Integrated Aeroservoelastic-Damage Tolerance- Reliability of Full-Scale Composite Aircraft

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2.6.4.4 Integrated Aeroservoelastic-Damage Tolerance-Reliability of Full-Scale Composite Aircraft

- **Interested Organizations:**
  UW, FAA, Boeing, USAF

- **UW Investigators:**
  E. Livne, K.Y. Lin, M. Tuttle

- **Objectives:**
  - Develop better understanding of effects of local structural and material variations on overall aeroservoelastic integrity
  - Develop computational tools (validated by experiments) for local/global linear/nonlinear analysis of integrated structures/ aerodynamics / control systems subject to multiple local variations/ damage
  - Establish a collaborative expertise base for response to FAA and industry needs, R&D, training, and education

2.6.4.4 Integrated Aeroservoelastic-Damage Tolerance-Reliability of Full-Scale Composite Aircraft

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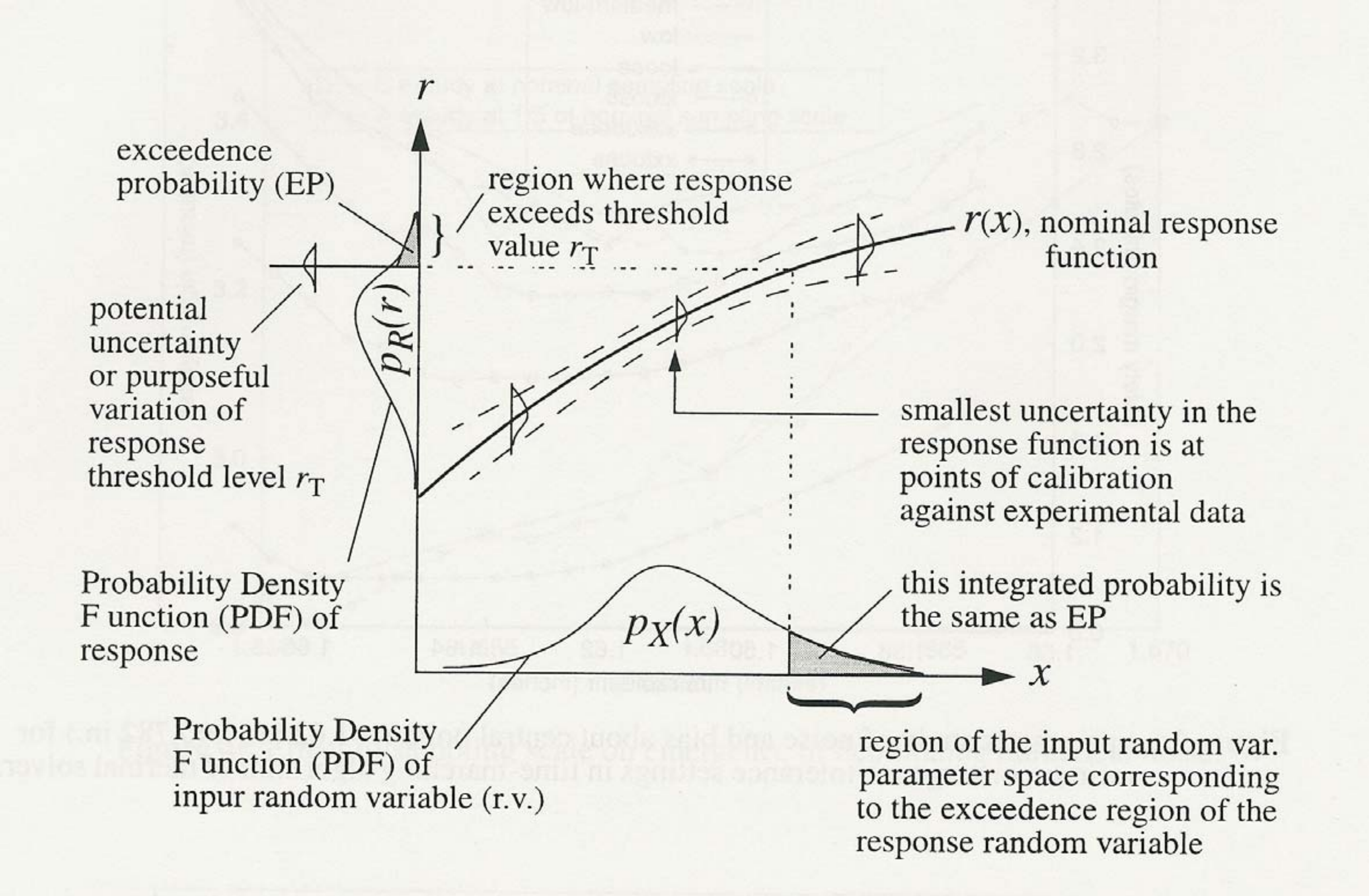
- **Payoffs:**
  - Better understanding of the underlying physics
  - Tools for rapid evaluation of structural uncertainty and digital flight control system modifications on load redistribution, local stresses, and resulting aeroservoelastic integrity
  - Identification of damage sensitive areas
  - Development of cost-effective fleet maintenance for a consistent level of safety
  - Foundation for future extension to advanced structures technology

Uncertainty Propagation:
Uncertain Inputs, Uncertain System



V.J.Romero, Sandia National Lab, AIAA Paper 2001-1653

Local / Global

- **Challenge:**

  Variation (over time) of local structural characteristics might lead to a major impact on the global aeroservoelastic integrity of flight vehicle components

- **Mechanisms of Local Degradation/ Structural Change:**
  - Material stiffness degradation
  - Moisture absorption (and changes in inertial characteristics)
  - Crack propagation and loss of local stiffness
  - Damage /repair effect on local stiffness
  - Delamination /delamination growth
  - Growth of a disbond
  - Joints/ hinges: nonlinearities, stiffness & damping variation
  - Discrete source damage (bird strike, etc.)

Nonlinear Aeroelastic Mechanisms

- **Structural sources: free-play in control surfaces, delamination, joint/hinge nonlinearity, amplitude-dependent damping**

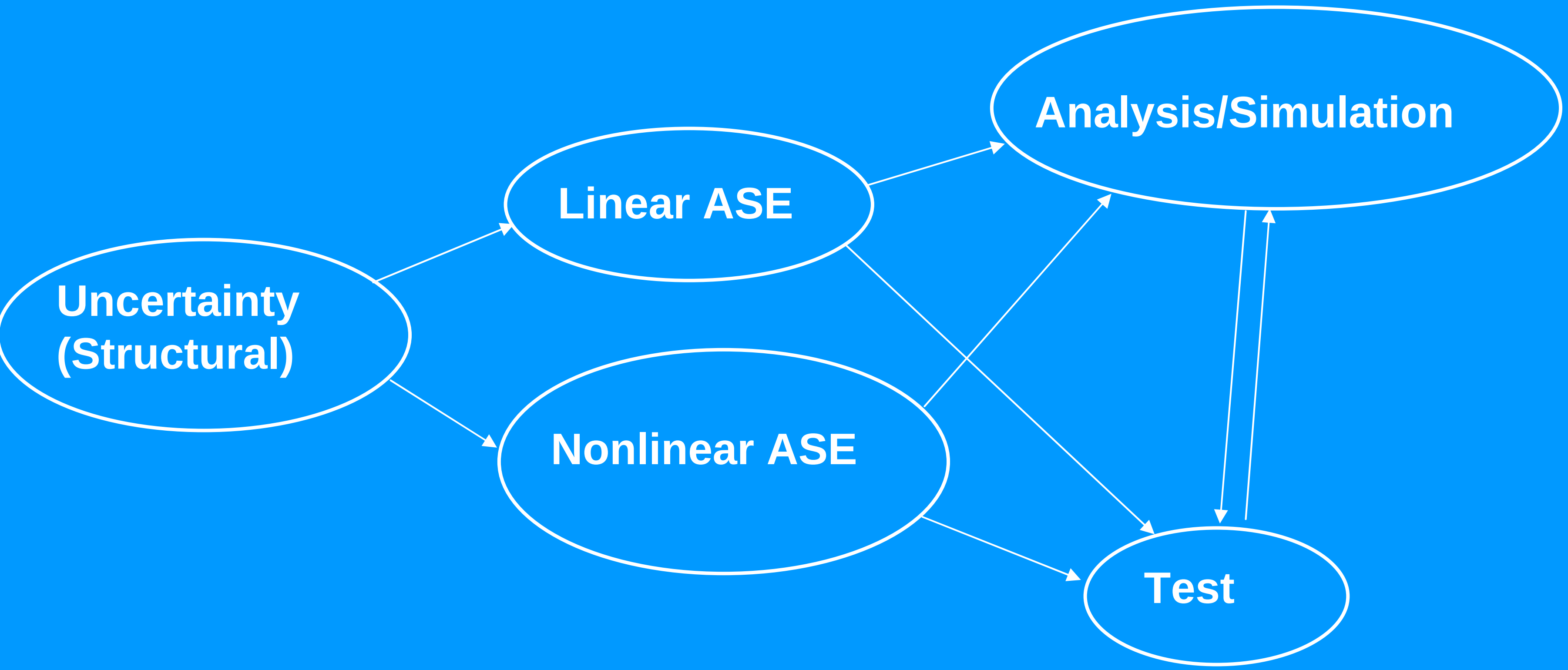
- **Consequences: limit cycle oscillation (vibration, fatigue), stability degradation**

Control / Structures

- **Challenge:**

  Digital flight control systems can be subject to considerable modifications over the life of an airplane. As a result, dynamic loads on the airframe can significantly change, affecting fatigue characteristics and the life span of the airframe

- At the same time, modifications of flight system control laws can be used to re-distribute loads and relieve stresses in critical areas. If, in the life of a fleet, fatigue problems are found in particular problem-areas, stresses in these areas can be relieved through activation of controls and load redistribution, reducing the cost and schedule of massive structural modifications


Analysis/Simulation
Linear ASE
Uncertainty (Structural)
Nonlinear ASE
Test

Approach

- Create computational capability for both deterministic and probabilistic analysis of linear and nonlinear ASE systems
- Utilize techniques of multidisciplinary design optimization for sensitivity and repetitive analyses of systems subject to large numbers of variations
- Test case selection for fundamental studies, guided by FAA and industry needs/ interests
- Computational studies of selected test cases, and selection of systems/ sub-systems for experimental work
- Construction of selected test systems, followed by structural and wind tunnel experiments and correlation with analytical predictions

Expand UW's Composite Aircraft Construction and Test Capabilities

Evolving Plan

Define/Review/Agree Specific Goals and Objectives	Boeing,UW,FAA
Select a Representative Composite Structure	Boeing,UW
Nonlinear Aeroservoelasticity (ASE)	
Control Surface Freeplay and Flutter	Boeing
Review of the Boeing Effort	UW(Livne),Boeing(ASE)
Define Options and the Roadmap	UW(Livne),Boeing(ASE)
Develop a Detailed Plan	UW(Livne),Boeing(ASE)
Uncertainty Quantification (UQ) for Linear ASE Systems	
Define Goals and Objectives	UW(Livne),Boeing(ASE)
Review the state-of-the-art	UW(Livne),Boeing(ASE)
Define Options and the Roadmap	UW(Livne),Boeing(ASE)
Develop a Detailed Plan	UW(Livne),Boeing(ASE)

Evolving Plan (continued)

Define Composite Damage and Degradation Scenarios	
Understand Reliability-Based Damage-Tolerant Design Methodology for Composite Airplanes Task	**Boeing(ASE), UW(Livne)**
Define Composite Damage/Degradation Scenarios	**UW(Lin, Tuttle), Boeing(Roe)**
Quantify Damage/Degradation for the Selected Configuration	**UW(Lin, Tuttle), Boeing(Roe)**
Develop a Detailed Plan of Analysis	**UW(Livne), Boeing (ASE)**
Develop a Structural Dynamics - Wind Tunnel Test Plan	
Define the Test Parameters	**UW(Livne,Lin,Tuttle) Boeing(ASE)**
Develop a Test Plan	**UW(Livne), Boeing(ASE)**

Boeing Team

- ASE
  - Carl Niedermeyer
  - Kumar Bhatia
  - Jim Gordon
  - John Kim
  - Jason Wu
- Composites
  - Jerry Roe
  - Dan Hoffman
  - ??

UW Team

- ASE
  - Eli Livne - Professor
  - Luciano Demasi – Postdoctoral Fellow
  - Levent Coskuner - Doctoral candidate
- Composites
  - Kuen Lin - Professor
  - Mark Tuttle – Professor
- Structural / Aeroelastic Reliability
  - ?

FAA

- Peter Shyprykevitch
- Larry Ilcewicz
- Gerry Lakin