



INTEGRATED AIRFRAME TECHNOLOGY FOR AFFORDABILITY  
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# INTEGRATED AIRFRAME TECHNOLOGY: the Future of Advanced Composites

David F. Taggart

Design Specialist

Lockheed Martin Skunk Works

TRANSPORTATION BEYOND 2000

Engineering Design for the Future

September 26-28, 1995

NASA Langley Research Center, Hampton, VA

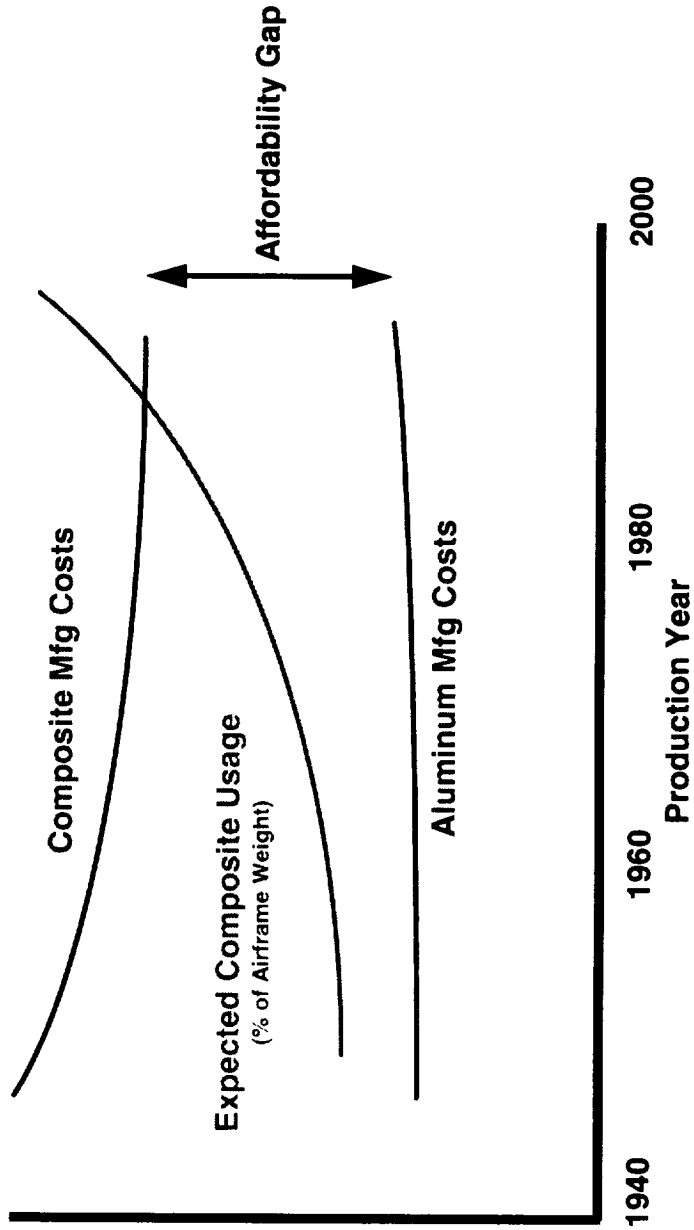
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## Cost Trend

- Increased Demand for Performance with a Decreasing Tolerance for Cost



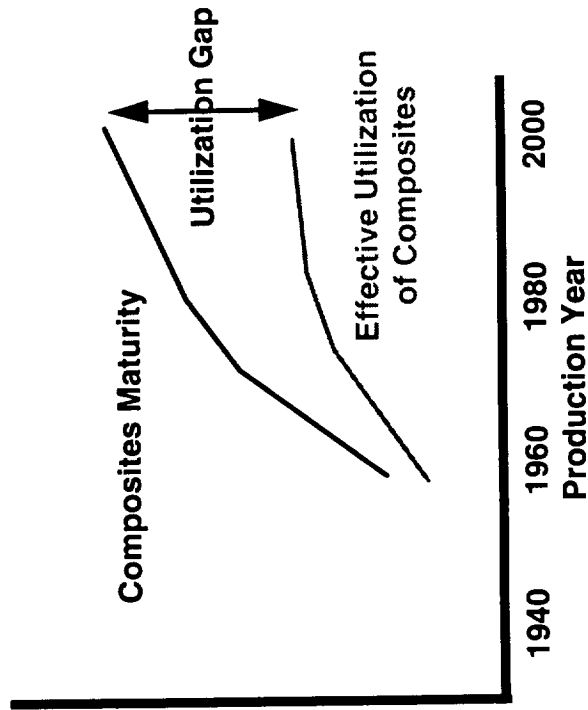
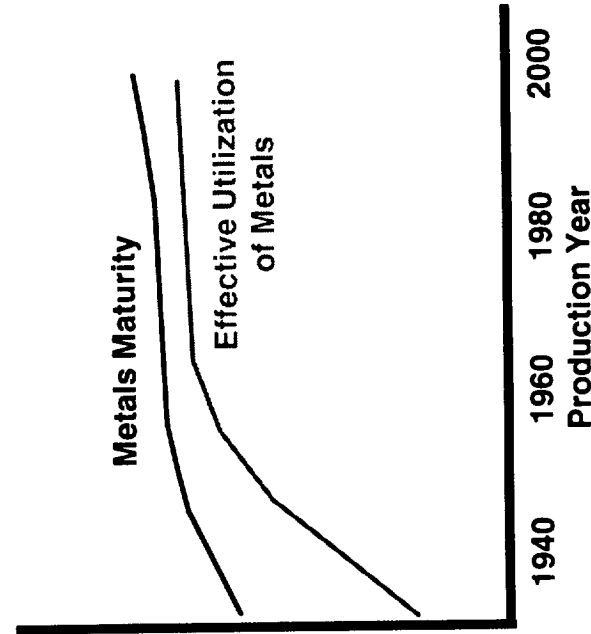


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## Technology Trend

- A gap exists between the potential of advanced composites and our ability to effectively utilize them (cost/weight)





## The Challenge



- Airframes must provide ever increasing performance at an *affordable* cost
- *Breakthrough* cost reduction compared to current airframe technology
- Design and Manufacturing *Integration*...

## Strategy



- ***A new paradigm:*** revolution in the integration of design and composite manufacturing
- ***System level focus:*** must provide space for innovation, primarily composites
- Tie to real aircraft ***performance*** needs
- Small, creative, ***highly focused*** team
- ***Interdependent*** Issues: Design, Tooling, Fab, Assy
- Must build to demonstrate ***feasibility, path to production***



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## Integrated Airframe Paradigm



- Three Facets of Integration:
  - Integration of components to form fewer, larger, globally complex components
  - Integration of design with composite material unique characteristics and material forms
  - Integration of design with cost effective attributes of existing and emerging manufacturing technologies



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## Integrated Airframe Paradigm

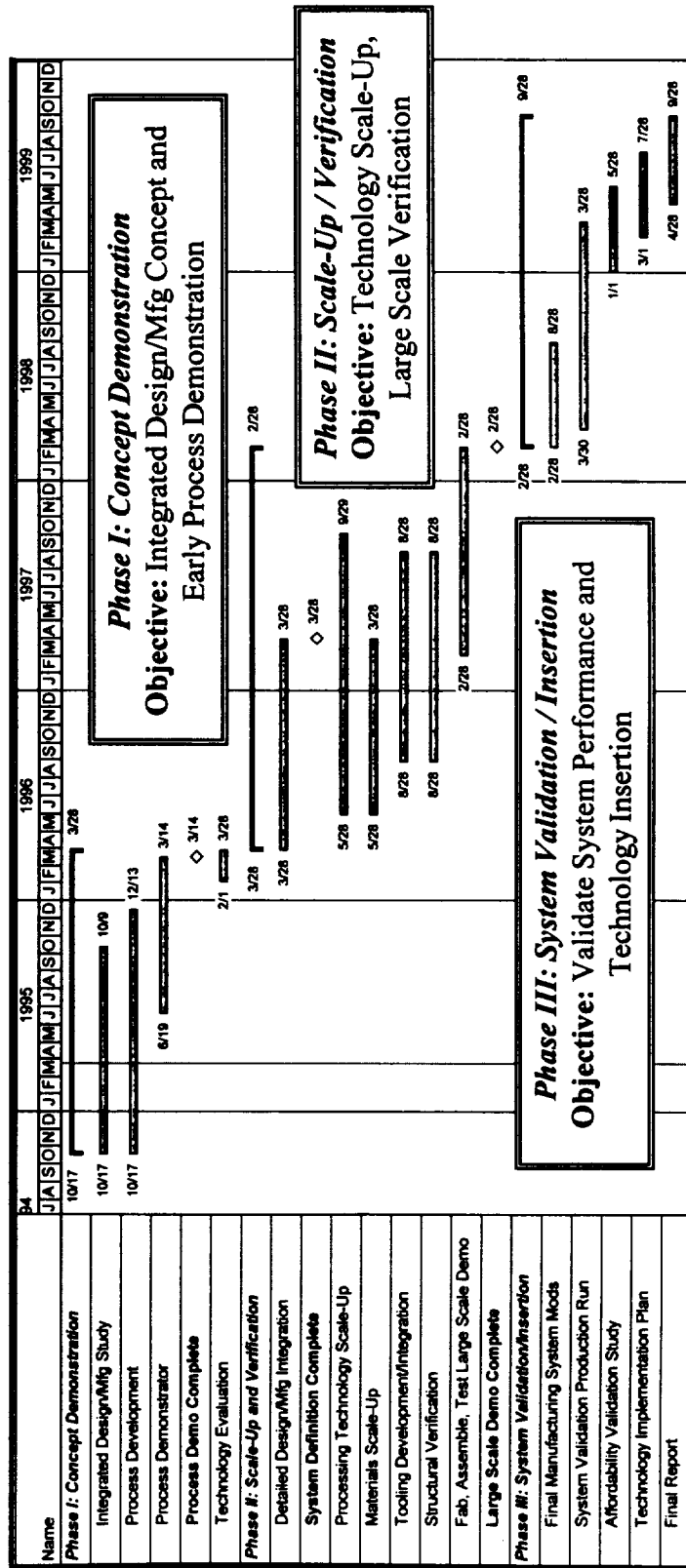


- Multi-Functional Components
- Fastenerless Assembly
- Structure-as-Tooling
- Highly Tailored, Continuous Load Paths
- Marry Design with Fab / Assy
- Integral Wing / Fuselage
- Electron Beam Curing, Fiber Placement, Large Scale Resin Infusion
- *Expand Traditional Solution Space*



# IATA Mission Statement

*Develop and Demonstrate a System which Integrates Composite Specific Design Approaches with Cost Effective Manufacturing Technologies to Produce Affordable, High Performance Carbon Composite Aircraft Structures in Prototype or Production Quantities*



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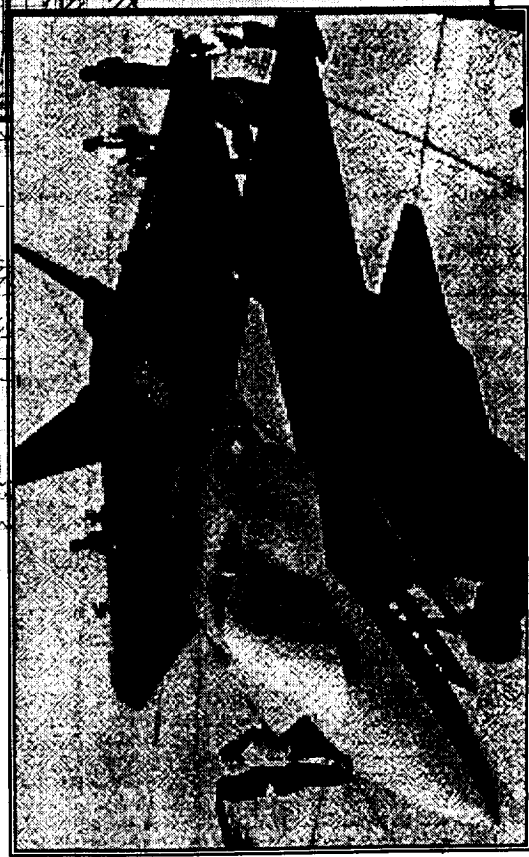
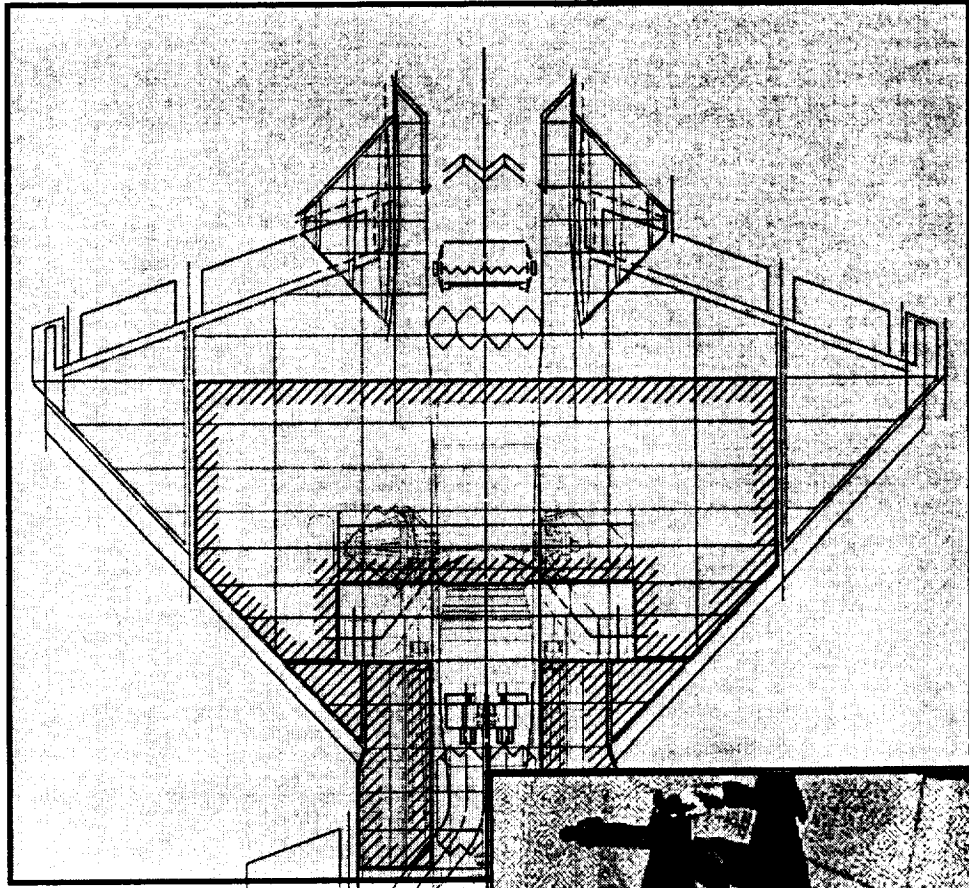




# JAST/ASTOVL Configuration 140

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**Blended Wing/Body**  
**Internal Weapons**  
**High G Loading**  
**Weight Critical**  
**High Packing Factor**  
**Wide Temperature Range**

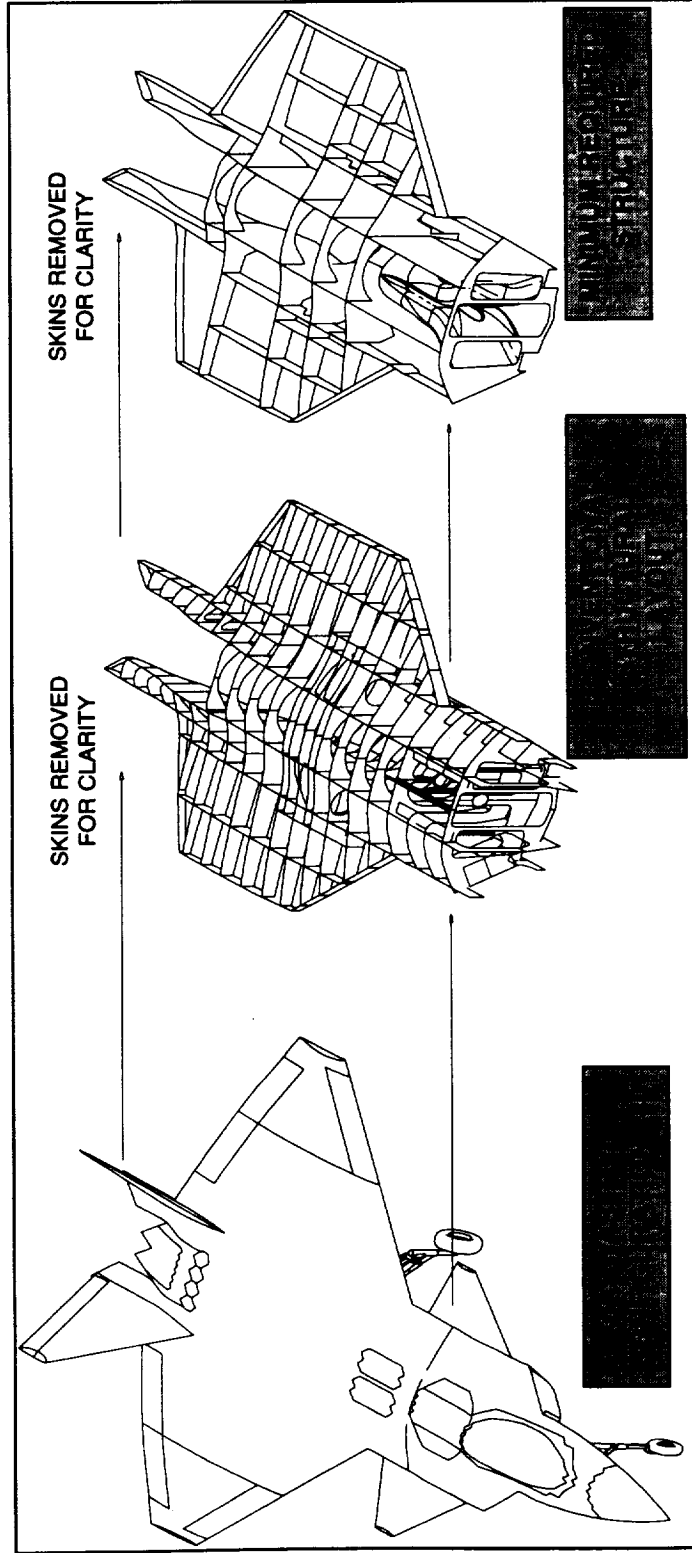


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# IATA Design Space



- A component must “earn its way” onto the airframe
- Multi-functional structure

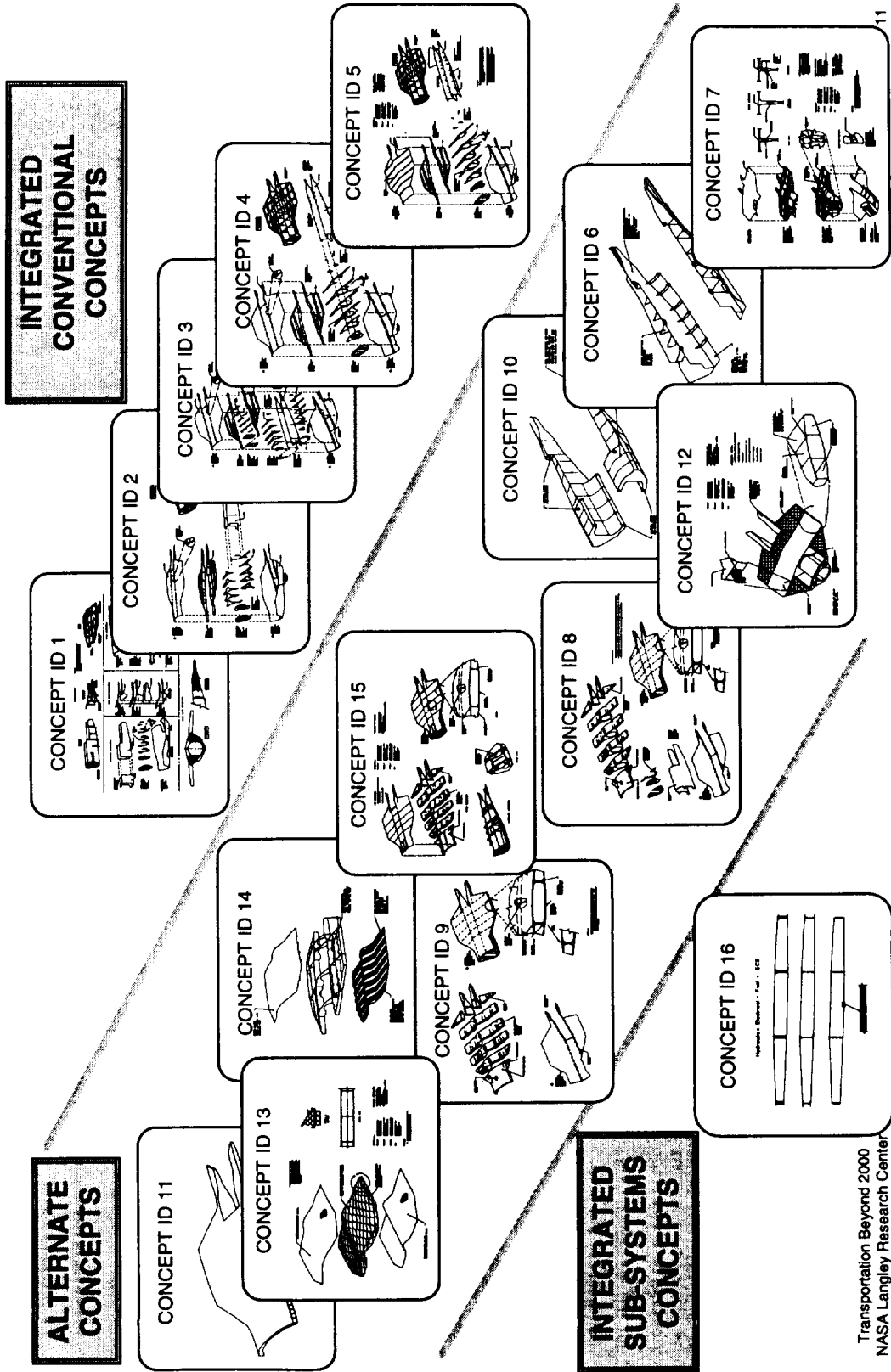




# Preliminary Concepts



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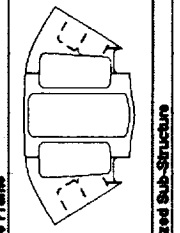
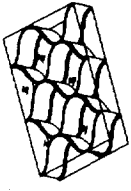
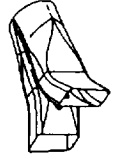

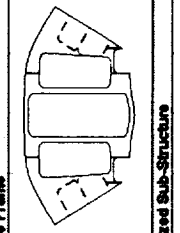
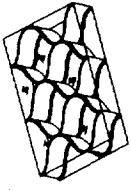
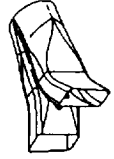

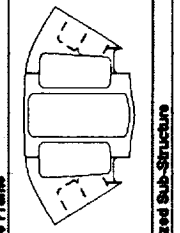
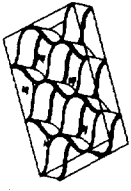
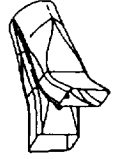

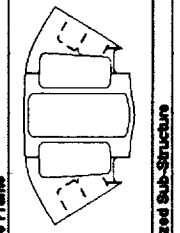
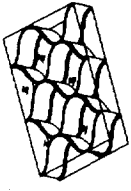
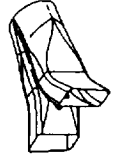

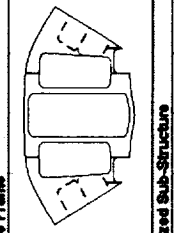
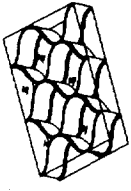
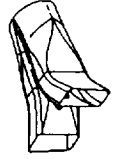

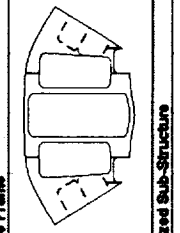
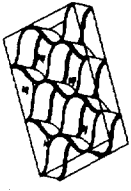
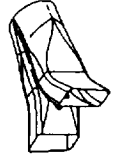

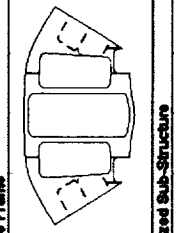
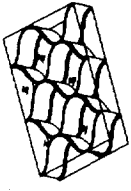
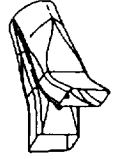

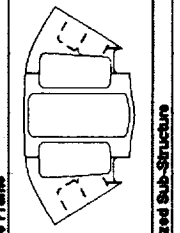
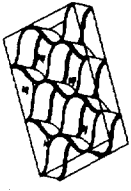
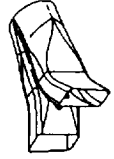
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# Component Level Design/Manufacturing



<p><b>Wing Rib</b></p>  <p><b>Solid:</b> Flat laminate w/ picture fra Stiffened pans Truss laminate</p> <p><b>Sandwich:</b> Sandwich w/ perimeter closeout</p>	<p><b>Fuselage Frame</b></p>  <p><b>Solid:</b> Corrugated + sticks Stiffened pans Fiber placed rope / truss</p> <p><b>Sandwich:</b> Cookie cutter / comb concept Embedded sticks</p>	<p><b>Ribbonized Sub-Structure</b></p>  <p><b>Solid:</b> Laminate with flange pick-up</p> <p><b>Sandwich:</b> Sandwich w/ solid laminate close-out</p>	<p><b>Inlet Duct</b></p>  <p><b>Solid:</b> FP Laminate w/ attach pad-ups FP quasi iso-grid</p> <p><b>Sandwich:</b> Full depth core entire surface Embedments at attachments</p>
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• Evaluations provide component solution space

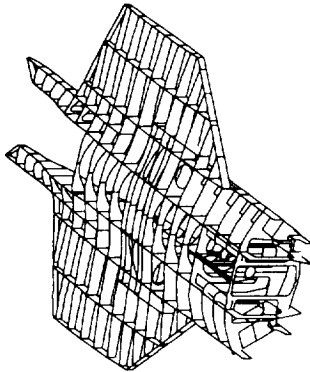
• Designed components for the process/material



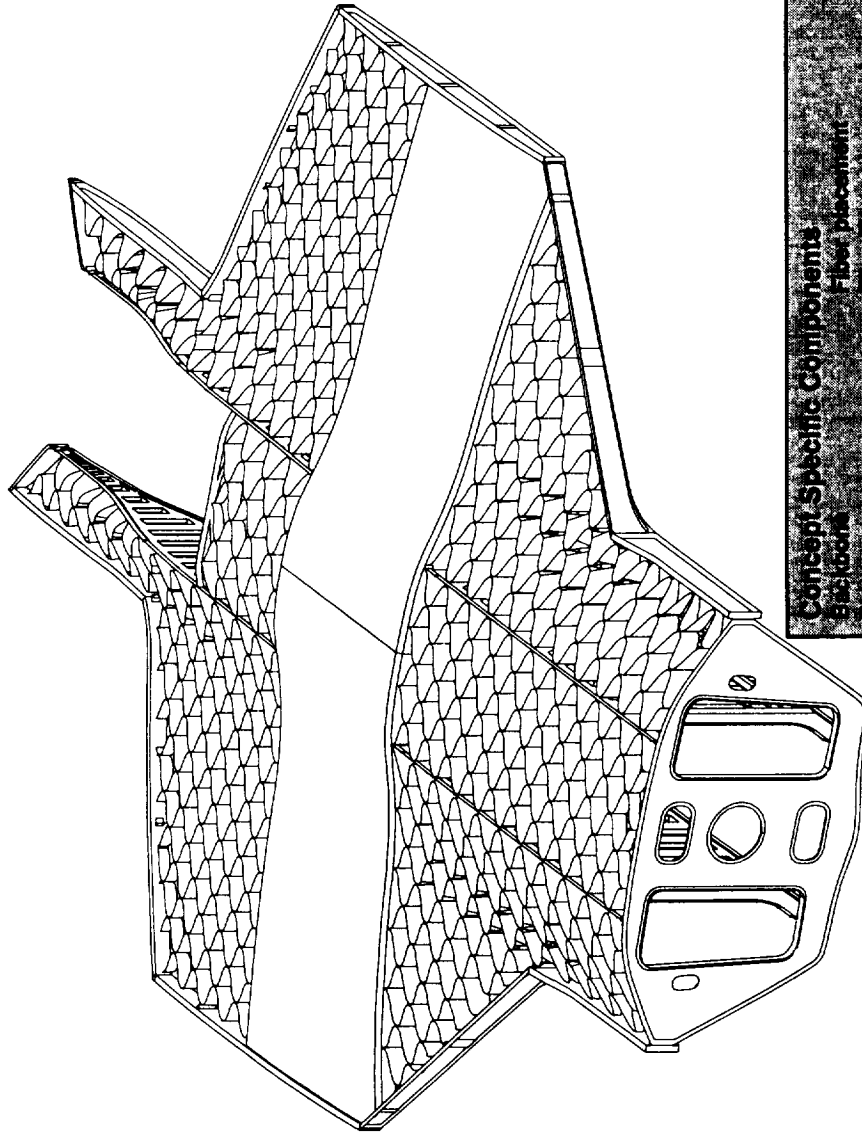
# Backbone Concept



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JAST / ASTOVL  
Config. 1A:  
Conventional Structure



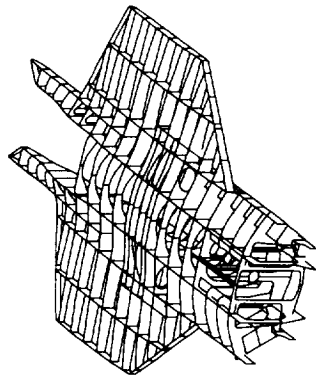
Concept Specific Components  
Fiber placement  
Fiber/Tape placement  
Auto RTM  
Auto VARTM  
Co-Join, Thermal E-Bond

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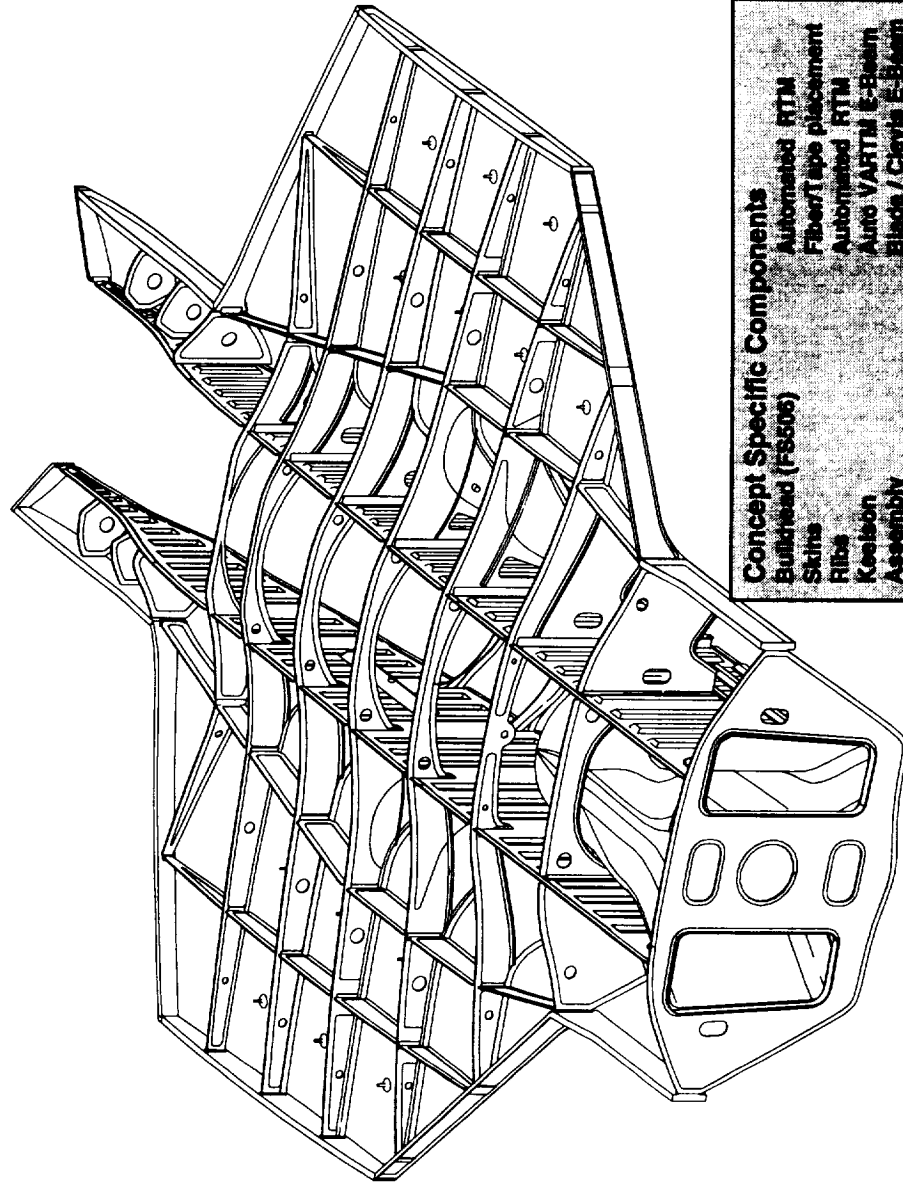
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# Over/Under Bending Concept



**FAST / ASTONL**  
 Curved, J-Box  
 Conventional Structure



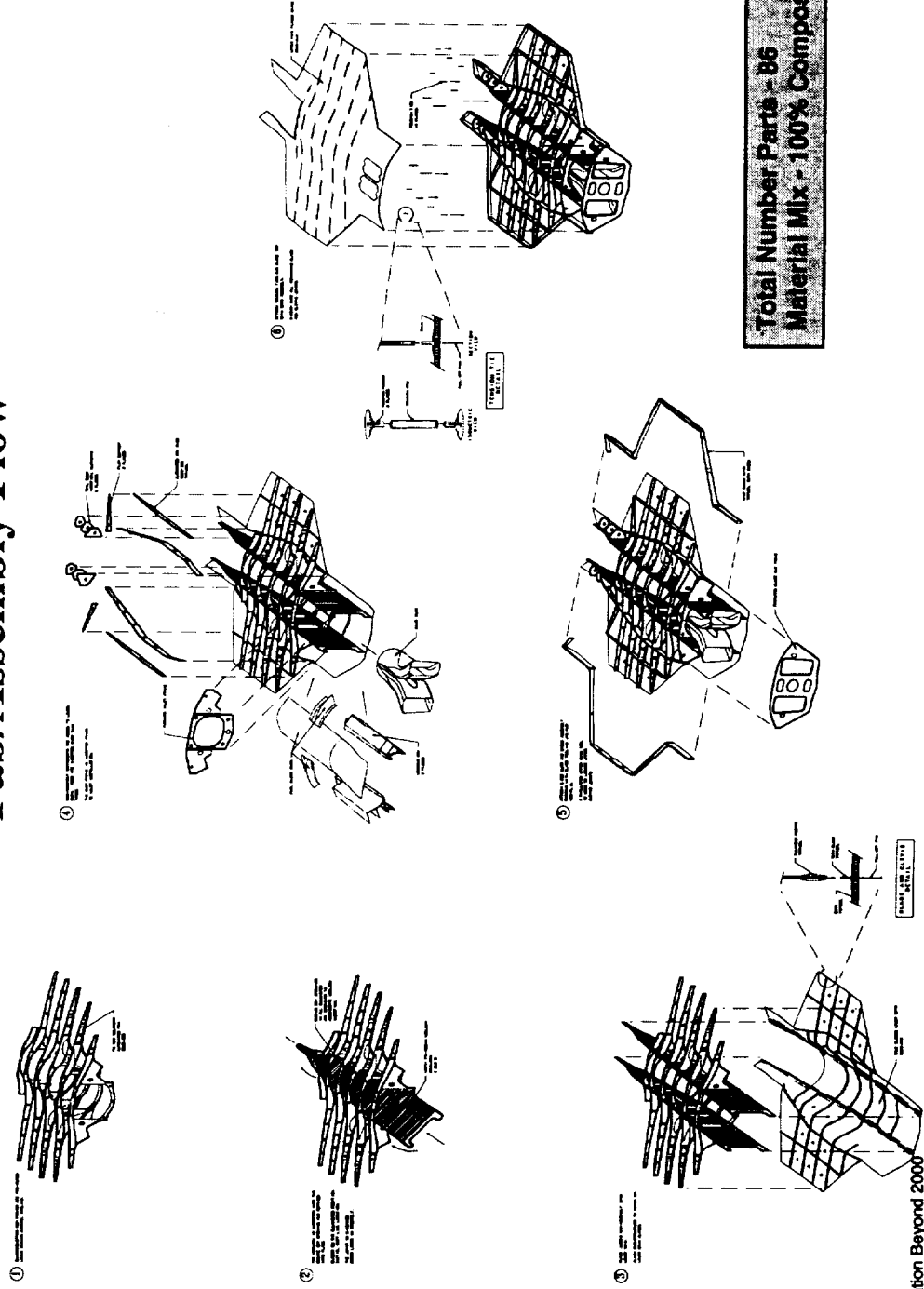
**Concept Specific Components**  
 Automated RTM  
 Bulkhead (FS5005)  
 Skirts  
 Ribs  
 Keelson  
 Assembly

Automated RTM  
 Fibertape placement  
 Automated RTM  
 Auto VARTM E-Beam  
 Blisks / Clevis E-Beam



# Over/Under Bending Concept Fab/Assembly Flow

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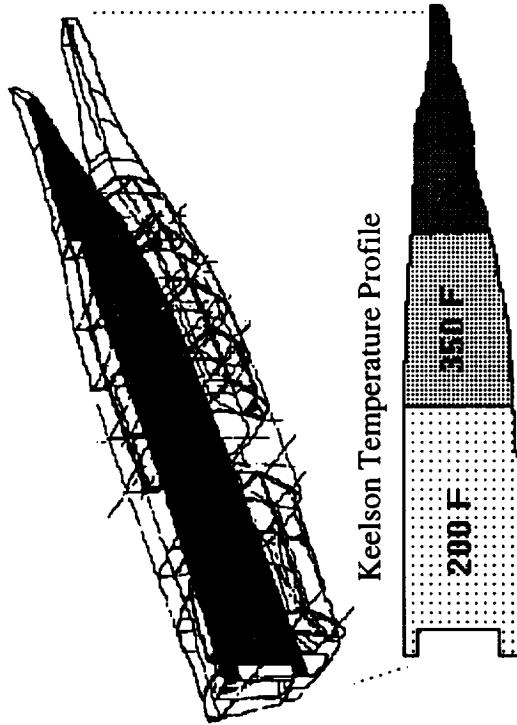
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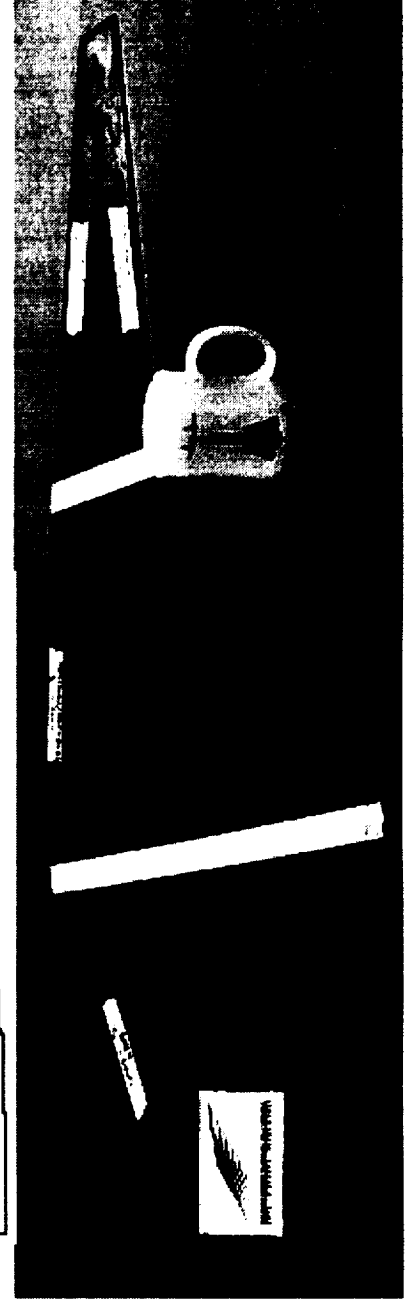
# Multi-Resin Structure Capability



- First application of Multiple Service Temperature Resins in a Single Continuously Reinforced Component



- Panel 1 Multi-Resin (Continuous Fabric)
  - Tg 400 F - FW3 Radical Polymerization
  - Tg 480 F - FW3/BMI4 (50/50)
  - Tg 570 F - BMI4 Radical Polymerization
- Panel 2 Multi-Resin (Continuous Fabric)
  - Tg 280 F - Cationic Polymerization
  - Tg 570 F - Radical Polymerization
  - Tg 390 F - Cationic Polymerization
- Panel 3 Multi-Resin (Interleaved Laminate)
  - Tg 280 F - Cationic Polymerization
  - Tg 570 F - Cationic Polymerization







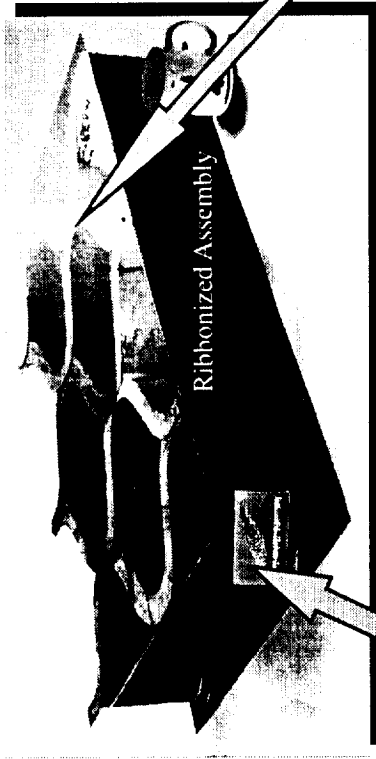
# Ribbonized Sub-Structure Feasibility Assembly



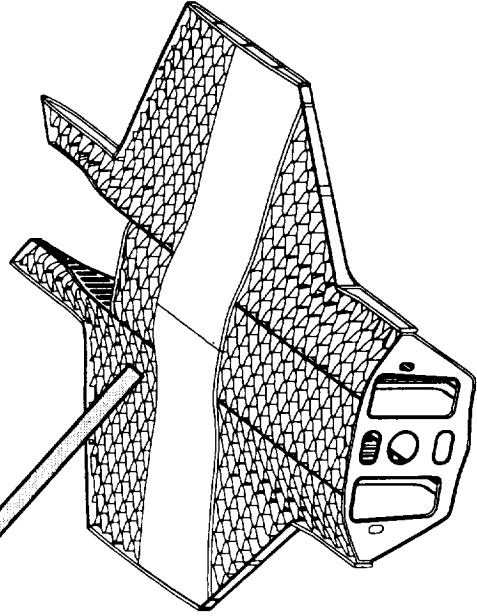
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## Industry Firsts with Electron Beam Resins & Prepreg Fabrics

- VARTM
- Stage Cure
- Conformable & Deep Draw
- Fabrics with VARTM process
- Bonded Assembly
- Low Cost Tooling



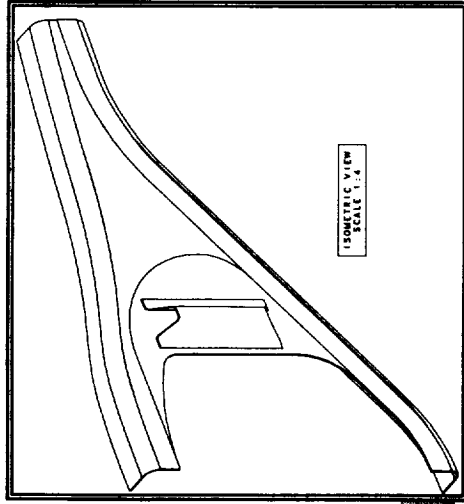
## Backbone Concept



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# Fiber Placed Backbone Concept



## Industry Firsts:

- E-Beam Tow Preg
- Fiber Placement of E-Beam Materials
- E-Beam Cure of Complex Structure
- Unbalanced, Tailored Laminate Architecture with No Warp

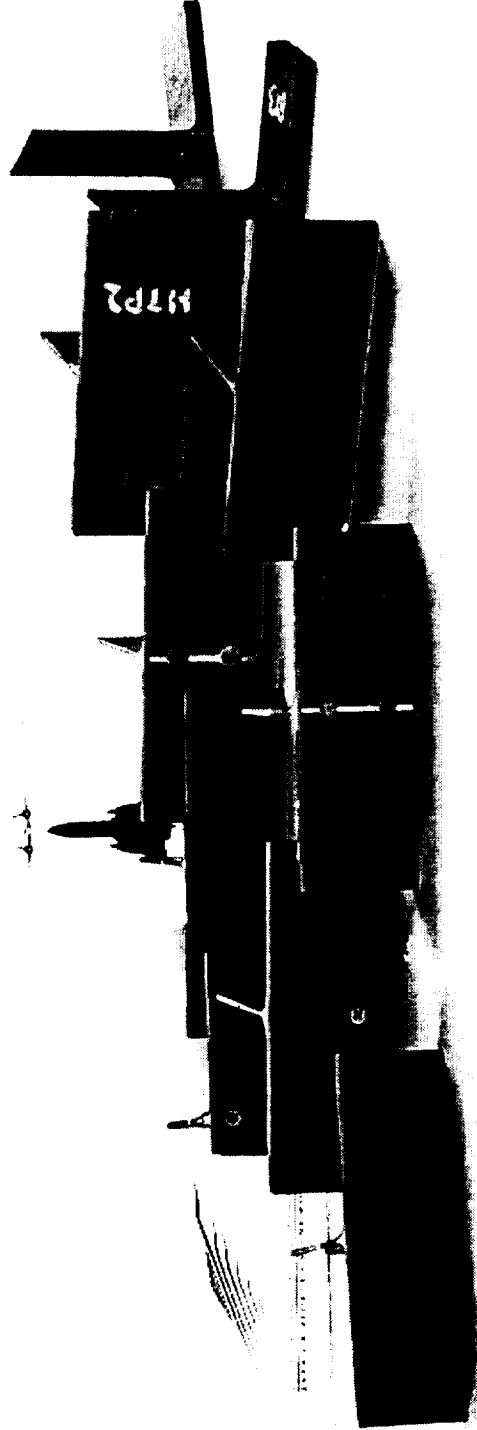
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# Fastenerless Assembly Approaches



- Fastenerless Assembly of Multiple Components
- Direct Reinforcement of Classic Composite Failure Modes
- Applicable to Co-Cure, Co-Bond, Sandwich, or Solid Laminate Approaches
- Current Focus on Blade/Clevis Low Tolerance Assembly Scenario

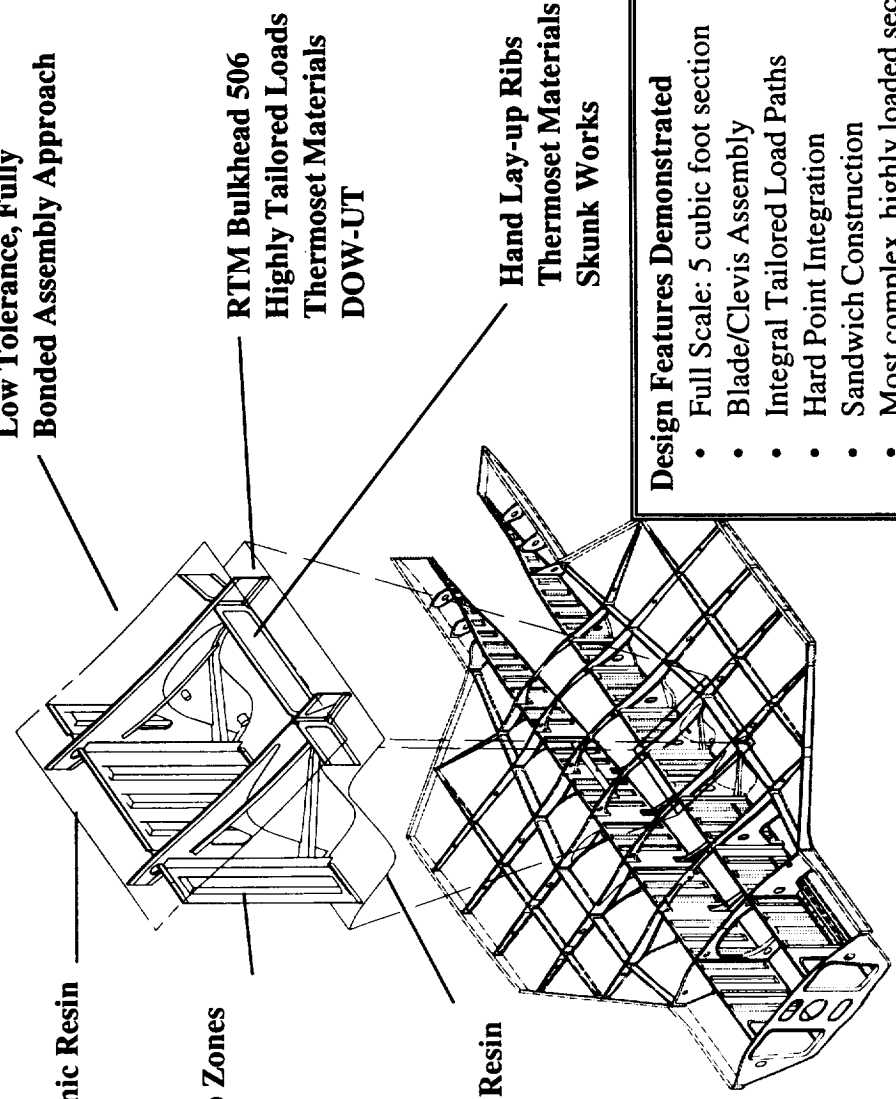


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# Full Scale Process Demonstration Assembly



**Fiber Placed Upper Skin**  
**Electron Beam Cured: Cationic Resin**  
**Alliant TechSystems**

**VARTM Keelson Multi-Temp Zones**  
**Electron Beam Cured:**  
**Cationic B & C Resins**  
**Skunk Works/AECL**

**Fiber Placed Lower Skin**  
**Electron Beam Cured: Cationic Resin**  
**Alliant TechSystems**

**Low Tolerance, Fully Bonded Assembly Approach**

**RTM Bulkhead 506**  
**Highly Tailored Loads**  
**Thermostat Materials**  
**DOW-UT**

**Hand Lay-up Ribs**  
**Thermostat Materials**  
**Skunk Works**

- Design Features Demonstrated**
- Full Scale: 5 cubic foot section
  - Blade/Clevis Assembly
  - Integral Tailored Load Paths
  - Hard Point Integration
  - Sandwich Construction
  - Most complex, highly loaded section





## Innovations/Path to Production

- ***Integrated Design***
- E-Beam Curing & VARTM
- E-Beam Curing & Fiber Placement
- Large Scale Resin Infusion (RTM/VARTM)
- Fabrication of Very Large Structure
- Fastenerless Assembly
- High Temperature Materials/Applications
- Hi-Shear Sandwich Construction
- Slotted Tab Assembly
- Integral Multi-Resin Structure
- Direct Web Reinforcement
- Multi-Cure Assembly Approach
- Snap-Fit Assembly Approach
- Energy Absorbing Fuel Cell Tension Ties
- Ribbonized Wing Sub-Structure
- Tailored Laminate Architectures



## Vision of Future



- Accomplish Paradigm Shift
- System Level Integration
- Composites More Affordable Than Metals
- Achieve Performance Potential
- Smart Structures: Active and Passive
- Integrated Sub-Systems
- Diverse Application to Structures in General

