EVALUATE BEST MODELS FOR CREEP-FATIGUE

THERMAL MECHANICAL MODULE
MULTIAXIAL MODULE
CUMULATIVE DAMAGE MODULE
MEAN STRESS MODULE

ENVIRONMENTAL ATTACK MODULE
COATINGS MODULE

INTEGRATED LIFE-PREDICTION MODEL

VERIFICATION ON BASE ALLOY SYSTEM
ALTERNATE ALLOY SYSTEM EVALUATION

CS-84-3932

Figure 3

CRACK PROPAGATION—ISOTROPIC MATERIAL
GENERAL ELECTRIC, LAFLER, AND SYRACUSE, LIU

SCREEN SPECIMEN CONFIG.
SCREEN CMOD/CTOD METHODS
SCREEN PATH-INDEPENDENT INTEGRALS

REVERSED LOADING MODULE
THERMAL GRADIENT MODULE
TMF PROPAGATION MODULE

TIME INDEPENDENT CRACK PROPAGATION PREDICTION METHODOLOGY
TIME DEPENDENT CRACK PROPAGATION PREDICTION METHODOLOGY

VERIFY USING HIGH TEMPERATURE ENGINE ALLOY

CS-84-3931

Figure 4

33
LIFE PREDICTION & CONSTITUTIVE MODELING
-ANISOTROPIC MATERIAL

PRATT AND WHITNEY, SWANSON

THEORETICAL MODEL DEVELOPMENT
U OF CIN, STOUFFER
U OF CT, JORDAN

SCREEN ALLOYS AND MODELS
COATING, TMF, MULTIAXIAL MODULES
FULL EVALUATION ON COATED SINGLE XTAL ALLOY SYSTEM
ALTERNATE COATED SINGLE XTAL ALLOY SYSTEM EVALUATION

BASE PROGRAM
UNCOATED SINGLE XTAL ROOT ATTACHMENT
OPT 1
EXPANDED HYDRAULIC SYSTEM
EXPANDED TEST CELL AREA
CENTRALIZED CONTROL ROOM
TENSION/TORSION BIAXIAL FATIGUE MACHINES
HCF/LCF MACHINES FOR CUMULATIVE DAMAGE
TMF MACHINE

UNCOATED SINGLE XTAL ROOT ATTACHMENT
OPT 2
EXPANDED TEST CELL AREA
CENTRALIZED CONTROL ROOM
TENSION/TORSION BIAXIAL FATIGUE MACHINES
HCF/LCF MACHINES FOR CUMULATIVE DAMAGE
TMF MACHINE

Figure 5

IN-HOUSE ACTIVITIES

UPGRADE FATIGUE LABORATORY

- HOST/SATELLITE COMPUTER SYSTEM
- EXPANDED HYDRAULIC SYSTEM
- EXPANDED TEST CELL AREA
- CENTRALIZED CONTROL ROOM
- TENSION/TORSION BIAXIAL FATIGUE MACHINES
- HCF/LCF MACHINES FOR CUMULATIVE DAMAGE
- TMF MACHINE

SINGLE CRYSTAL/COATING THERMAL MECHANICAL FATIGUE PROGRAM

- PWA 1480 BARE AND COATED
- STAND ALONE COATING
- TROIKA EFFORT
- FUNDAMENTAL APPROACH TO UNDERSTANDING OF CYCLIC FLOW AND CRACKING BEHAVIOR OF COMPLEX ALLOY/COATING SYSTEM

Figure 6