Composite Materials & Structures Technologies At NASA Langley Research Center

Mark J. Shuart
NASA Langley Research Center

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Outline

- Today's Lessons Learned
- Materials and Structures Technology Development
- Future Materials and Structures Applications

Materials, Processes, and Manufacturing

Lessons Learned

1. Materials development in conjunction with product development creates undue risks.

2. **Experienced materials and processing engineers should be included in the design phase and must be readily available to correct problems in production processes.**

3. Manufacturing process scale-up development tests should be conducted to optimize the production processes.

4. Co-curing and co-bonding are preferred over secondary bonding which requires near perfect interface fit-up.

5. Mechanically fastened joints require close tolerance fit-up and shimming to assure a good fit and to avoid damage to the composite parts during assembly.

6. Dimensional tolerances are more critical in composites than in metals to avoid damage to parts during assembly. Quality tools are essential to the production of quality parts.

7. Selection of the tool material depends on part size, configuration, production rate, quantity, and company experience.

8. Tool designers should anticipate the need to modify tools to adjust for part springback, ease of removal, or maintain dimensional control of critical interfaces.

Structural Design, Analysis, and Testing

Lessons Learned

1. Design and certification requirements for composite structure are generally more complex and conservative than for metal structure.

2. Successful programs have used the building-block approach with a realistic schedule that allows for a systematic development effort.

3. The use of basic laminates containing 0/90/+45/-45 plies with a minimum of 10% of the plies in each direction is well suited to most applications.

4. Mechanical joints should be restricted to attachment of metal fittings and situations where assembly or access is impractical using alternative approaches.

5. Large, co-cured assemblies reduce part count and assembly costs but may require complex tooling.

6. Structural designs and the associated tooling should be able to accommodate design changes associated with the inevitable increases in design loads.

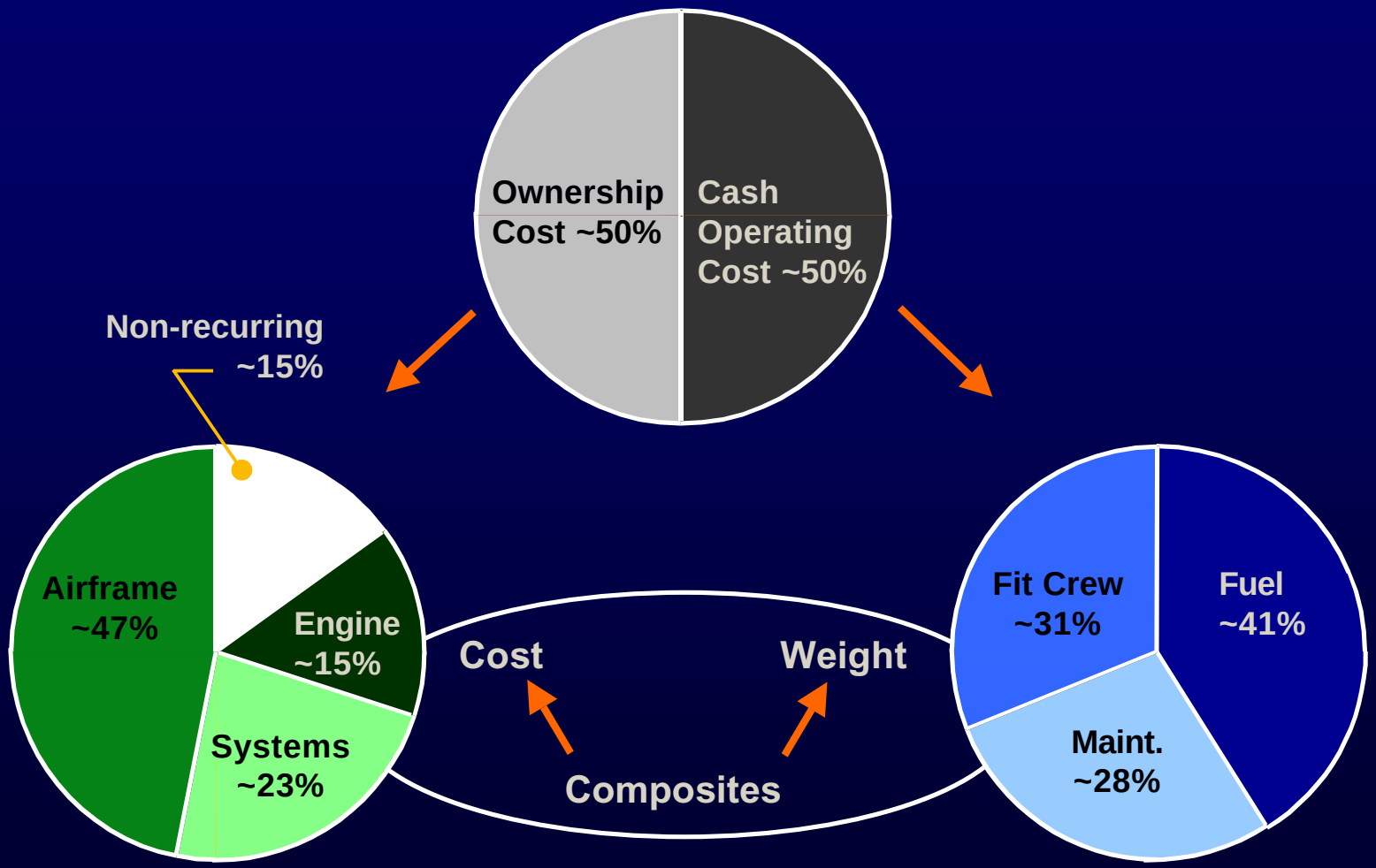
7. Understanding and properly characterizing impact damage would eliminate confusion in the design process and permit direct comparison of test data.

Quality Control, NDE/I, and Supportability

Lessons Learned

1. Automated processes can help to reduce QC costs.
2. Inspection and quality control should focus on aspects of the process and part that have a direct bearing on part performance.
3. Determine and understand the effects of defects on part performance.
4. **Supportability should be addressed during design so that composite structures are inspectable, maintainable and repairable.**
5. Most damage to composite structure occurs during assembly or routine maintenance of the aircraft.
6. Repair costs are much higher than for metal structures.
7. Improved Standard Repair Manuals are needed for in-service maintenance and repair.
8. Special long-life and low-temperature curing repair materials are required.
9. Moisture ingestion and aluminum core corrosion are recurring supportability problems for honeycomb structures.

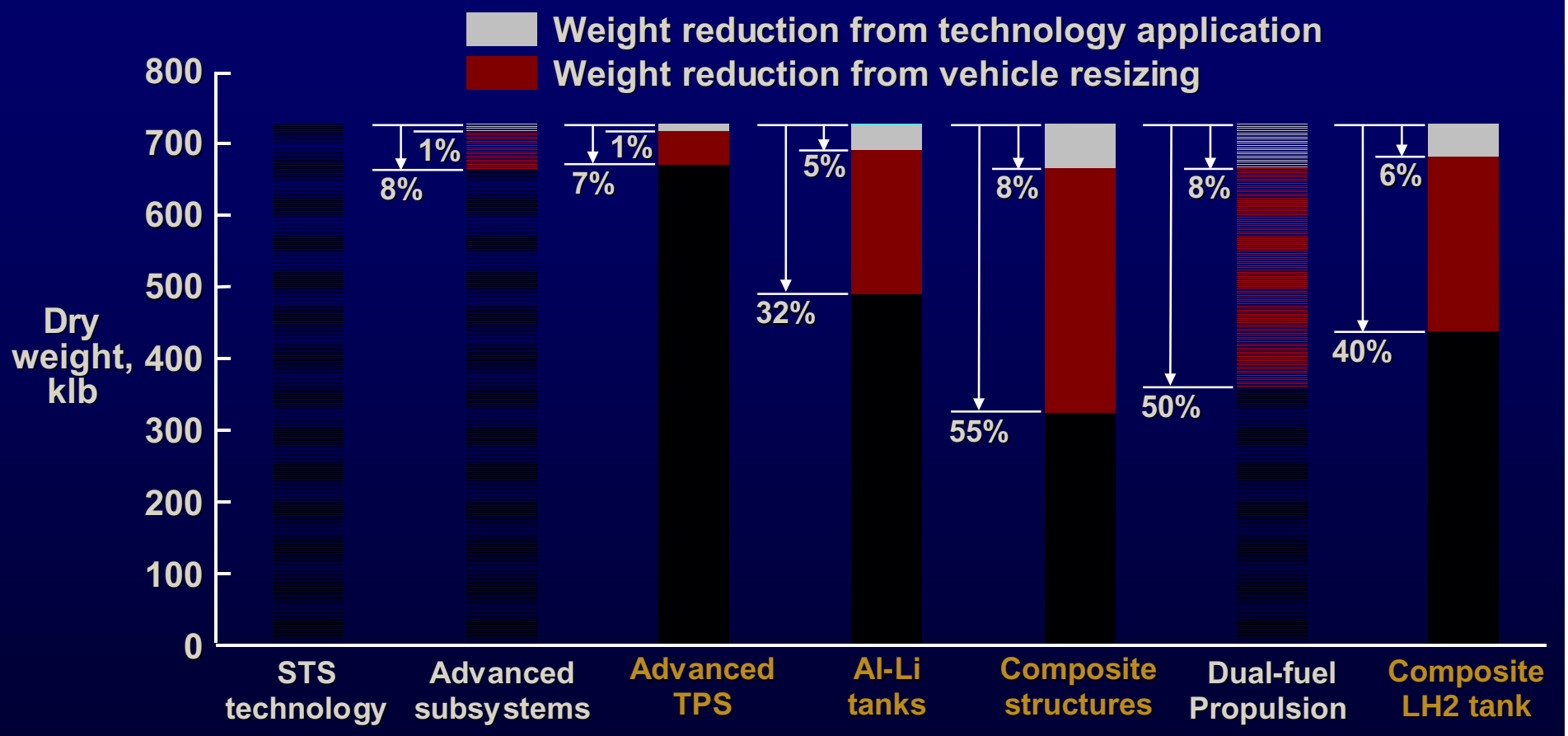
Impact of Composites on Aircraft Direct Operating Costs



Ownership Cost
(Less Profit)

Cash Operating Cost

Predicted Weight Savings from Incorporation of Advanced Technologies

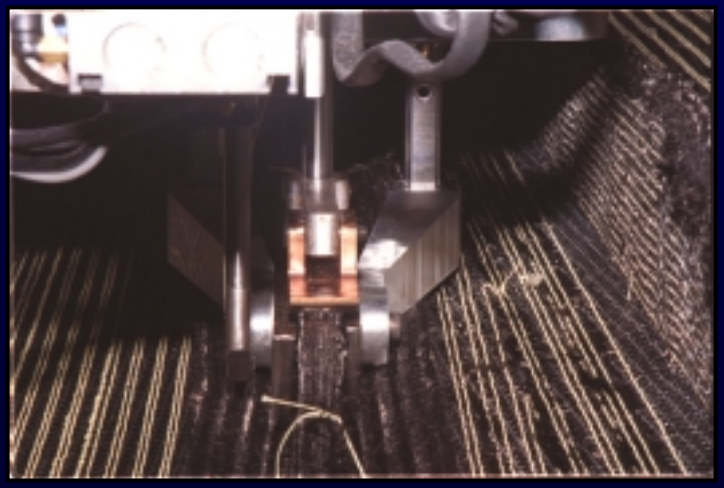


Major Weight & Cost Reductions are Possible from Advanced Airframe Structures and Materials!

Stitched Semi-Span Wing Lower Cover Preform

AST Composite Wing Program Cover Panel Cost Verification and Improvements

Original Stringer Jig Tooling Concept



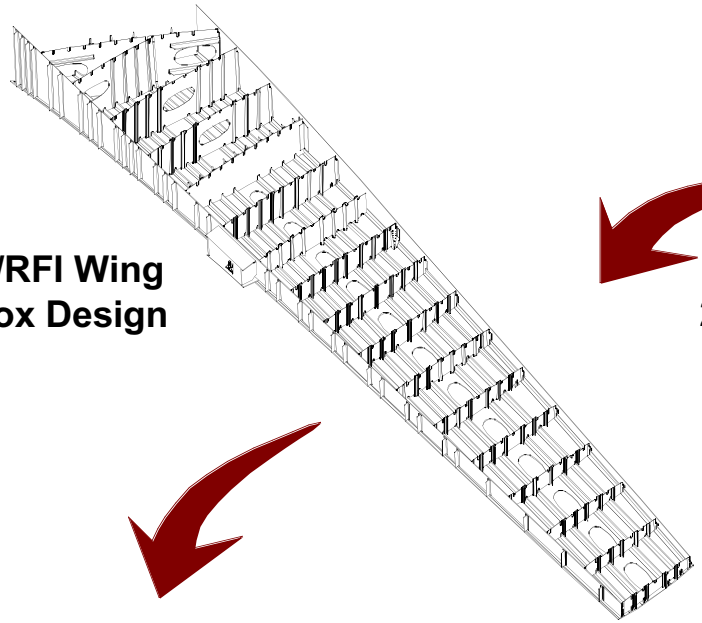
Jigless Stringer Tool Concept

Accomplishments to Date

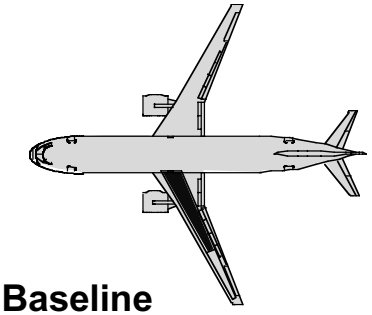
- Projected cost savings (22%) above program goal of 20%
- Reduced touch labor component of cost by 50%
- Demonstrated higher learning than predicted (79% vs. 85%)
- Optimized stitching sequence
- Improved quality through tooling improvements
- Eliminated use of all stringer jig tooling

Stitched/RFI Composite Semi-Span Wing Test Article

AST Composite Wing Program
Semi-Span Test Article

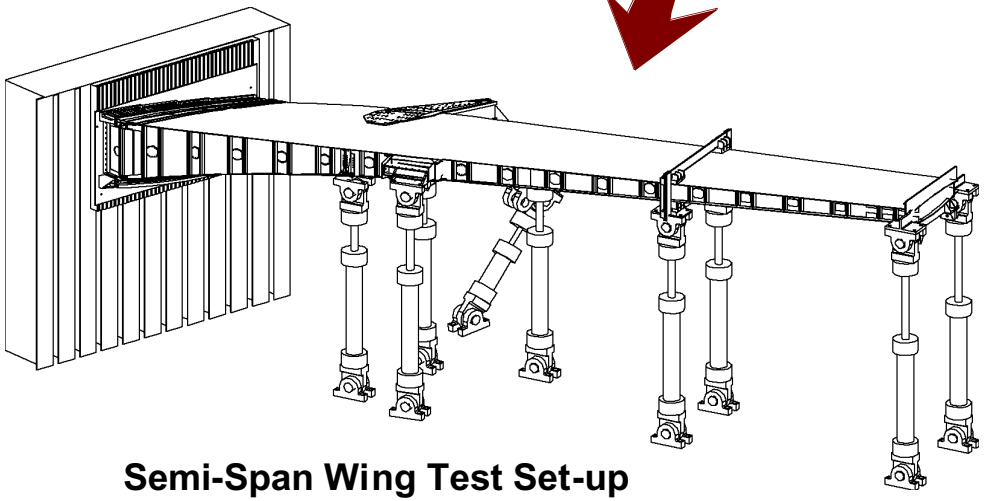


S/RFI Wing
Box Design



220-PAX Baseline
Configuration

Mounted on NASA
Langley Strong-Back



Semi-Span Wing Test Set-up

Status

- Test article delivered to Langley Sept. 1999
- Test conditions
  - 1G down load
  - Brake roll
  - 2.5G up load

IM7/PETI-5 Skin Stringer Cobond Panel

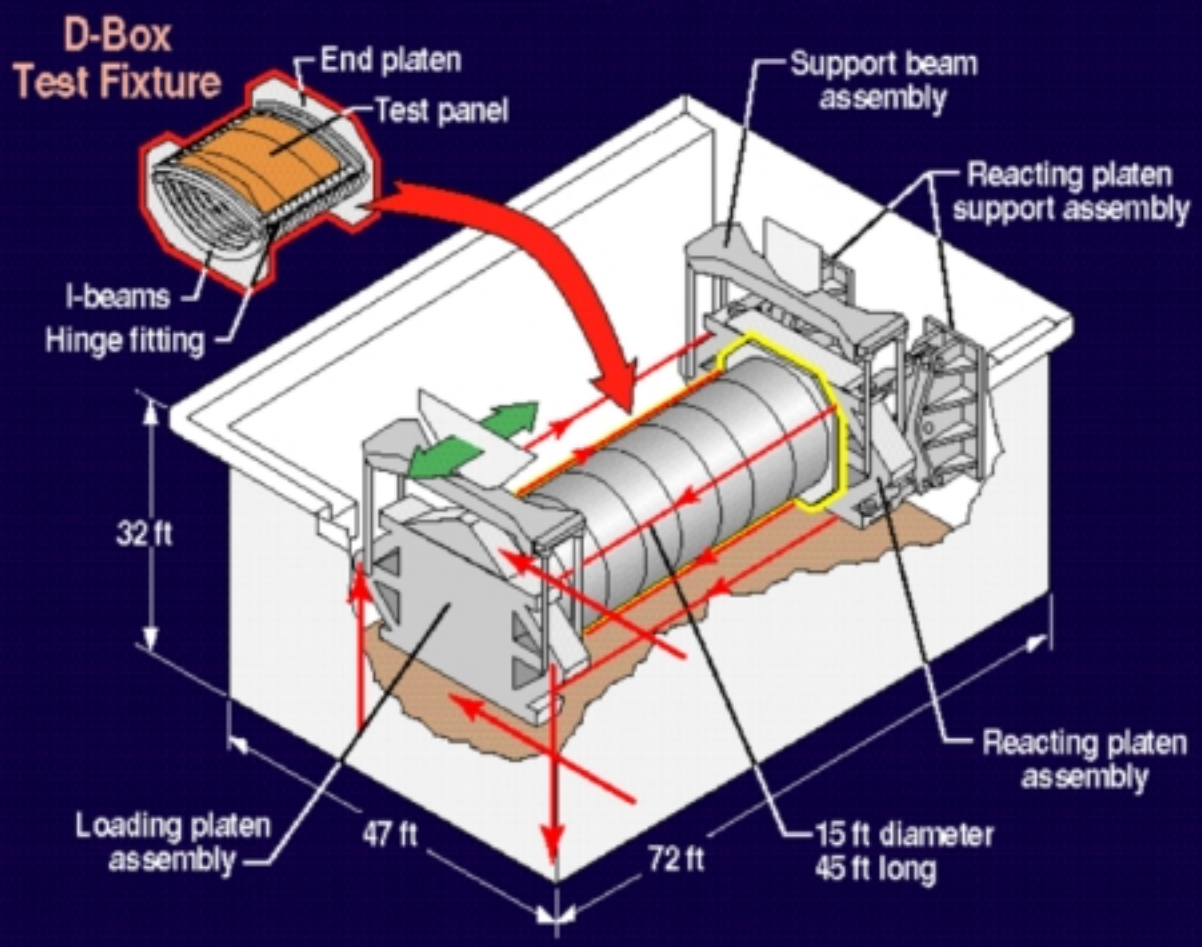
Objective

Demonstrate the Cobonding process developed for small skin stringer panels can be successfully scaled-up for larger structures.

Accomplishment

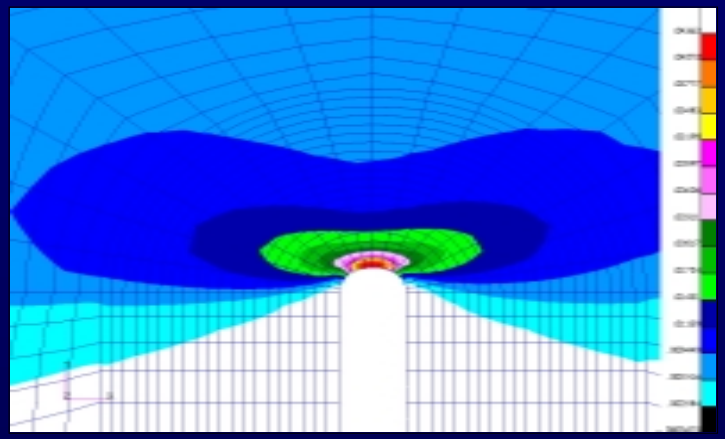
- High mechanical properties and long term stability
- Curved fuselage panel, 6ft. By 10ft.
- Uniaxial compression tests conducted with impact damage (to DUL) and discrete source damage (>DLL, 181.7 kips)

Combined Loads Test Machine

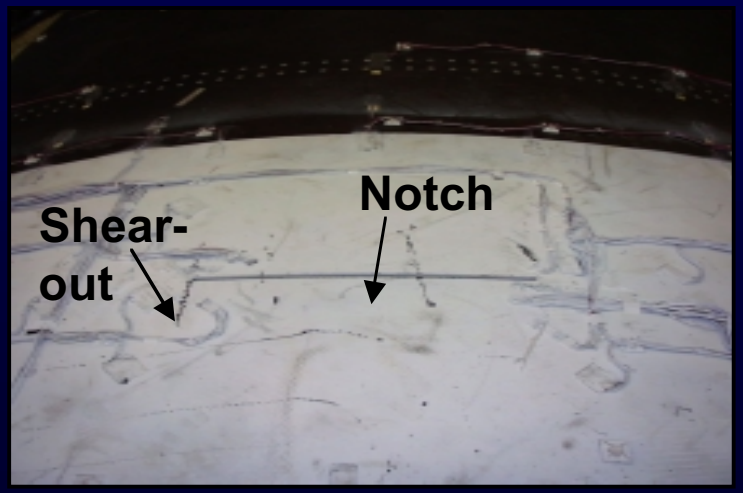


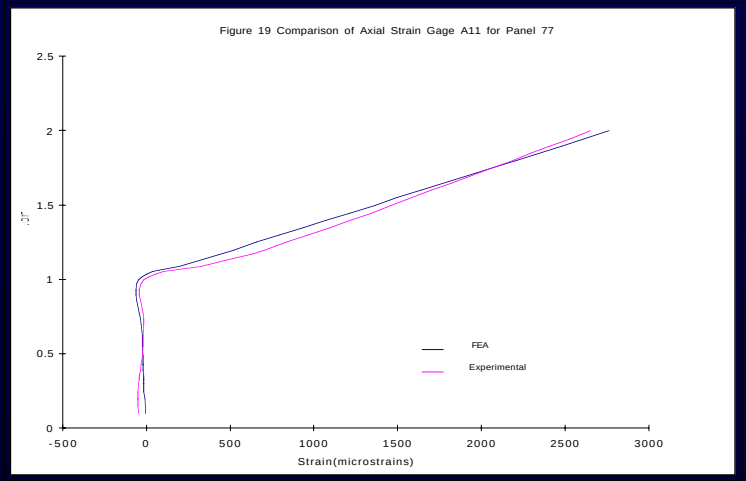
Curved Composite Sandwich Crown Subcomponent Test

Looking Down on Panel in COLTS



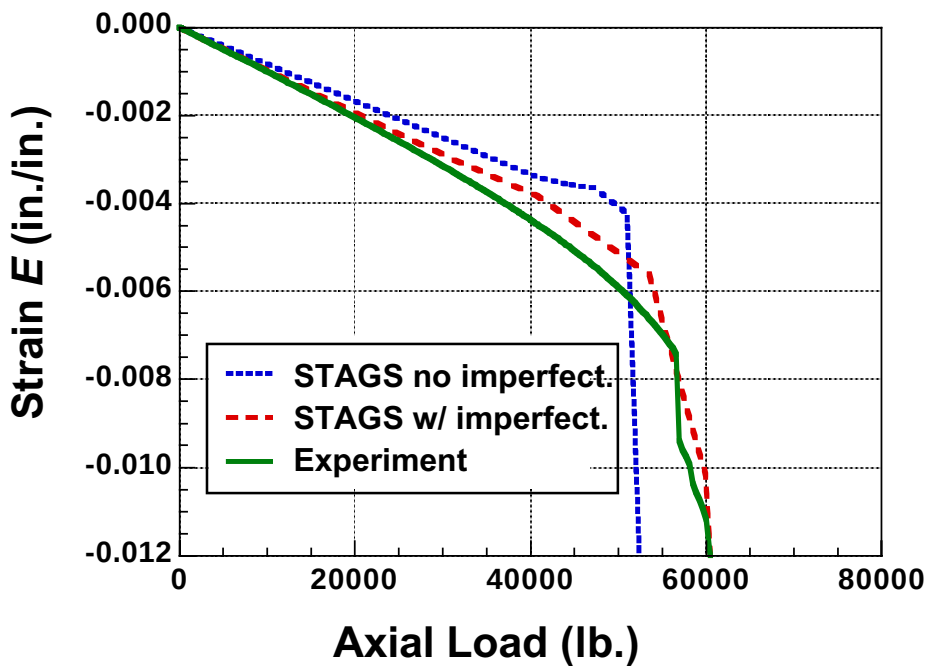
Predicted Strain Contours Near Notch Tip

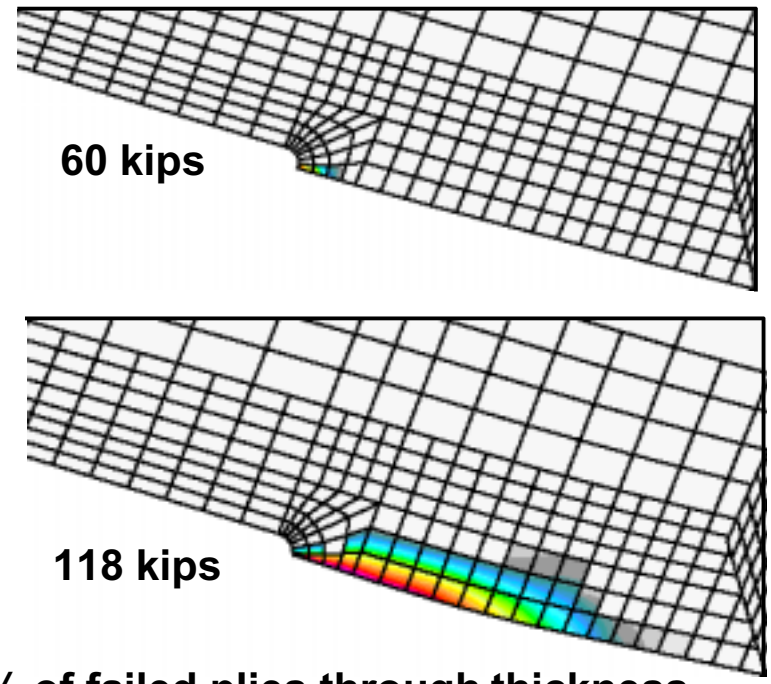




Measured Axial Strain -vs- FEA Prediction

STAGS Progressive Failure Analysis of Curved Notched HSR Panel

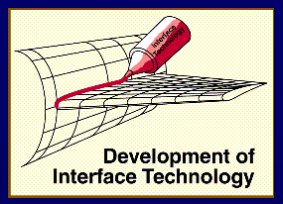




% of failed plies through thickness
(red = 100%)

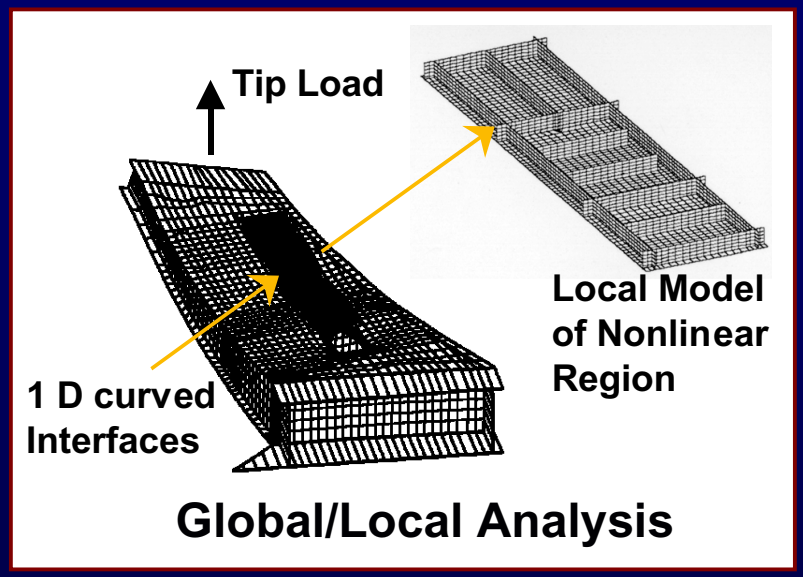
	Analysis no imperfections	Analysis w/ imperfections	Experiment
Damage initiation load (kips)	51	53	57
Panel failure load (kips)	120	118	118

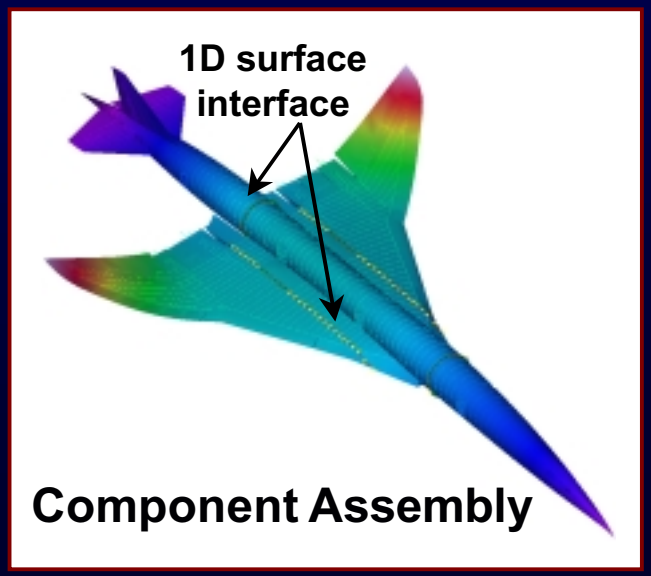
Interface Technology into MSC/NASTRAN



Enabling Capability for Connecting Dissimilar Meshes along Curve or Surface Interfaces

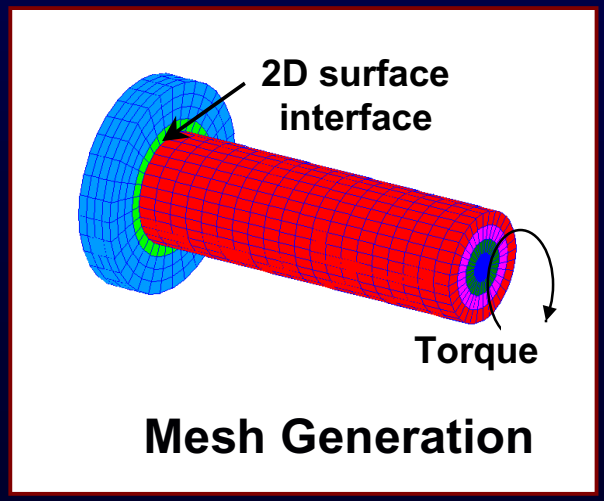
- 1D Curved Interface Capability for 2D Shell FEM Models
- 2D Surface Interface Capability for 3D Solid FEM Models
- Shell-to-Solid Transition Interface Capability





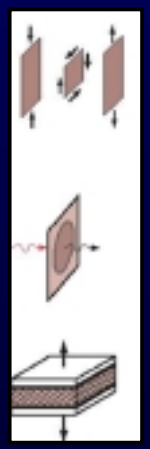
Facilitates

- Global/Local Analysis
- Component Assembly
- Automatic/Manual Mesh Generation
- Adaptive Refinement

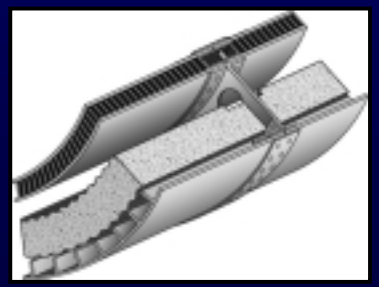


Development of Advanced Cryotank and Airframe Structures Building-Block Approach

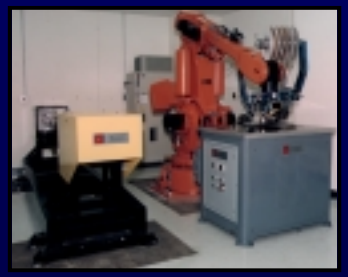
- Mechanical Properties
- H2 Permeability tests (4 in. x 4 in.)
- Flatwise Tension Tests (2 in. x 2 in.)



Coupon Testing for Material Properties



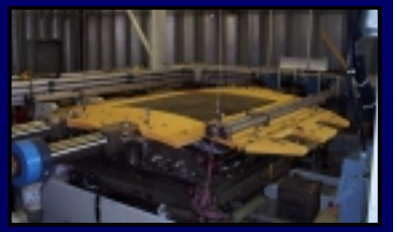
Design Concepts and Analysis Development



Manufacturing Process Development and Scale-up

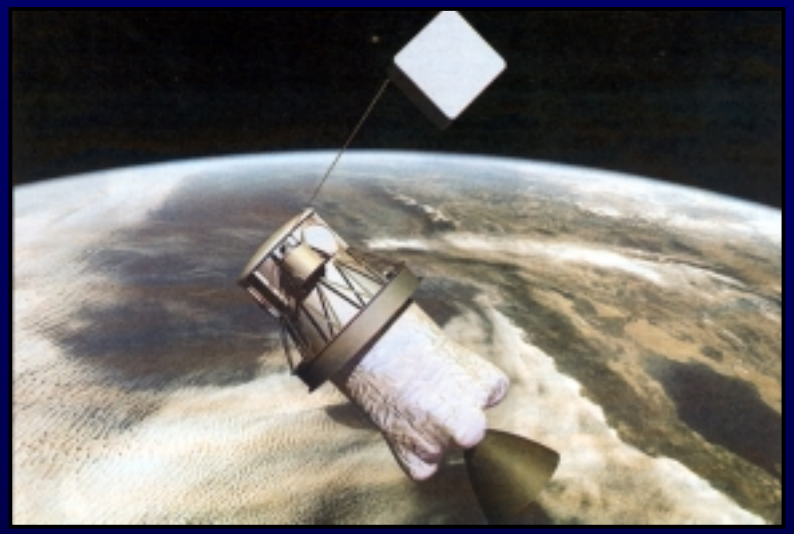
Concept Demonstration at Component Level

- Gr-Ep/Foam Panel (LaRC TEEK HH)
- Thermally Cycled PMC/Foam Insulation
- Fluted Core Splice Joint



Full-Scale Structural Verification

Application of LaRC-Developed Materials



Tethers for Propellant-Free Propulsion

- Atomic Oxygen Resistance
- High Specific Strength
- Selected for ProSEDS Flight Demonstration

Solar Thermal Propulsion Upperstage

- Low Color, Low Solar Absorption
- High Reflectivity
- Selected for Primary Collector on Boeing's SOTV

Programs, Products, and Services for 2009

1. Application-Specific Aero-space Programs
   - Affordable "Point-to-Point" Personal Aircraft
   - Large Transport Aircraft (e.g., Blended-Wing Body)
   - Sensorcraft
   - Lunar/Mars Transportation Vehicles for Human Exploration
2. Brilliant Products and Systems
   - Multifunctional Materials and Structures
   - Highly-Integrated Instruments and Structures for Sensorcraft
   - Ultra-Smart Materials and Structures
   - Radiation Effects and Radiation Shielding Materials
3. Computing, Design, and Analysis Methods and Tools
   - Optical, Quantum, and Biological Computers
   - Fully Immersive Concept-To-Flight Design Environment
   - Flexible Integration of Modeling and Design Techniques
   - Intelligent agents, Fuzzy, and Nondeterministic Analysis Methods
4. Experimental Methods and Test Techniques
   - Remote access to facilities and laboratories through virtual reality
   - Automated, Digitally-Controlled Testing Techniques

Structures & Materials Skills Evolution

- Classical metals, polymers, ceramics, and composites development skills transitioning to nano-, smart-, functionally graded, multifunctional, environmentally friendly, computational, and biomimic designed M&S systems

- Classical applied mechanics, dynamics, aeroelasticity, and computational methods skills transitioning to multidisciplinary computational aero-servo-thermal-structure-materials methodology; and mathematically nondeterministic, nonlinear, fuzzy, probabilistic, design and analysis tools

- Traditional point-by-point external diagnostic sensors skills transitioning to intelligent, distributed, in-situ diagnostic, and self-healing systems.

Concluding Remarks

- Today's lessons learned are the foundation for future designs
- New materials, processing, structural concepts will enable dramatically improved applications
- Reusable launch vehicles and future spacecraft will demonstrate advanced materials and structures technologies