The Future for Advanced Structural Materials and Computational Design

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Discussion Topics

• Background
• Complexity driving costs and development cycle time
• Computational methods applications
• Increased computational methods for materials & structures
• Need holistic system
Key Drivers for Aerospace Structures

- **Affordability**
  - Technology development costs
  - Design and non-recurring costs
  - Operations costs
    - Reduce weight - Lower fuel burn
    - Maintenance - Repair
  - Environmental – carbon footprint to build, operate and dispose

- **Performance**
  - Safety
  - Payload & range

- **Speed to market**
  - Leverage new technology
Aerospace Complexity

New technologies have rapidly transformed aerospace products into extremely complicated ones.
Complexity Driving Longer Development Cycles

767
Launch Order – 1978
Delivered – 1982
4 years

777
Launch Order – 1990
Delivered – 1995
5 years

787
Launch Order – 2004
Delivered – 2011
7 years

Market desires shorter cycles to take advantage of new capabilities
Complexity Drives Analysis Demands for Airframe Structure

Non-recurring Analysis
Hours / lb of Airframe

We’ve gone from 5:1 designers to analyst to 1:1 designer to analyst
Complexity Drives Increased Building Block Testing to Provides Data for Structural Analysis

- Component tests
- Sub-component tests
- Structural elements tests
- Allowable development
- Material specification development
- Material screening and selection

Analysis validation

Design-value development

Material property evaluation

Tier 1

Tier 2

Tier 3

~ size of structural test programs

1980s | 2000s
---|---
2 | 2
2 | 15
25 | 2,500
500 | 10,000
5,000 | 100,000

Major growth in cost & time
Expanding Design Space is Rapidly Increasing Complexity

Material Combinations, Fiber Orientations, Manufacturing Techniques, . . .
Going Forward

Given the complexity, how do we reduce costs and shorten development cycles?
Computational Methods Widely Used in Other Engineering Disciplines
Computational Effect on Product Design Cycle

Computer Aided Design has reduced design time 60%
Certify and Qualify New Materials & Structures Faster

Goal is to Provide a Modeling, Simulations and Analysis Approach Supported by Experience, Test and Demonstration

Time to Insertion Readiness Reduced by 55%
Atoms to Aircraft – Applying Computational Methods Down the Structural Value Chain

Materials & structures designed, analyzed, and qualified in digital form, with requirements driven by system & life-cycle requirements

- **Reduced time and cost**
- **Increased design space**
- **Increased performance**

Constituent Design

Material Configurations

Molecular Modeling

Material Models

Element Design

Computational Allowables

Failure Modeling

Sub-Component Designs

Component Designs

Virtual Testing & Sim

Computational Design Values

Vehicle

Full Scale

- **Design Values**
- **DaDT**
- **Analysis Validation**

- **Structural Performance**
- **Damage Tolerance**
- **Static & Fatigue**
- **Analysis Validation**

- **Static**
- **GVT**
- **Fatigue**
- **Flight**

- **Mechanical Props**
- **Knock-downs**
- **Environmental**
- **Effects of Defects**

- **Producibility**
- **Accept/Reject**
- **NDT Standards**

- Material Development
- Process Development
Atoms to Aircraft

Building Block Testing Provides Data for Structural Analysis

Tier 3
- Full-scale tests
- Analysis validation
- Design value development
- Major growth!

Tier 2
- Material property evaluation
- Material property development
- Material development
- Major growth!

Tier 1
- Sub-component tests
- Computational models
- Computational analysis

Constituent Design
Material Configurations

Material Development
- Process Development
- Accept/Reject
- Assembly
- NDT Standards

Material Models

Molecular Modeling

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Failure Modeling

Sub-Component Designs

Component Designs

Virtual Testing & Sim

Full Scale

Vehicle

Computational Design Values

- Design Values
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Mechanical Props
- Envelope
- Effects

Shorten Material Development Cycle from ~12+ years to ~6 years
Molecular Modeling & Predictive Laminate Performance

Accurate predictive data in an order of magnitude less time
Structural Materials also Need Multi-Functional Performance

Interactions between these conditions complicates analysis
Manufacturing Processing Effects

- Producibility limits
- Inspection Standards
- Quality & Effects of Defects
- Process Tolerances
- Manufacturing Scale-up
- Assembly Tolerances

Structural Methods Must be Tolerant of Materials and Processing Variability
Linking Modeling & Simulation of Other Effects

- Producing Tolerances Build-ups – GD&T
- Quality & Effects of Defects
- Process Tolerances
- Electromagnetic effects
- Effects of Lightning Strikes

- Material Development
- Process Development
- Producibility
- Inspection Standards
- Quality & Effects of Defects
- Process Tolerances

- Molecular Modeling
- Constituent Design
- Element Design
- Material Configurations
- Material Models
- Computational Allowables

- Component Designs
- Sub-Component Designs
- Failure Modeling
- Computational Design Values

- Design Values
- DaDT
- Analysis Validation
- Mechanical Props
- Knock-downs
- Environmental
- Effects of Defects

- Full Scale
- Vehicle
- Virtual Testing & Sim
- Static
- GVT
- Fatigue
- Flight

- Flammability Performance
- Producibility
- Accept/Reject
- NDT Standards
- Flammability Performance

2011 Users Conference
Summary

• Complexity drives increased costs and longer development

• Computational methods must be extended to routinely handle complex application design spaces

• Material properties must be linked to structural simulations seamlessly

• Modeling and simulation activities should be linked into a more holistic system

We must reduce costs and shorten development cycles