Presentation Theme:
Analytical Approaches

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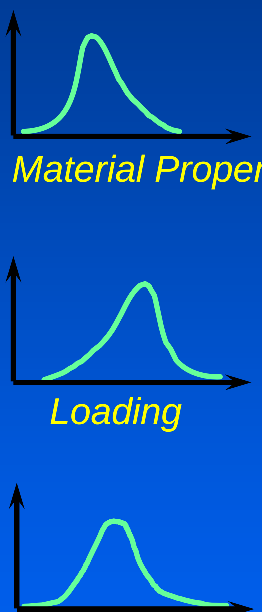
Motivations for Probabilistic Design & Analysis

- **Quantify risk and reliability**
  - Identify/reduce over-conservatism in design
  - Risk/cost-based design optimization
  - Risk/cost-based maintenance planning -- minimize life-cycle costs
- **Identify key variables & failure modes controlling design**
  - Identify critical data/research needs – better resource allocation
  - Minimize variation sensitivity -- more robust design
- **Reduce certification/reliability testing**
  - Minimize full scale testing -- use testing to validate models
  - Simulation more cost effective than full scale testing
  - Analysis can examine wider range of variables, scenarios

Reliability Analysis Based on Predictive Model

Model Input Uncertainties

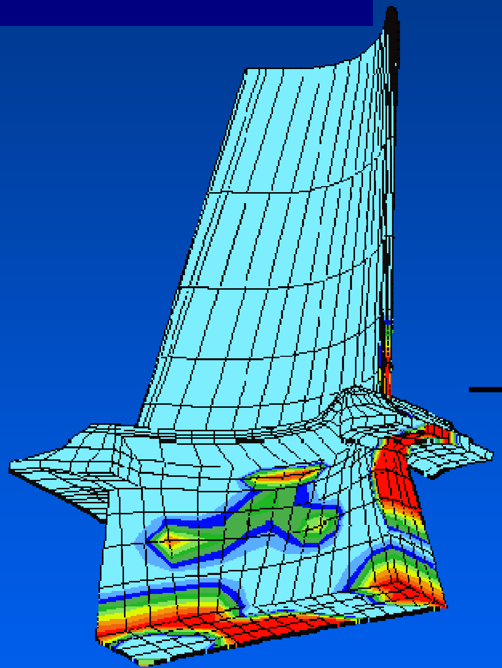


Material Property

Loading

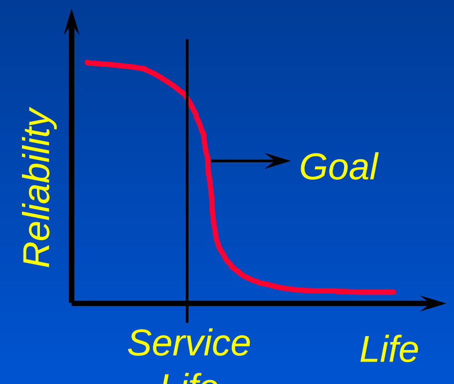
Geometry/ Boundary Conditions

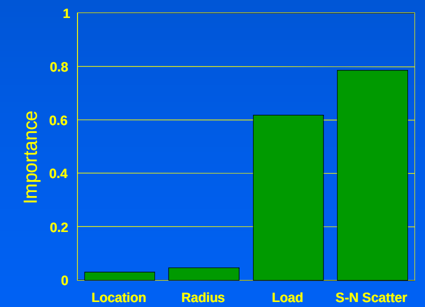
Physical Model



Response and Failure Model

Reliability Function





Complexity of most physical models rules out Monte Carlo Simulation

Tools for Reliability Analysis

- **NESSUS®** - General purpose probabilistic analysis
- **NASA Lewis (1985)** - Motivated by structural evaluation of space propulsion components such as the Space Shuttle Main Engine

- **DARWIN®** - Gas turbine rotor design risk assessment
- **FAA (1997)** - Motivated by uncontained engine failures from hard alpha defects in titanium structures such as at Sioux City, Iowa

- **PROF** - Aircraft risk assessment
- **USAF (1991)** - Motivated by need to quantify structural risks associated with inspections, replacement, and retirement of aging aircraft

General Purpose Analysis Code

Developer/User Considerations

- **Range of Users:** NASA, Air Force, Navy, Army, National Labs, NSF/NIH, Automotive, Heavy equipment, Rotating Machinery, Oil & Gas, Biomechanics, Medical devices
- **Range of Applications:** Component/system reliability, Reliability-based optimization, Reliability test planning, Inspections, Design certification, Risk-based cost analysis
- **Probabilistic Analysis Methods:** First/second-order reliability methods, Fast probability integration, Response surface, Monte Carlo simulation, Importance sampling
- **External Program Interfaces:** ABAQUS, NASTRAN, ANSYS, DYNA, NASGRO, Organization-specific, User-defined
- **Computing Platforms:** PCs → Super Computers
- **Support:** Bug-fixes, Training, Enhancements

Special Purpose Analysis Code

Developer/User Considerations

- **Specific Institutional Users/Steering Committee**: FAA, General Electric, Honeywell, Pratt & Whitney, Rolls-Royce Allison
- **Specific User Needs**: Integrate finite element stress analysis, fracture mechanics analysis, non-destructive inspection simulation, and probabilistic analysis to assess the risk of engine component fracture
- **Specific Technical Needs**: Defect formation and distribution modeling, crack nucleation and growth data and modeling, probabilistic modeling, software tools, technology transfer
- **Support:** Bug-fixes, Training, Enhancements

Special Purpose Analysis Code

User Considerations

- **Range of Users:** Air Force Research Laboratory, Aeronautical Systems Center, Air Logistic Centers, Contractors
- **Application:** Computes probability of fracture in metallic aircraft structures at the component, aircraft and fleet levels
- **Computational Considerations:** Consistent with Air Force deterministic damage tolerance analysis methods
  - Fracture mechanics-based crack growth and failure
  - Aircraft usage
  - Inspection
- **Probabilistic Inputs:** Fracture toughness, maximum spectrum stress, POD, equivalent initial and repaired flaw size
- **Support:** Bug-fixes, Training, Enhancements

The Future

- The user and application base is ever expanding
- Reliability based design now part of a growing number of companies critical design/manufacturing process
- Analysis complexity will grow as computer speeds grow
- Acceptance of analytical approaches will increase as physical data become available and with validation to large, complex tests
- Technology transfer and training are essential