Structural Life and Reliability Metrics—Benchmarking and Verification of Probabilistic Life Prediction Codes

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Over the past two decades there has been considerable effort by NASA Glenn and others to develop probabilistic codes to predict with reasonable engineering certainty the life and reliability of critical components in rotating machinery and, more specifically, in the rotating sections of airbreathing and rocket engines. These codes have, to a very limited extent, been verified with relatively small bench rig type specimens under uniaxial loading. Because of the small and very narrow database the acceptance of these codes within the aerospace community has been limited. An alternate approach to generating statistically significant data under complex loading and environments simulating aircraft and rocket engine conditions is to obtain, catalog and statistically analyze actual field data. End users of the engines, such as commercial airlines and the military, record and store operational and maintenance information. This presentation describes a cooperative program between the NASA GRC, United Airlines, USAF Wright Laboratory, U. S. Army Research Laboratory and Australian Aeronautical & Maritime Research Laboratory to obtain and analyze these airline data for selected components such as blades, disks and combustors. These airline data will be used to benchmark and compare existing life prediction codes.

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On The Application of Probabilistic Methods for Gas Turbine Engines
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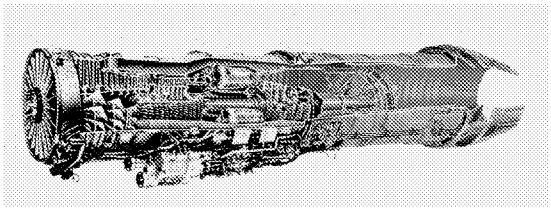
STRUCTURAL LIFE AND RELIABILITY METRICS—BENCHMARKING AND VERIFICATION OF PROBABILISTIC LIFE PREDICTION CODES



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STATE OF THE ART

- Probabilistic life prediction codes are not verified with full-scale engine components
- Database is limited to simple rig specimens
- Lack of funds and time for full-scale engine component testing under controlled conditions
- Engine company data limited and proprietary
- Multiple codes do not correlate with each other and possibly not with limited data available

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NEEDS

- Affordable and statistically significant database for critical engine components
- Ability to benchmark and verify existing reliability and life prediction codes with full-scale engine components
- Ability to develop reasonable engineering confidence in available analytical tools or modify the codes accordingly

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PROJECT OBJECTIVES

- Obtain from UAL reliability and life data for critical engine components and flight operating conditions information
- Develop a statistical database for each component selected for analysis
- Independent analysis by multiple participants of the life and reliability of the selected components
- Comparison of analysis with airline database

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BENEFITS

- Enhanced aviation safety and accident prevention
- Low cost design and manufacturing for new production engines
- Reduced life-cycle and maintenance costs
- Reliable design for finite life
- Airline on-time performance, airport throughput
- Military readiness

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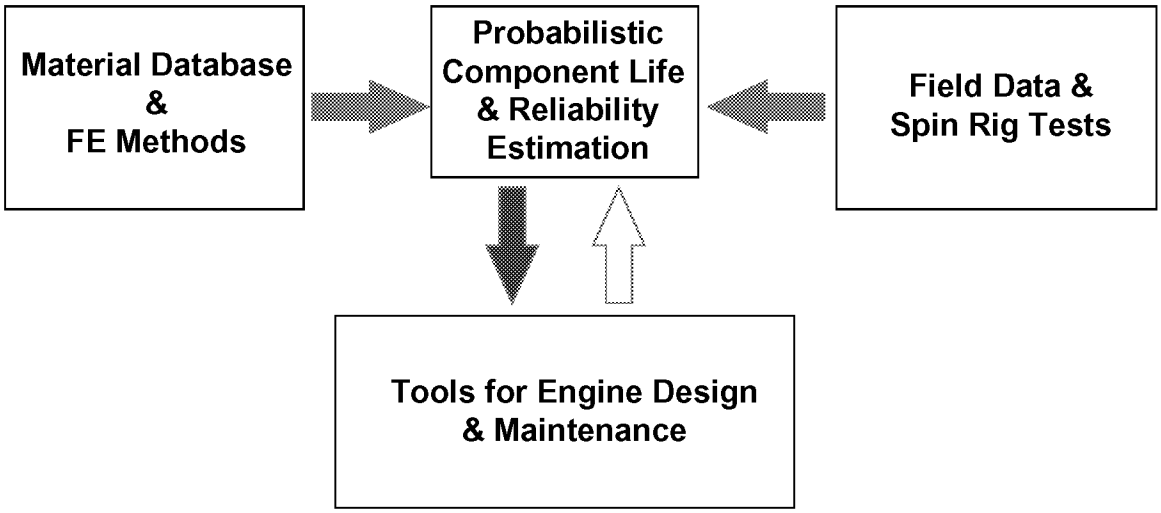
Basic Philosophy of the Project



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PARTICIPANTS

NASA GRC, Cleveland
UAL Maintenance, San Francisco
USAF Wright Labs, Dayton
NAVAIR, Pax River
Aeronautical & Maritime Research Laboratory (AMRL), Australia
Ohio Aerospace Institute (OAI), Cleveland

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APPROACH

Obtain Statistical Maintenance Database on:

- **Turbine Disk**
- **Fan Blade Hub**
- **Turbine Blade**
- **Combustor**

Define Operating Profile for Each Component

Statistically Analyze Data

Independent Probabilistic Life Prediction of Each Component

Compare Prediction with Field Data

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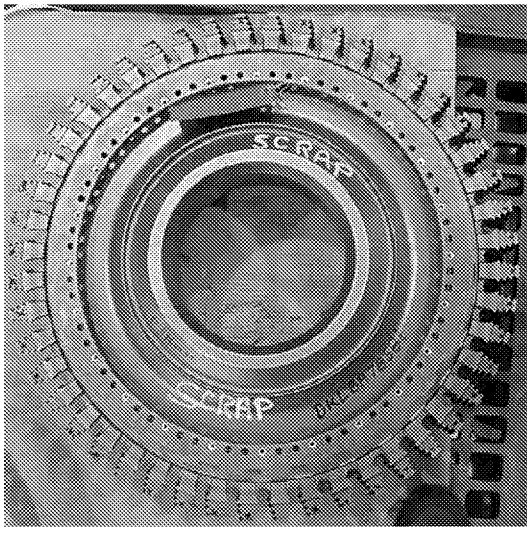
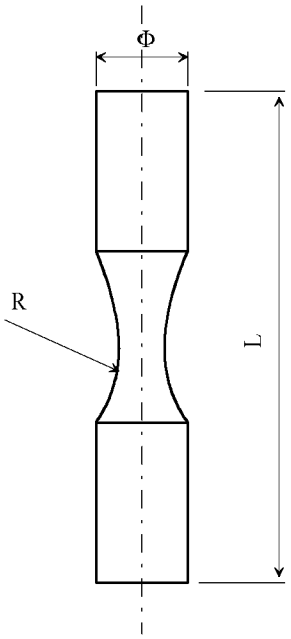
APPROACH—For Turbine Disks

- Test to Failure in Spin Rig
  10 Disks Retired for Time
- Develop Statistical Database
  for Disk Material For Life
  Prediction Purposes
- Apply Statistical Database
  to Disk Life Prediction



COUPON TESTING



Material: Disk material, IN 100

Static and Fatigue tests

Fatigue test matrix:

- **Stress levels: 3-4 appropriate stress levels**
- **Temperature range: 3-4 appropriate temperatures 72 °F to ~1400 °F.**

TEMPERATURE	STRESS			
	x_1	x_2	x_3	x_4
1. ROOM	✔	✔	✔	✔
2. 500° F		✔		
3. 1000° F		✔		
4. 1400° F		✔		

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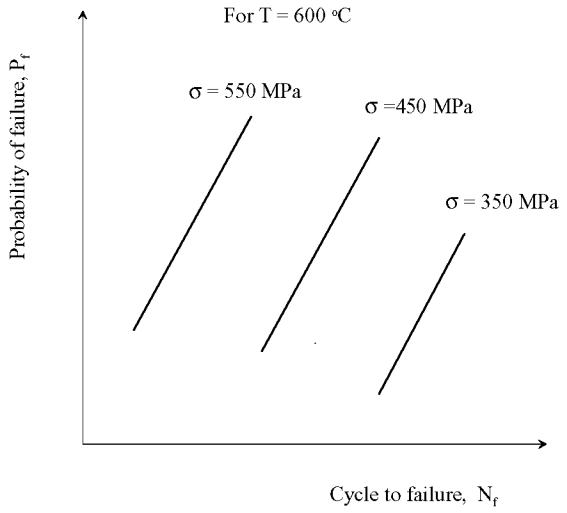
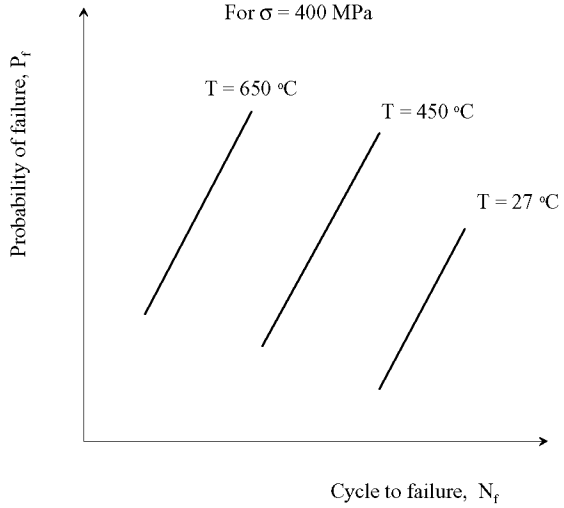
ANALYTICAL TOOLS

Sample: Weibull Analysis of Test Data



Effect of stress



Effect of temperature

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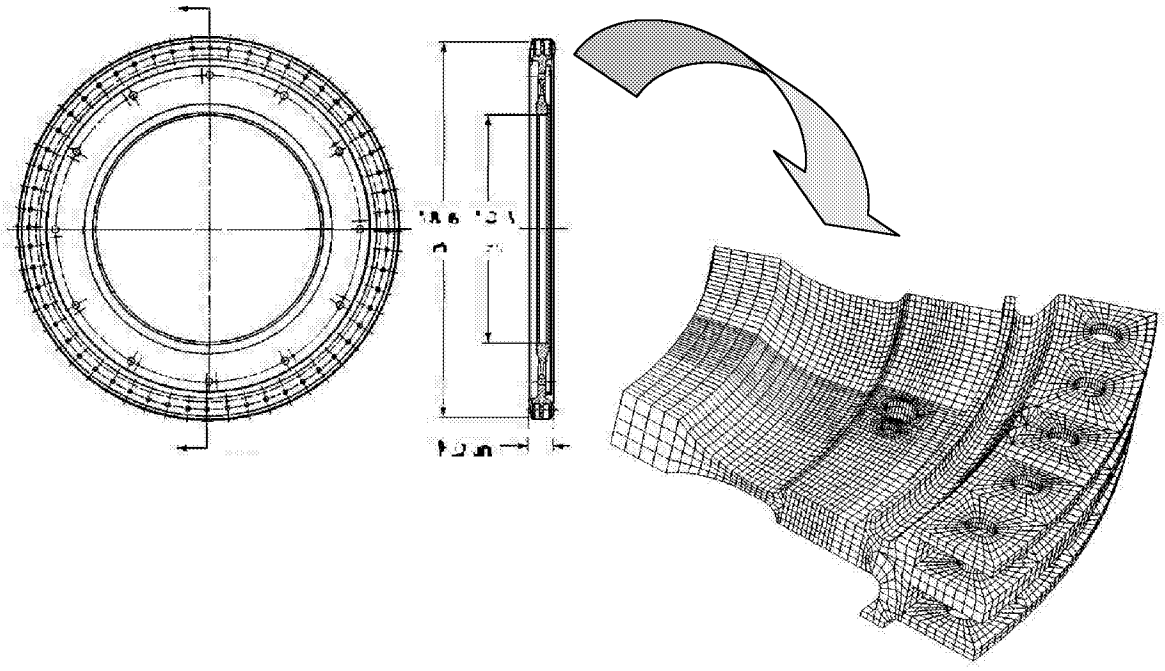
Finite Element Analysis Of Selected Components



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CURRENT STATUS

- Field Data Collected and Statistically Analyzed
- Retired Disks Collected for Spin Testing
- Material Procured for Coupon Test Specimens
- Perform Coupon Testing and Analyze Data
- FEA and Component Life Prediction
- Probabilistic Life Prediction and Compare with Field Data
- Endurance Tests of 10 Turbine Disks