

A&P Technology

World Leader in Braided Reinforcements

David J Kehrl

Presentation to AMTAS March 16, 2010



Recreation



Marine



Aerospace



Industrial



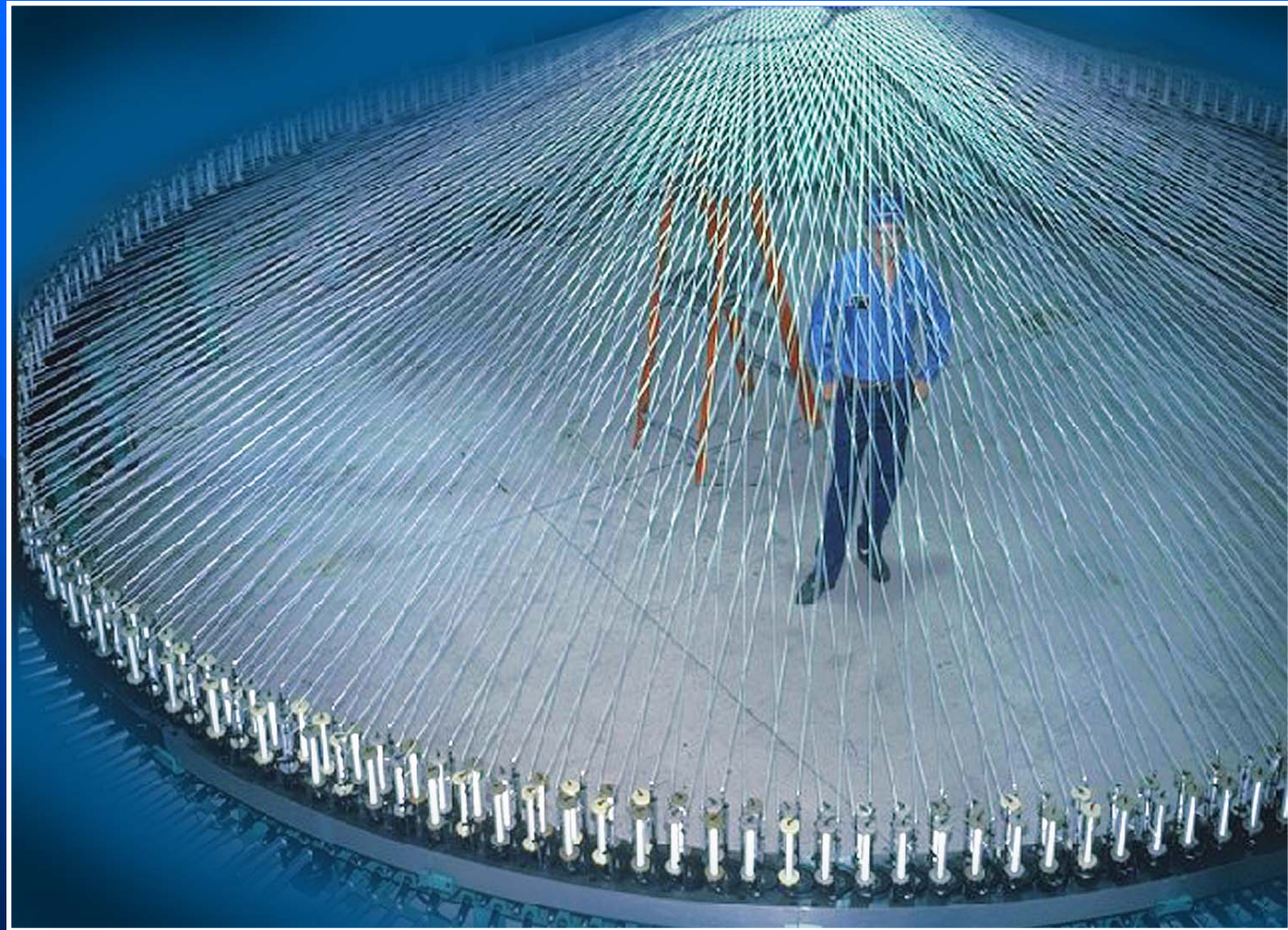
Inflatable

Discussion topics

- Braiding process and forms
- Aeroengine Outlet Guide Vane with Cellular Core
- Braided radius Fillers aka Noodles
- Current applications using braid
- Development thru production example
- Developing applications
- Summary & questions

Megabraiders

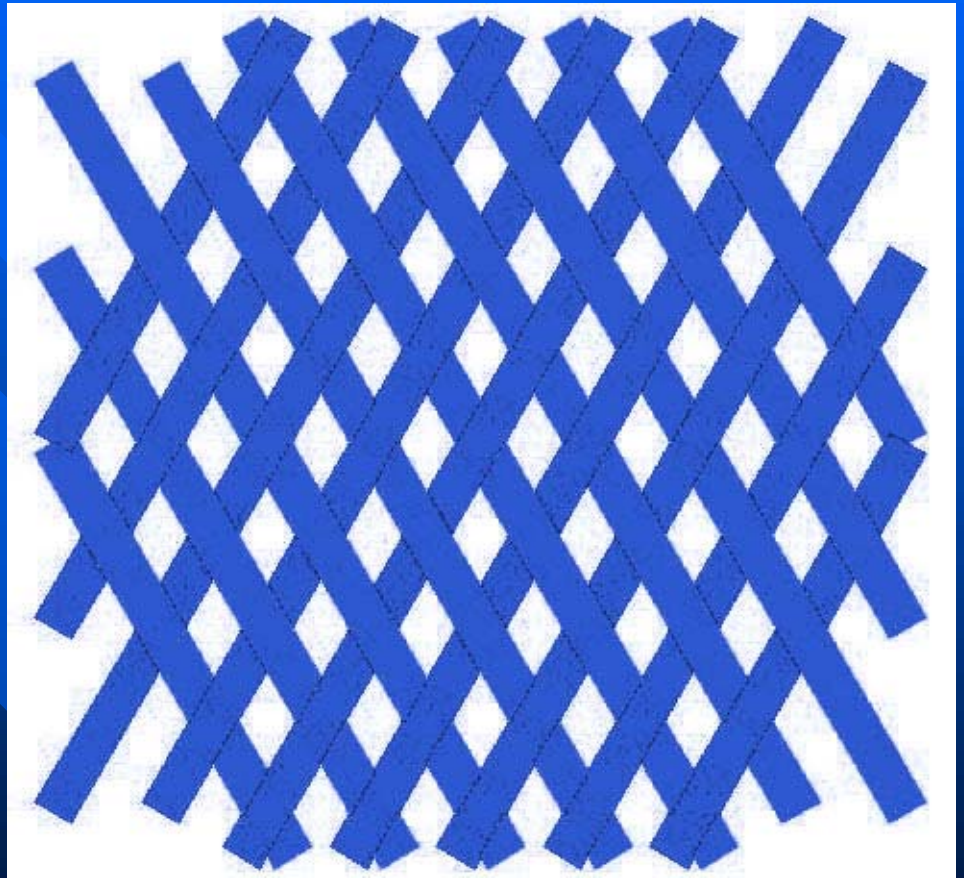
- 800 Carrier
- 600 Carrier
- 500 Carrier
- 400 Carrier
- 336 Carrier
- 272 Carrier
- 208 Carrier
- 172 Carrier



A&P Technology designs and fabricates our own braiding machinery. We have the largest braiding machinery in the world.

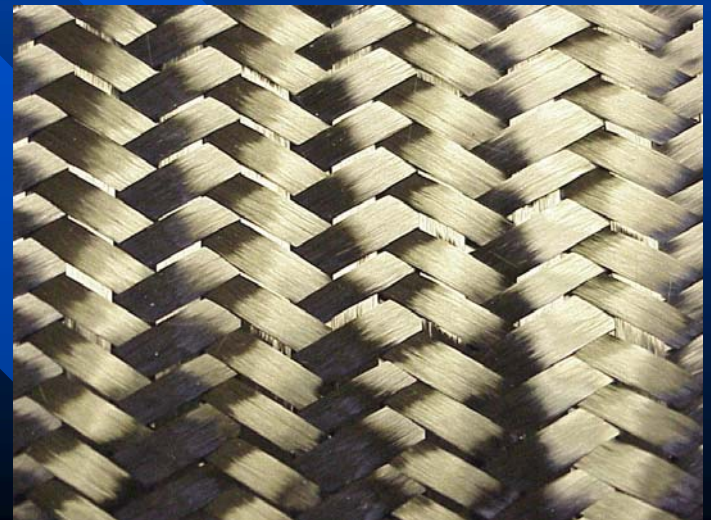
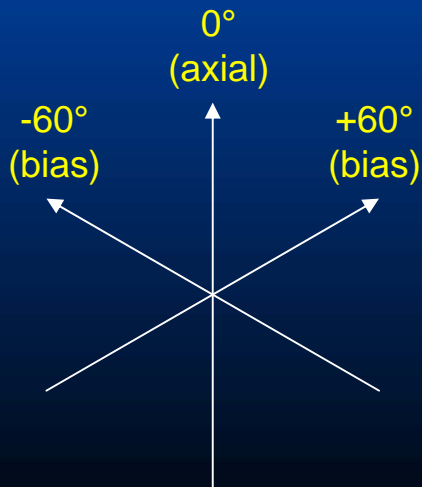
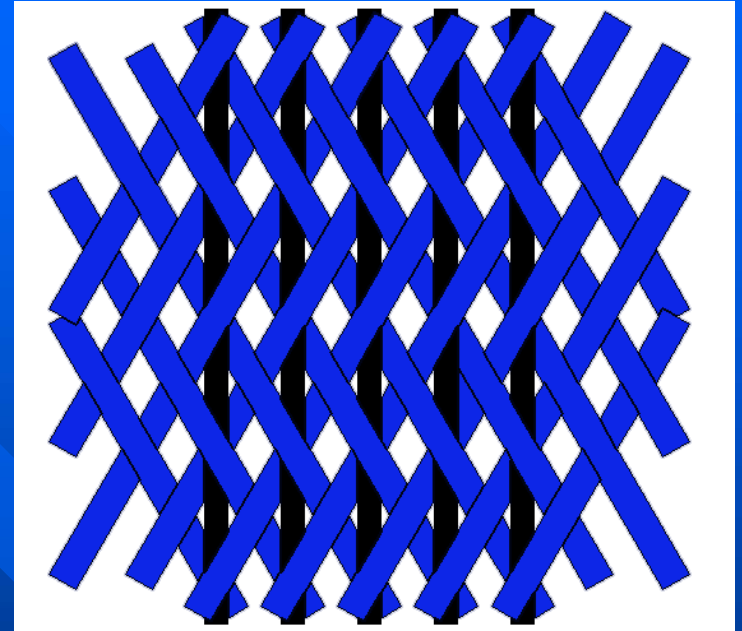
Biaxial

- Flexible diameter, good conformability & drape
- Fibers in the bias direction only
- Construction dependent fiber orientation ranging from 15 to 75 degrees

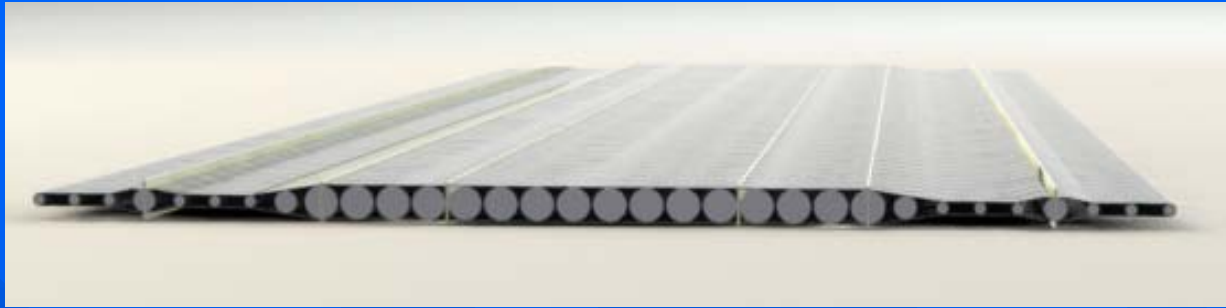


Triaxial

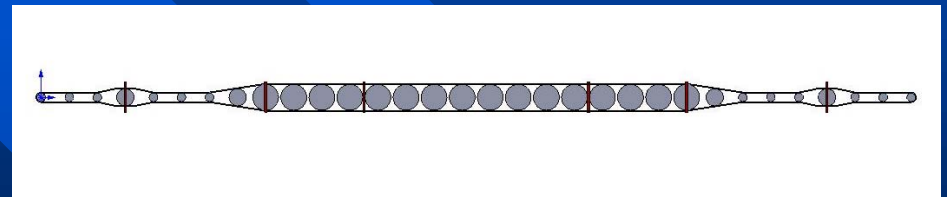
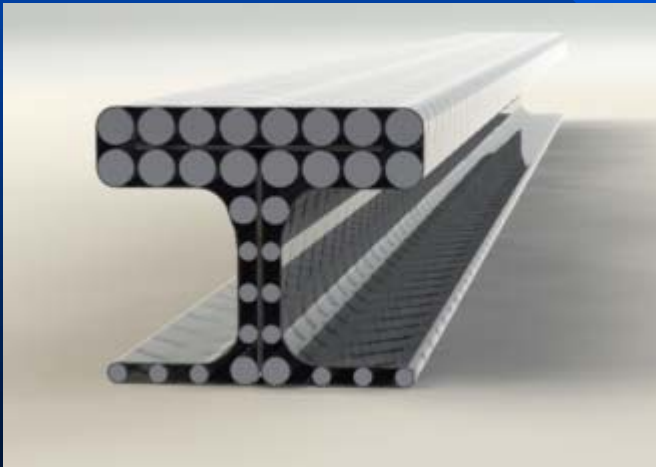
- Locked diameter or width
- Fibers in both axial and bias directions
- Fiber orientation ranging from 10 to 80 degrees



Ability to Selectively Add Axial Fibers



Single Ply Axial Content Varied from shear to axially dominated regions of part

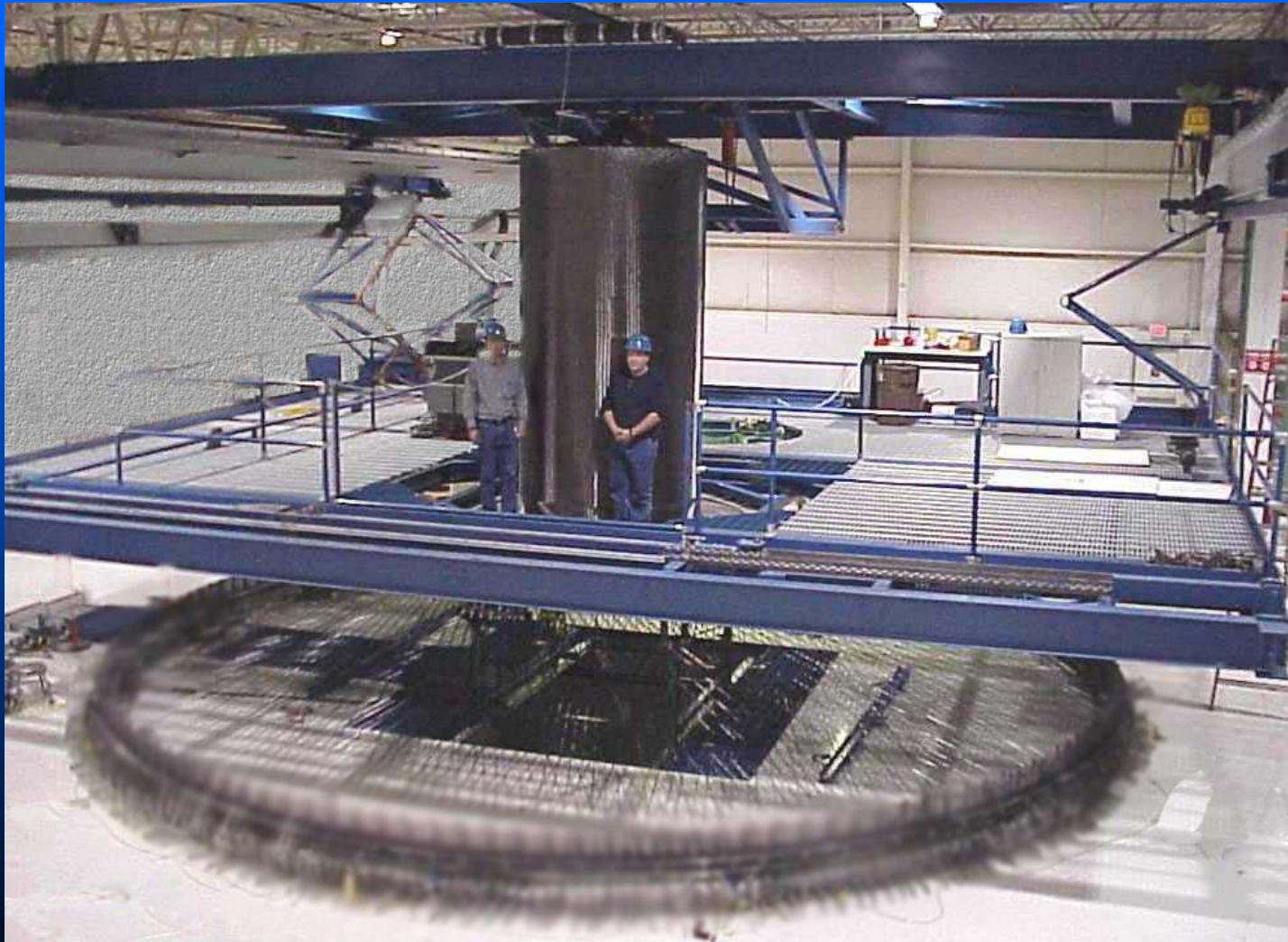


Cross Sectional View of I-Beam

Fold Section

Overbraid Architectures

Mantis



Mantis Capabilities

Hoop Winding



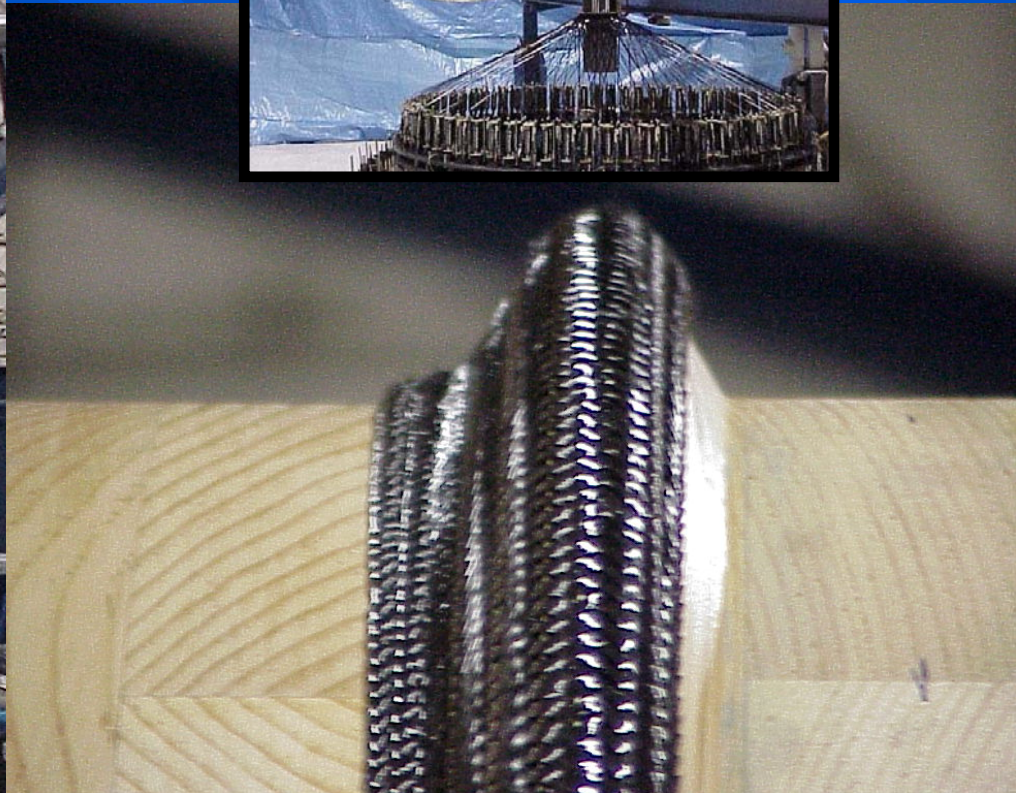
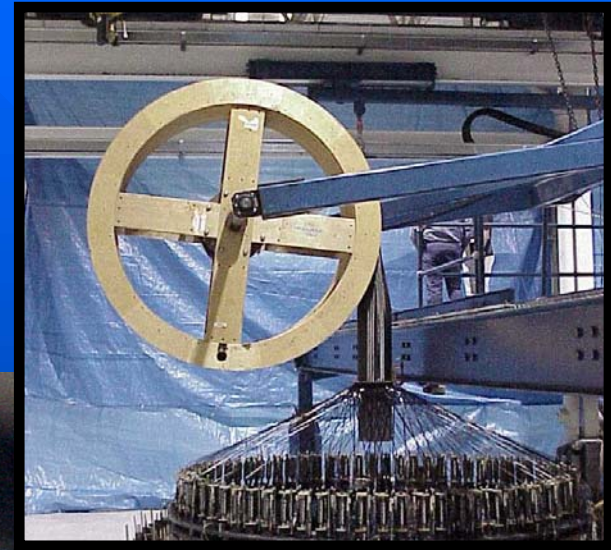
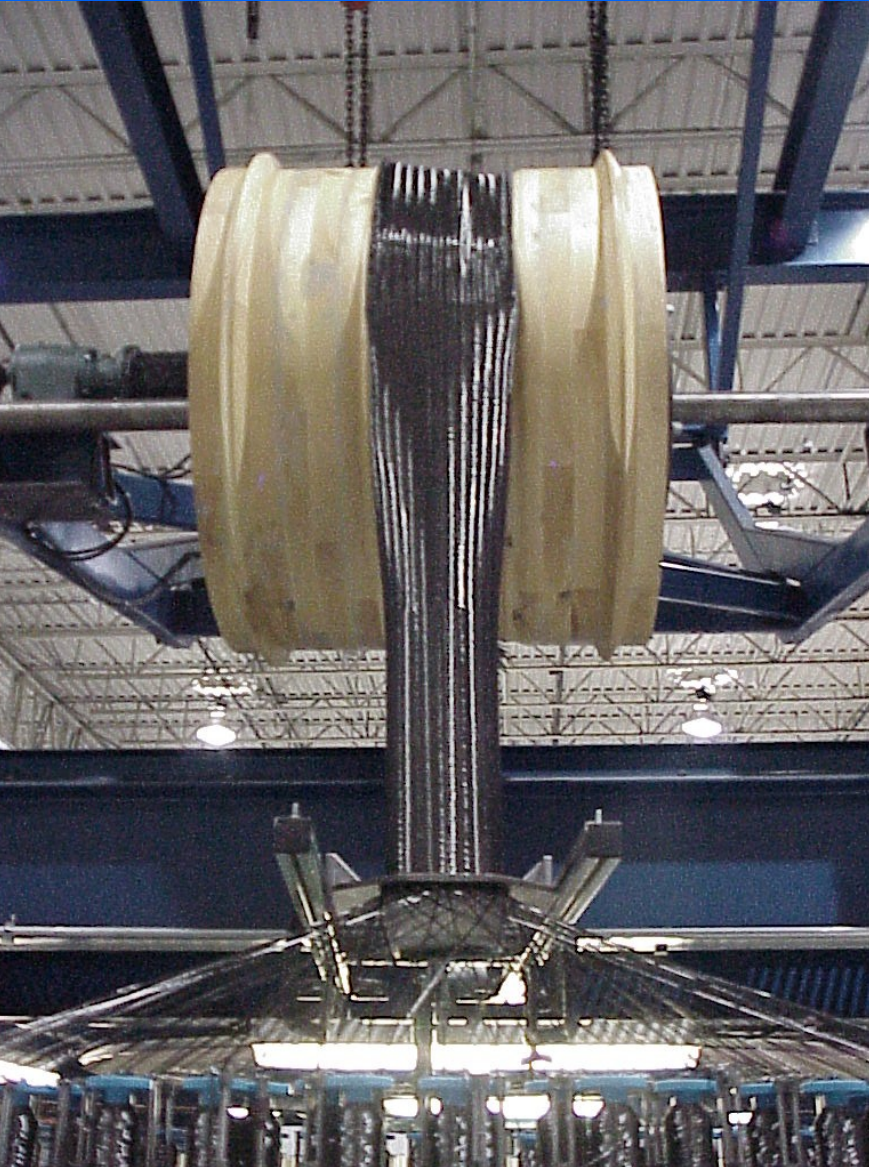
Variable Formation Diameter



Integrated Control System



Contoured Braids

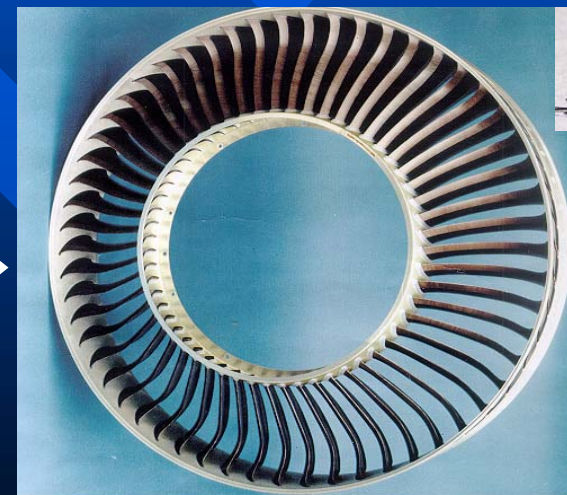


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Braided Stator Vane Preform

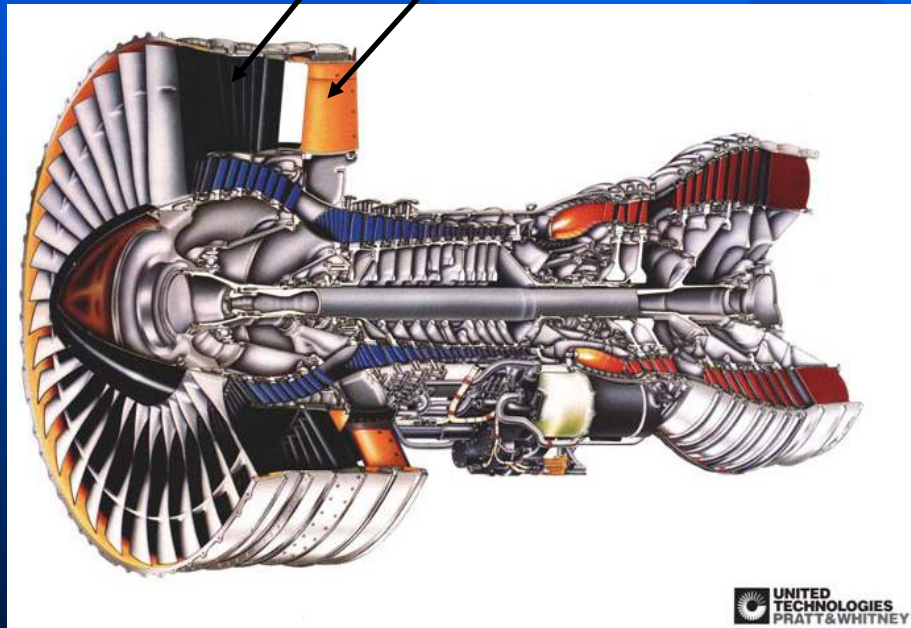
Highly optimized with intermediate and standard modulus carbon and kevlar and variable braid angle



Aeroengine Outlet Guide Vanes with Cellular Core Technology

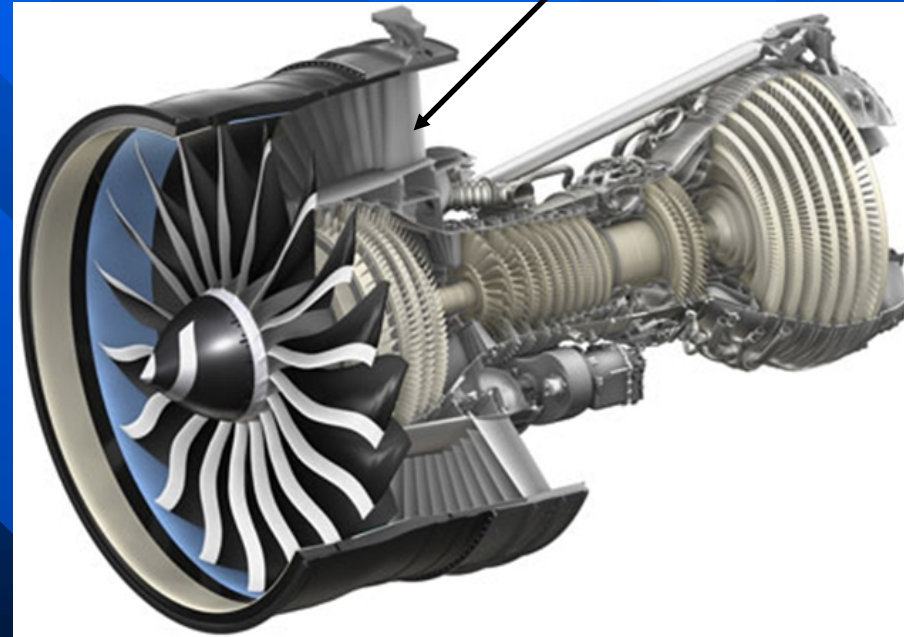
OUTLET
GUIDE VANE
(OGV)

FAN FRAME



Pratt & Whitney PW400

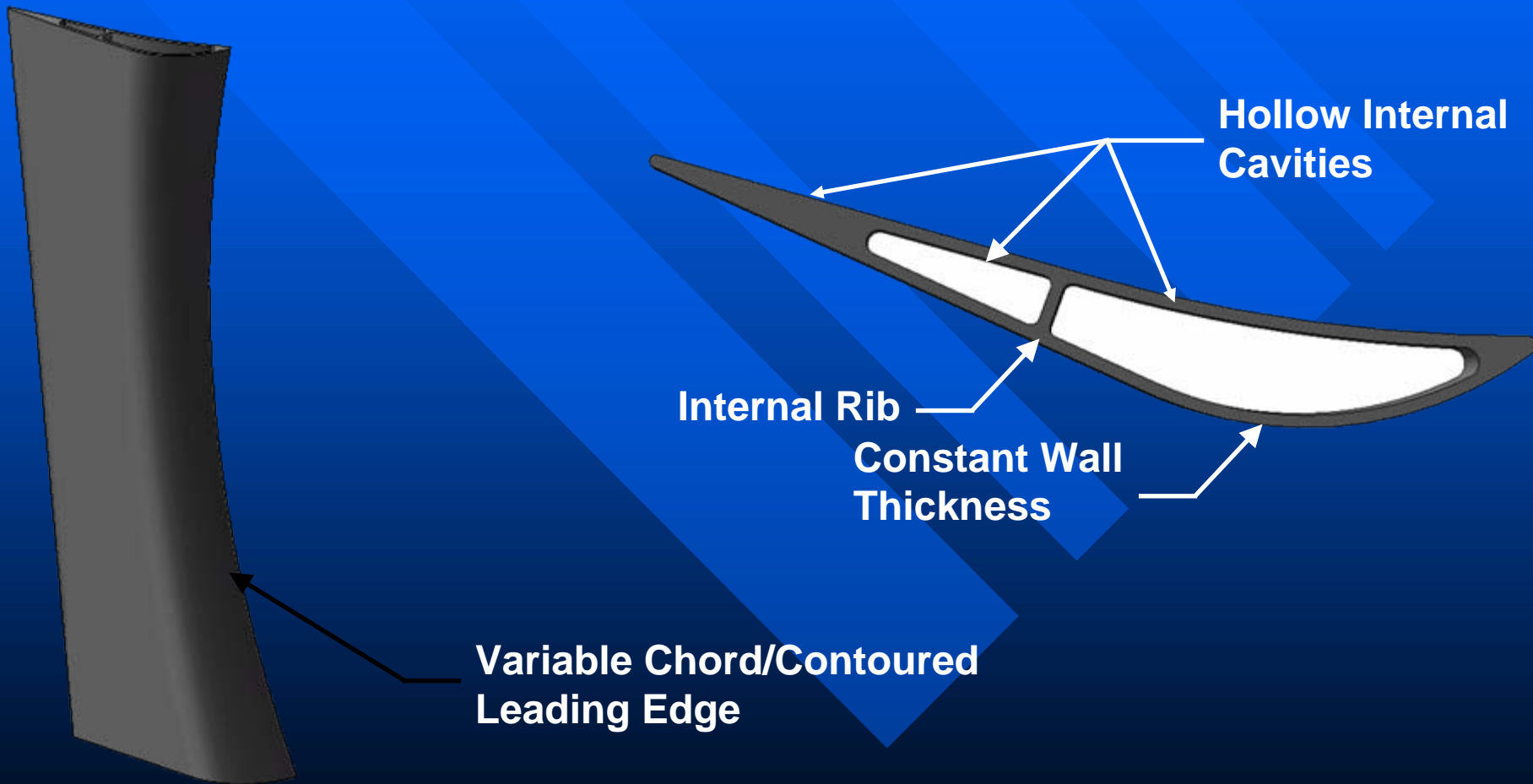
GUIDE VANE AND FAN FRAME
INTEGRATED... "VANE
FRAME", "STRUCTURAL
OGV"



GE90

Aeroengine Outlet Guide Vanes with Cellular Core Technology

Structural Arrangement

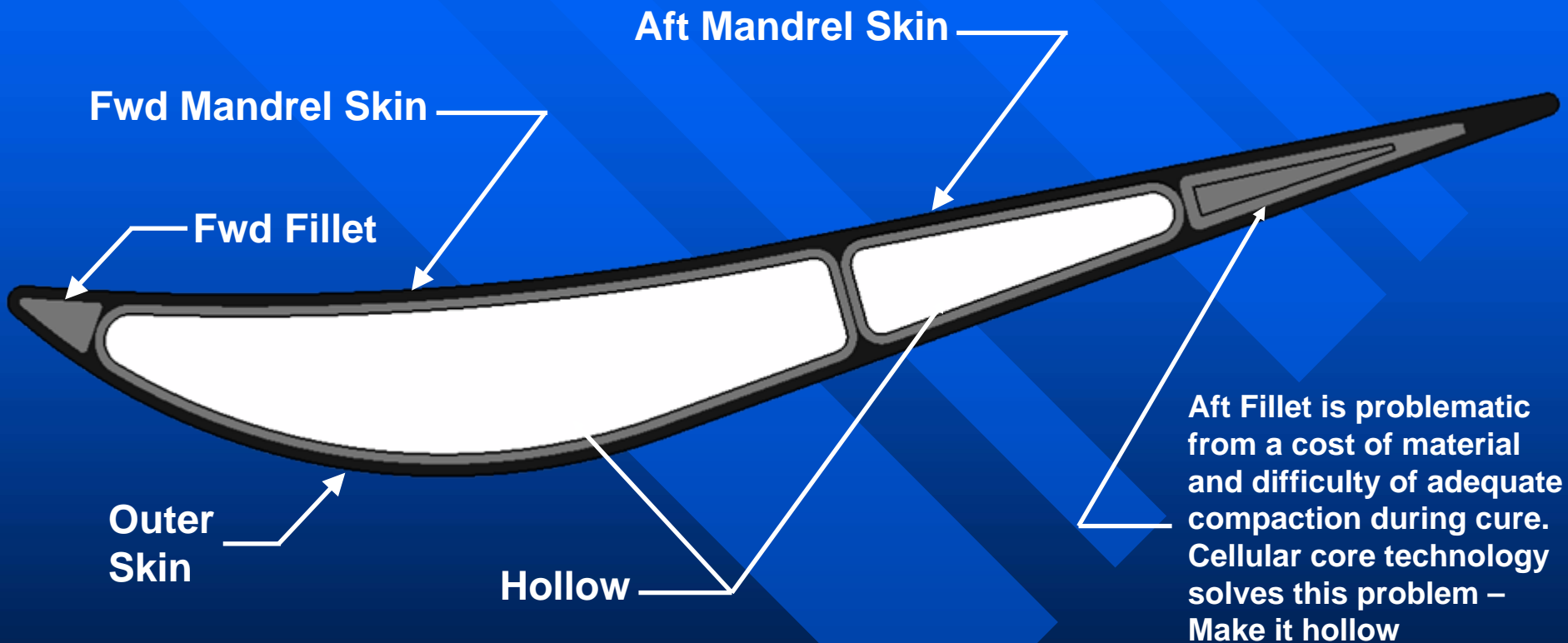


Aeroengine Outlet Guide Vanes with Cellular Core Technology

Scale Model Created For Demonstration Purposes. Approximately 1:3 Scale Relative To Typical Large Commercial Turbofan

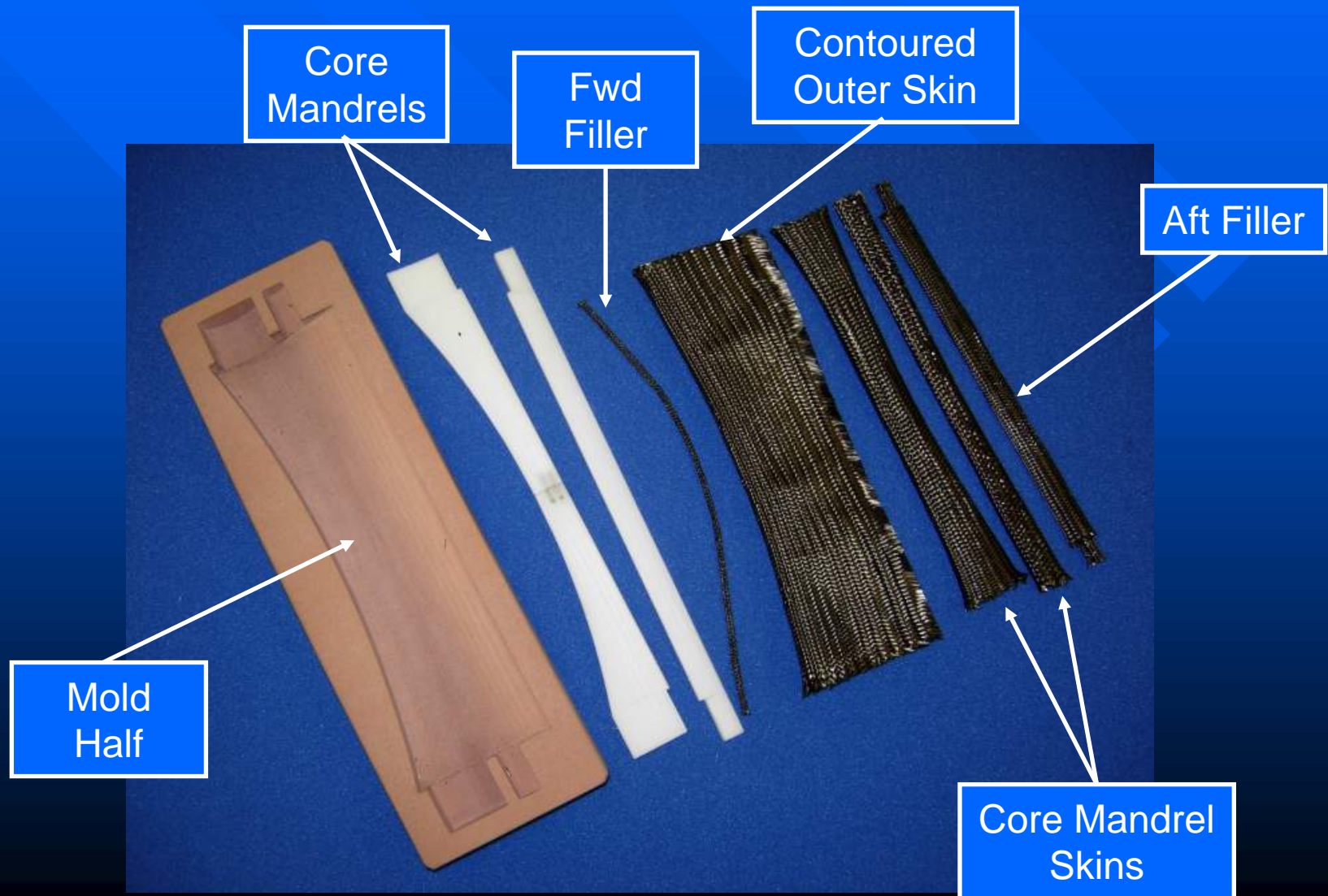


Aeroengine Outlet Guide Vanes with Cellular Core Technology



Aeroengine Outlet Guide Vanes with Cellular Core Technology

Demonstration Model



Aeroengine Outlet Guide Vanes with Cellular Core Technology

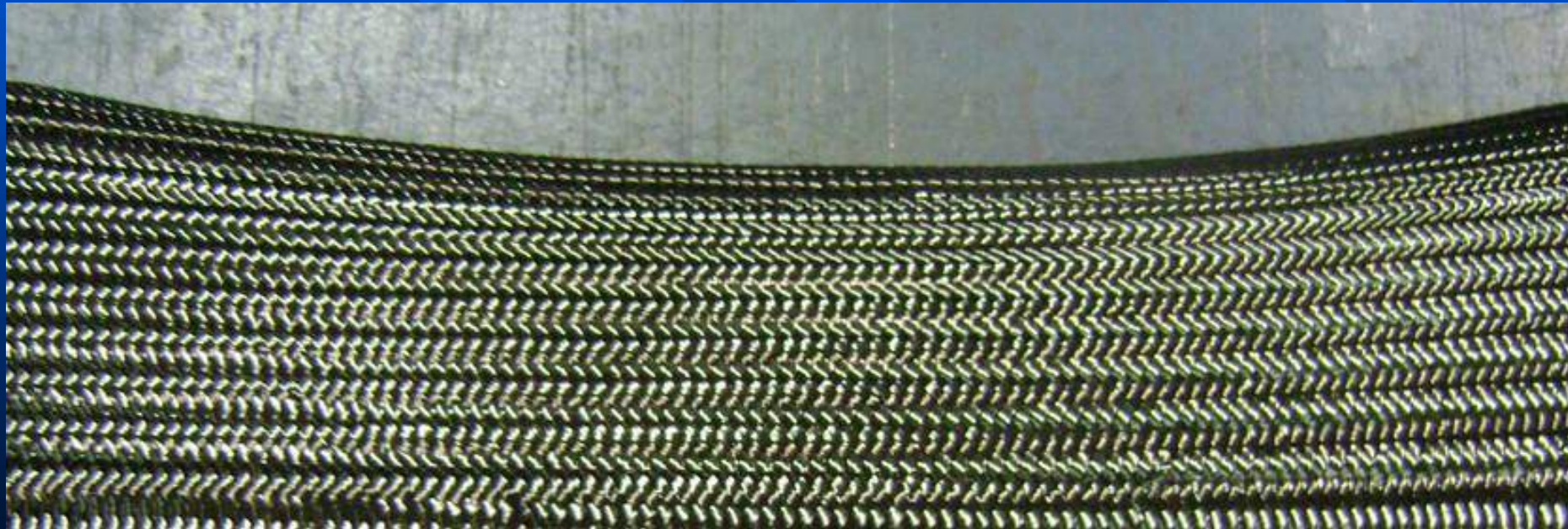
Preform Loaded In Mold



Aeroengine Outlet Guide Vanes with Cellular Core Technology

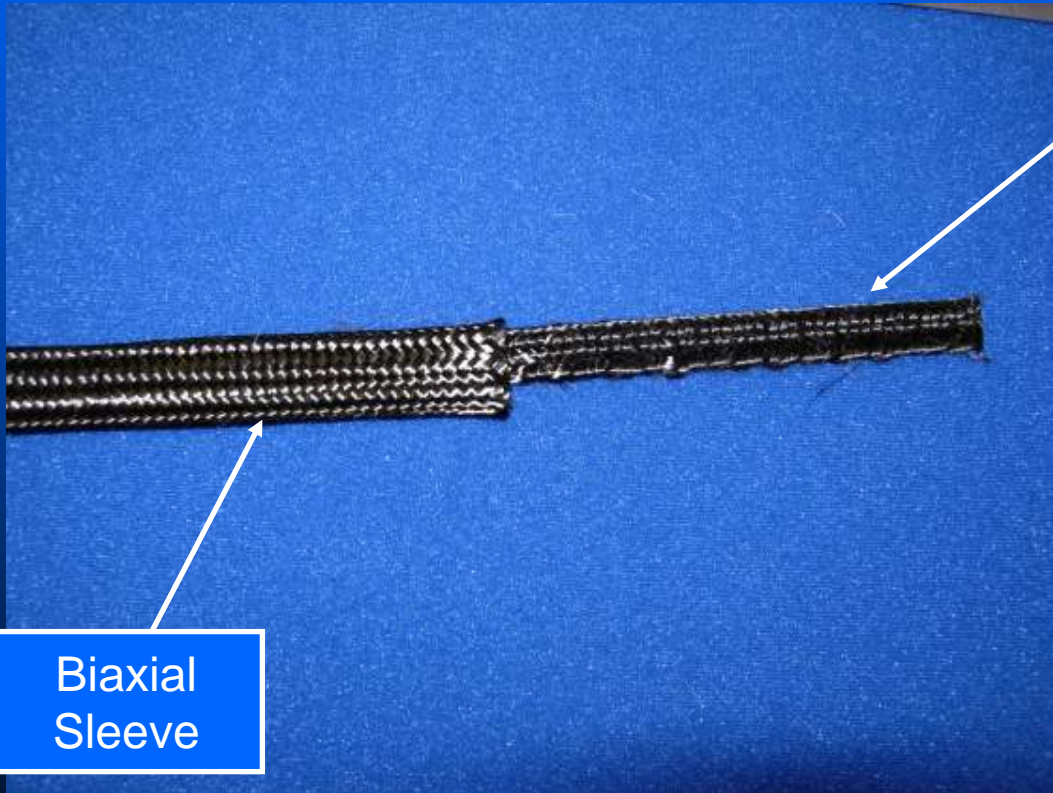
Contoured Leading Edge

Braid Parameters Computer Controlled To Produce A Contoured Preform Of Constant Thickness. Fiber Continuity Maintained At The Leading Edge



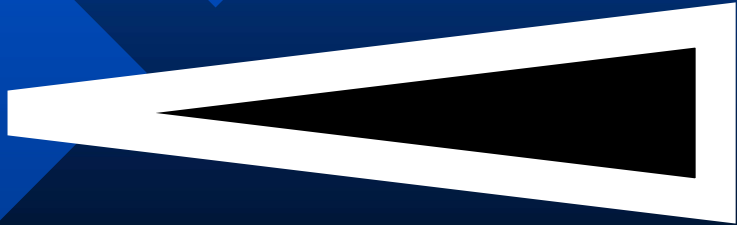
Aeroengine Outlet Guide Vanes with Cellular Core Technology

Tapered Triaxial Tape Inside Biaxial Sleeve Creates High Aspect Ratio Triangular Aft Filler



Biaxial Sleeve

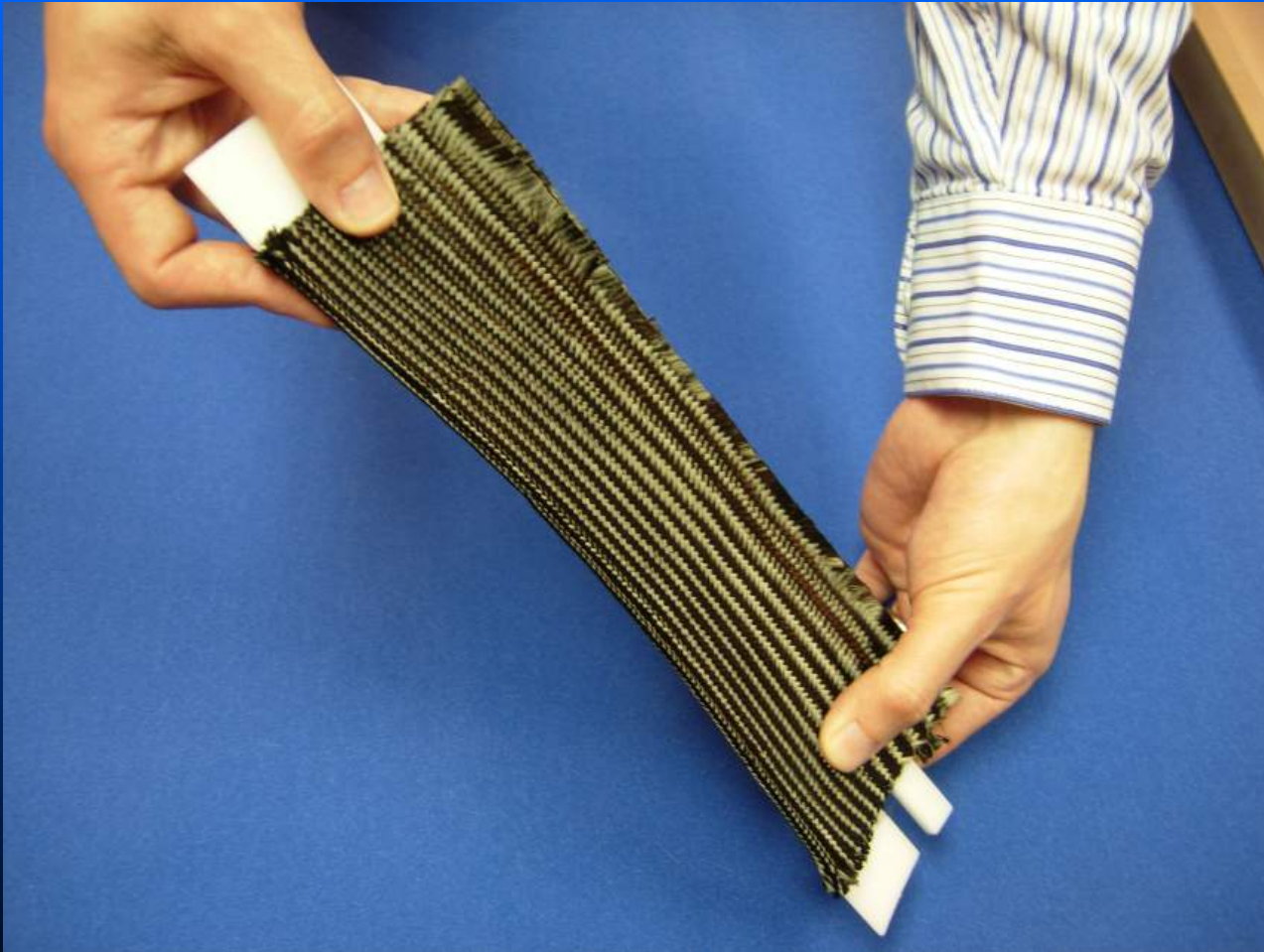
Triaxial Tape With Axial Positions Loaded Increasing Fiber Content Provides Appropriate Thickness Taper



Resulting Cross Section, Shaped To Fill Trailing Edge

Aeroengine Outlet Guide Vanes with Cellular Core Technology

Finished Preform

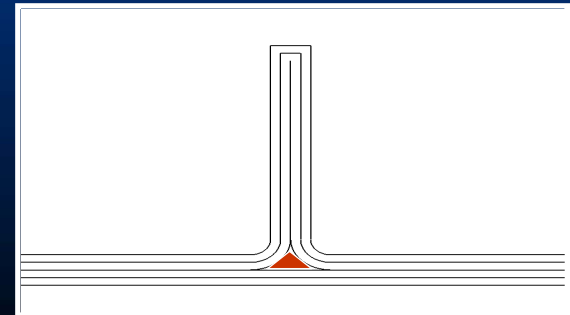
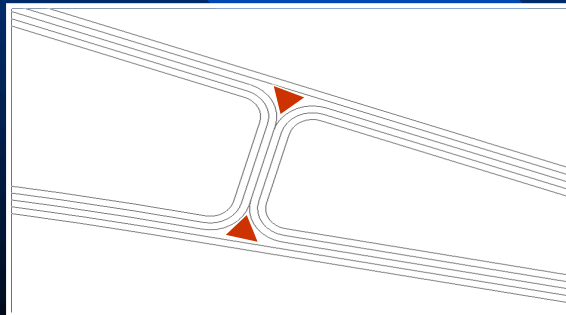
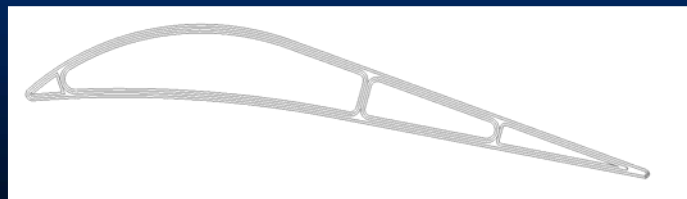


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Fillet Preforms

- Can tailor filler modulus and shape to match surrounding structure
- Expect improved interlaminar tension and shear performance when compared to uni tape solutions
- There are lots of dials we can turn to optimize performance
- We are initiating a multi phase DOE test program and are looking for joint venture partners to share the data and expense

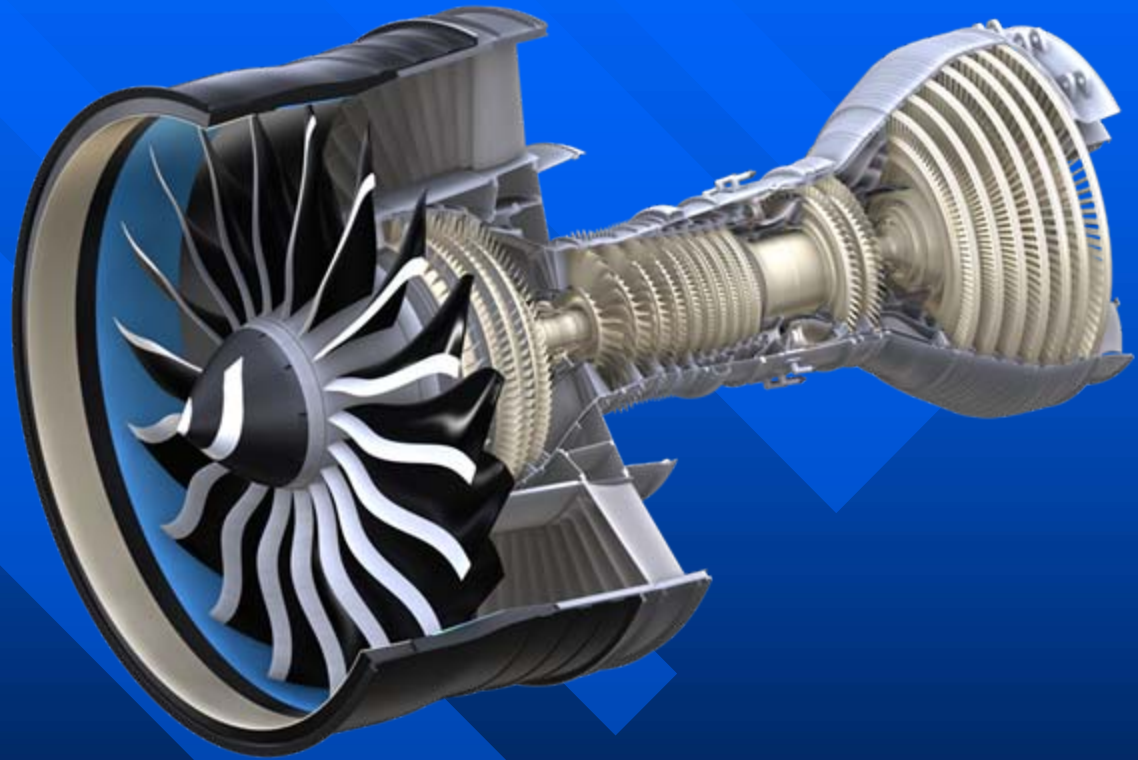


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Braid Use in Fan Cases

- Tougher than alternatives
- More damage tolerant than alternatives



Braid use in Propellers

- Fatigue strength better than metallic alternatives by an order of magnitude



Aerospace Structures



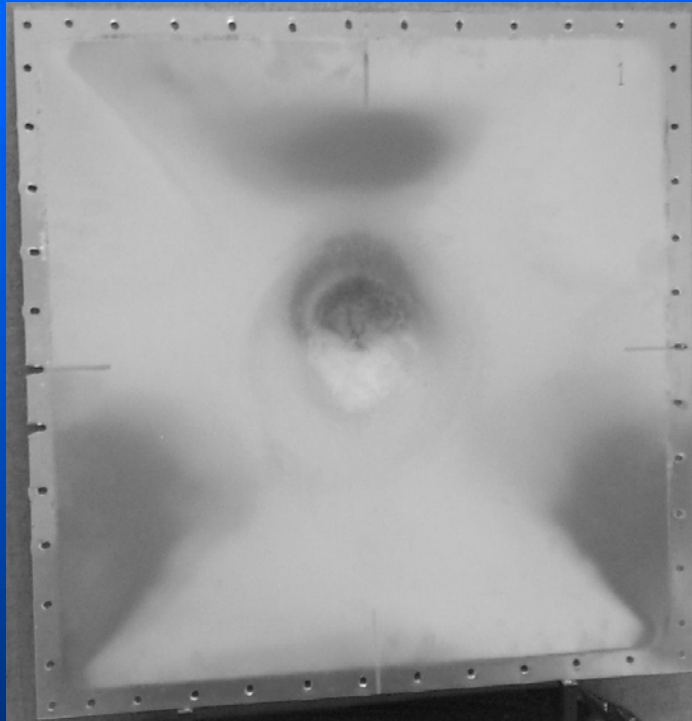
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Development of Braided Jet Engine Fan Cases with NASA

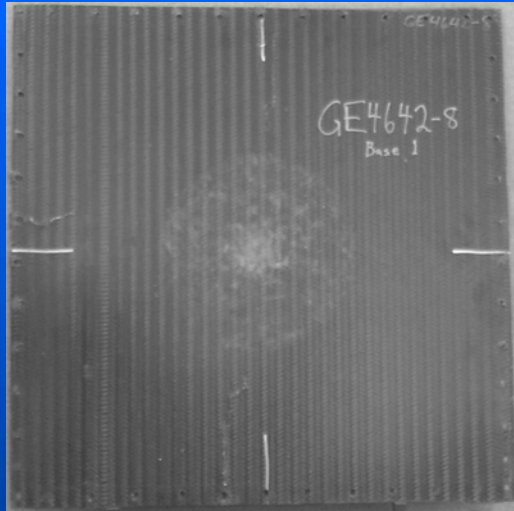
- Relationship dates to HSCT (~1992)
- Requirement to survive bladeout and subsequent spool down
- Baseline material is aluminum
- Impact tests of flat panels leading up to full-scale engine tests
 - Failure is engine program slide

0.071" Aluminum Panels after Impact

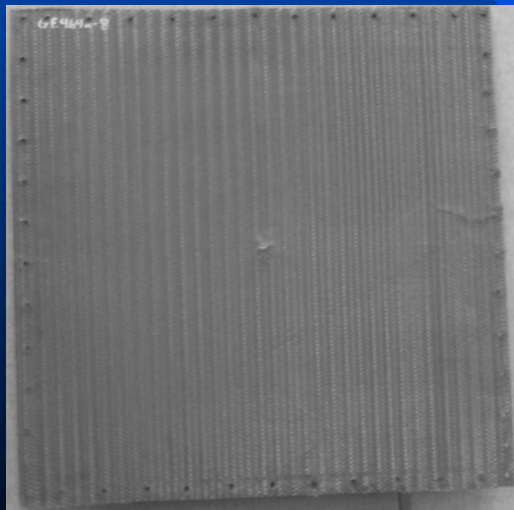


(0+/-60) Composite Panel after Impact (Velocity below penetration threshold)

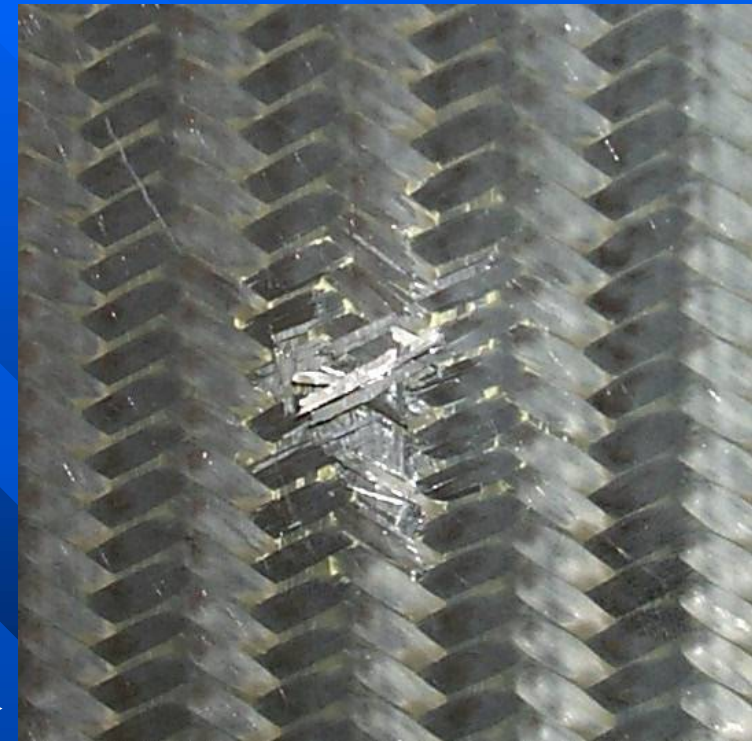
Front



Back



Close-up view
at center of
panel



Fiber and matrix failure in back ply

(0+/-60) Composite Panel after Impact

(Velocity above penetration threshold)



Front



Back

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Pressure Vessel Damage Tolerance



Over-wrapped, Aluminum Lined Pressure Vessels

Filament Wound Vs. Braid



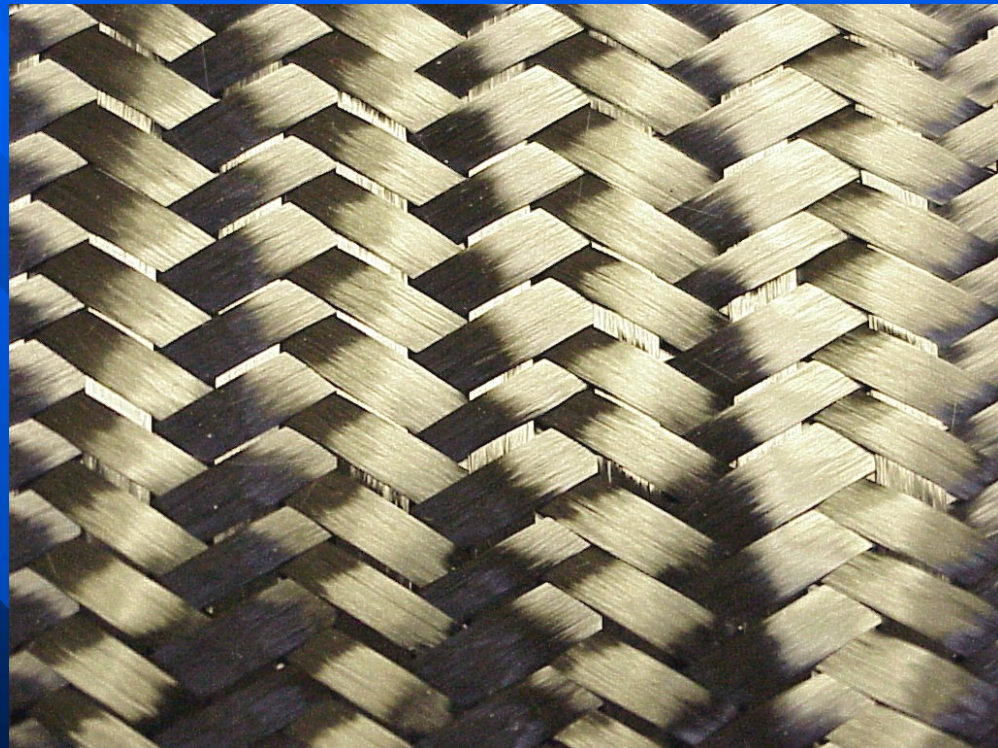
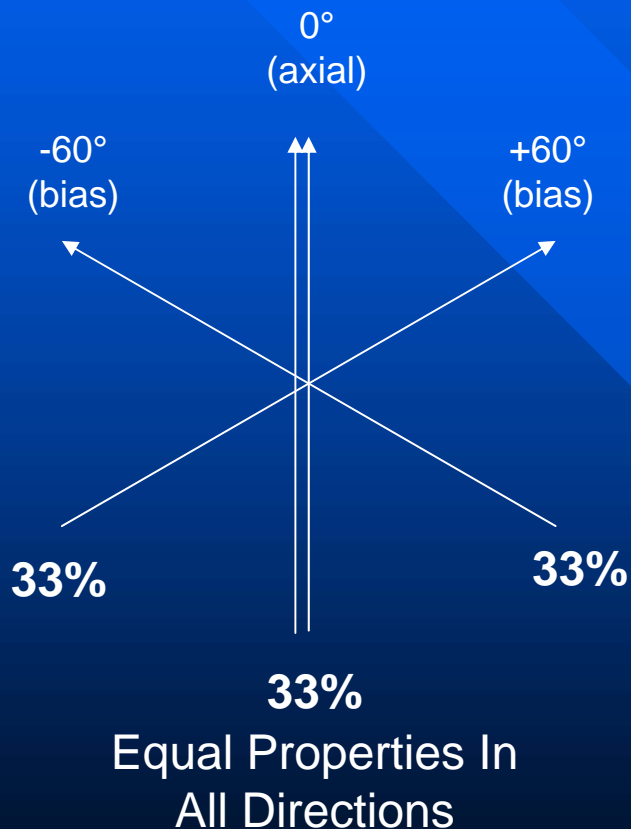
Filament Wound



Braid

QISO™

- Quasi-Isotropic Reinforcement in a Single Braid Layer
- Balanced and Symmetric with One Ply



U Maine Composite Bridge

- Braided Sleeves
- Inflated and shaped to curvature
- Resin infused, cured and shipped to site
- Arches installed
- Decking Installed
- Arches filled with concrete
- Covered with soil and traditional road surface
- Completed under budget and schedule



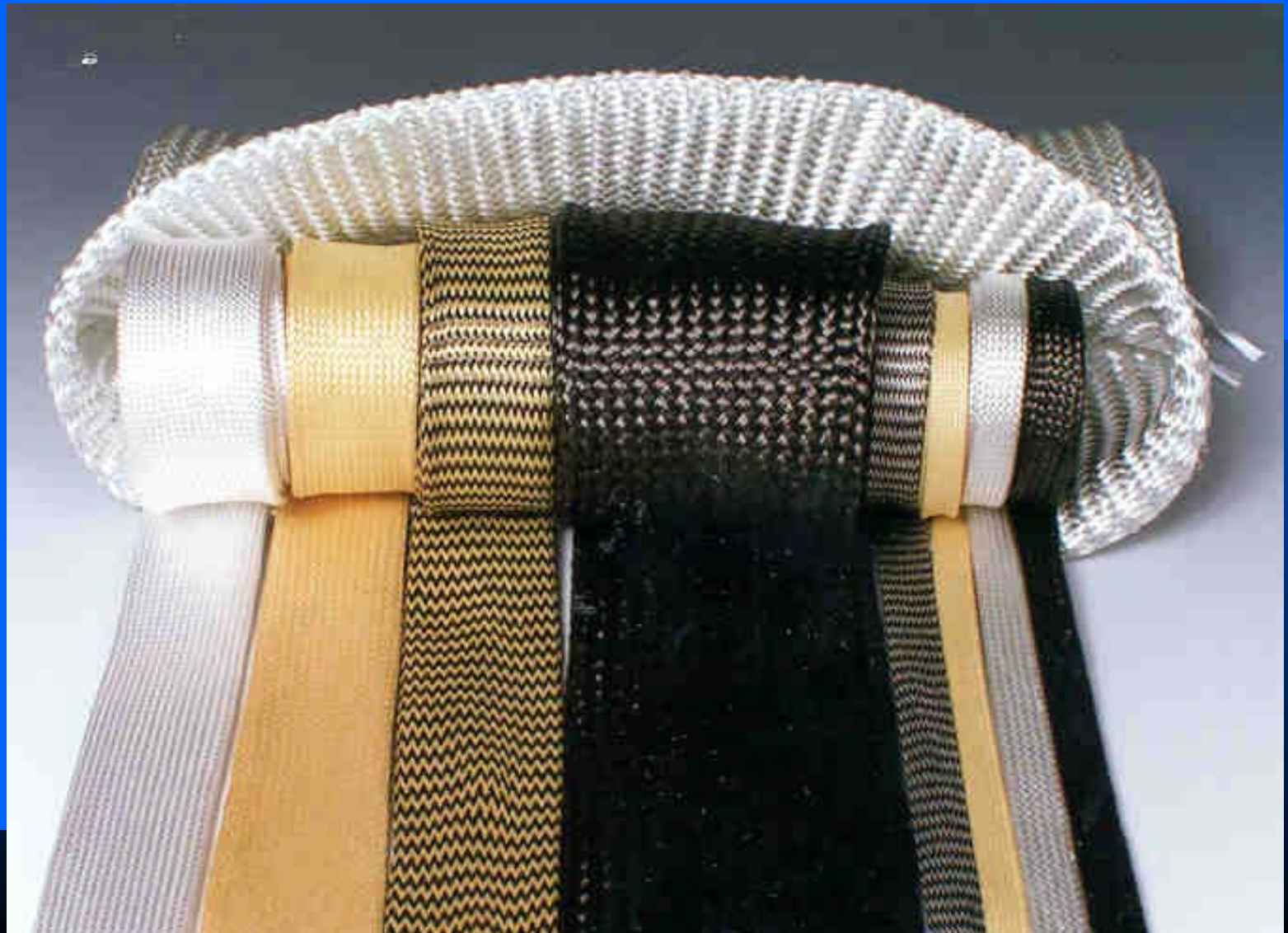
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Summary & Questions

- Braiding is the only process that can create closed sections with continuous fiber (no ply edges except at ends).
- Braid has superior large notch performance due to inherent crack arrestment features in triaxial construction
- Braid polar or cartesian coordinate system can map to most complex curvatures
- Questions

A&P Technology



The background features a dark blue gradient that transitions from a lighter shade at the top to a darker shade at the bottom. Overlaid on this gradient are several parallel, diagonal stripes in a slightly lighter shade of blue, running from the top-left towards the bottom-right.

Back Up Slides



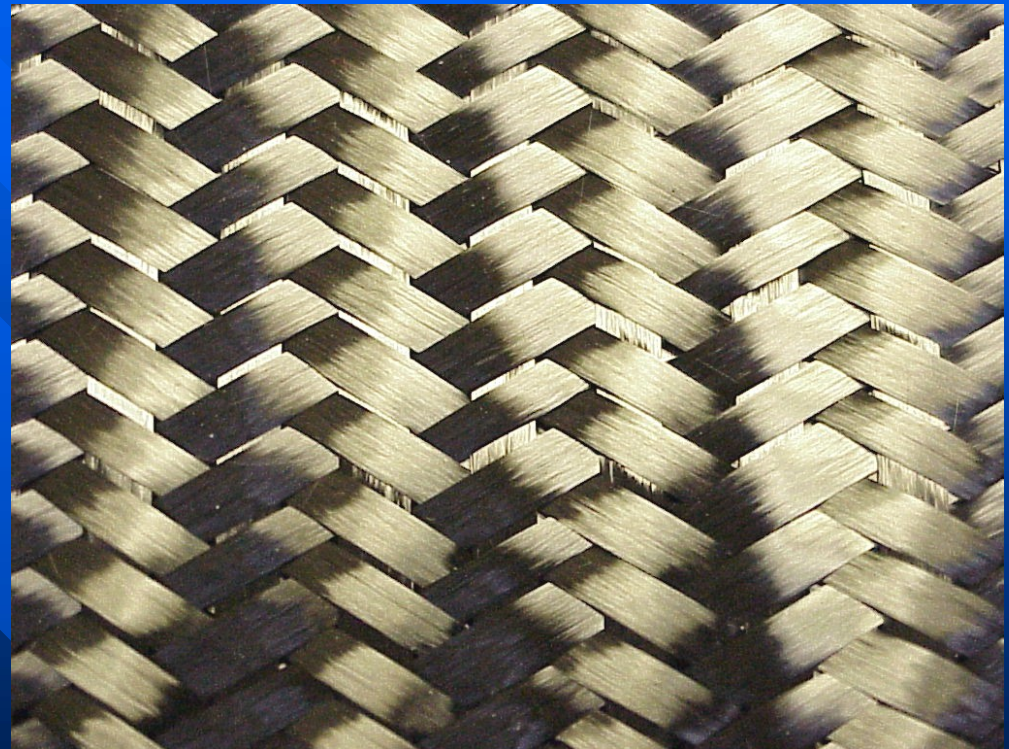
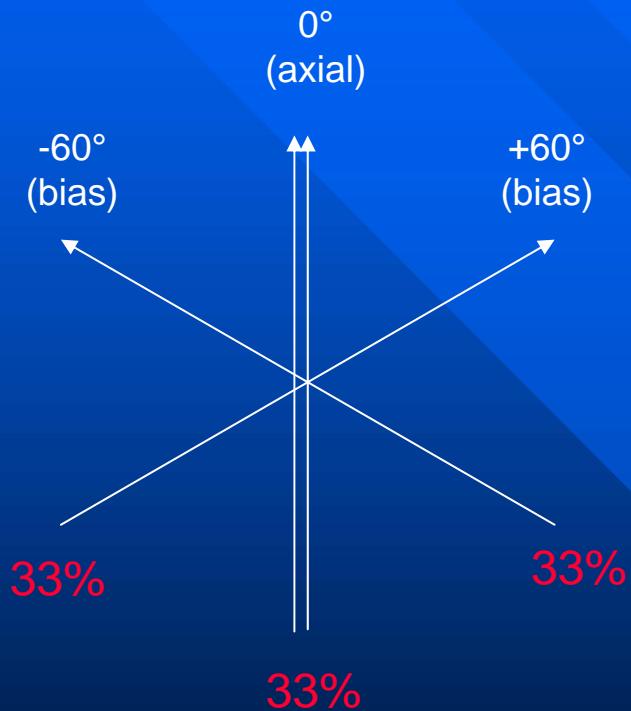
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Slit From A Sleeve



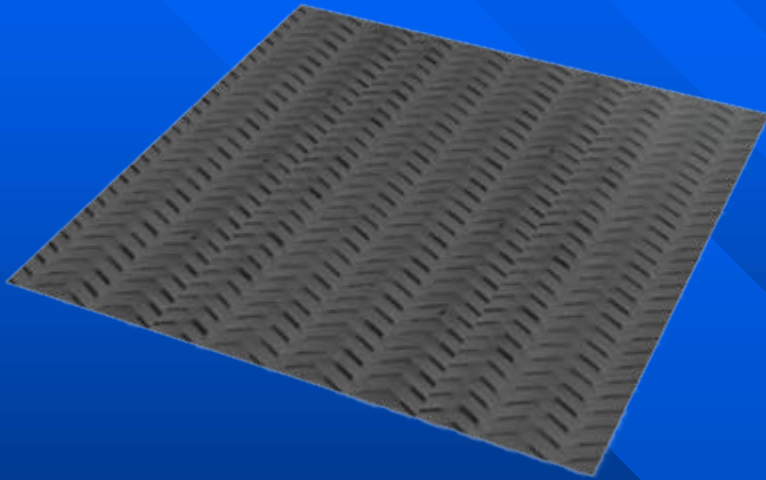


0, +/- 60° fabric

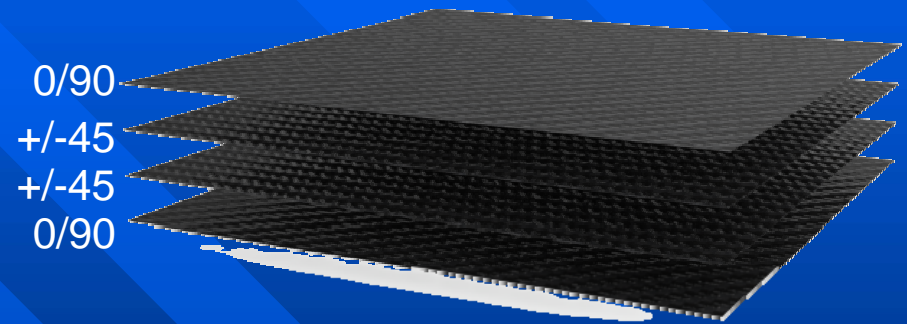


**Equal Properties In
All Directions**

To achieve a balanced laminate

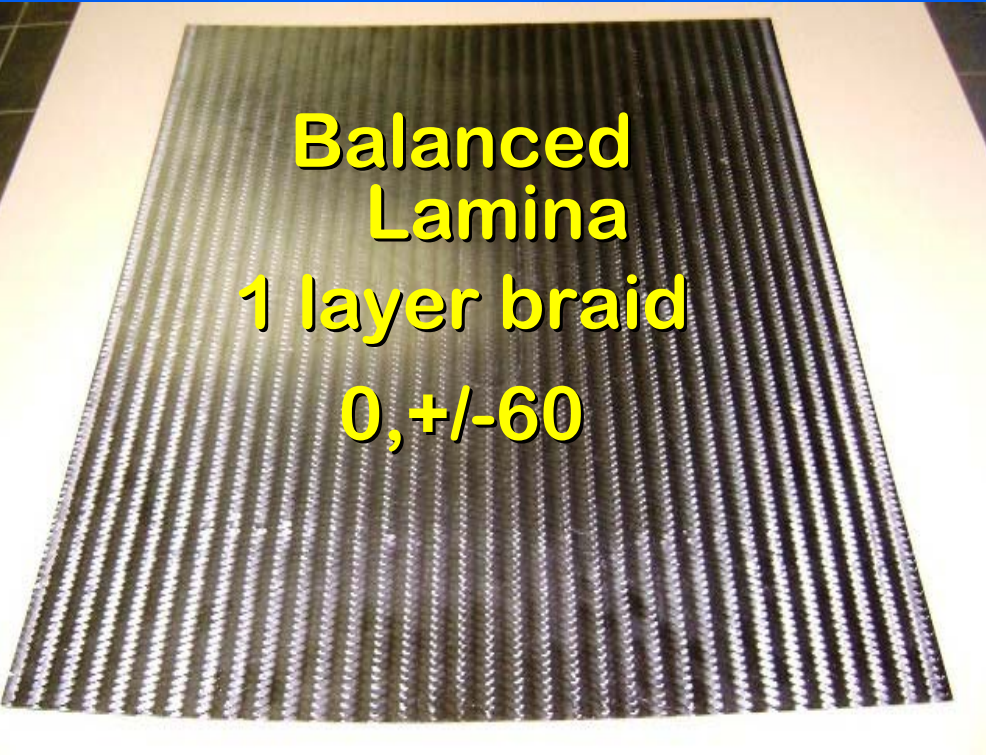


1 layer braid

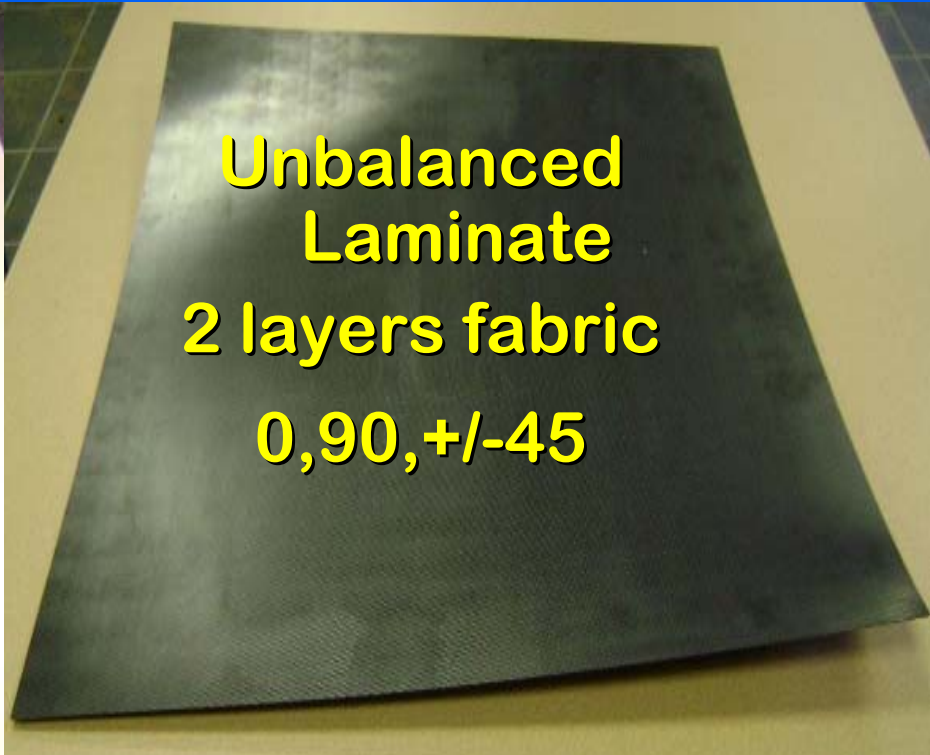


4 layers woven

- QISO allows for decreased layup time
- decreased thickness, less weight



**Balanced
Lamina
1 layer braid
0, +/-60**

The image shows a rectangular piece of a braided fabric with a distinct woven pattern. The fabric is dark grey or black with lighter grey threads visible at the intersections. The braiding is oriented vertically, creating a series of parallel ridges and valleys.

**Unbalanced
Laminate
2 layers fabric
0,90,+/-45**

The image shows a rectangular piece of a laminate fabric. The fabric is dark grey or black and has a smoother, more uniform appearance compared to the braided fabric. It is oriented vertically, similar to the braided fabric.



Variable Widths can be Produced