

National Aeronautics and Space Administration



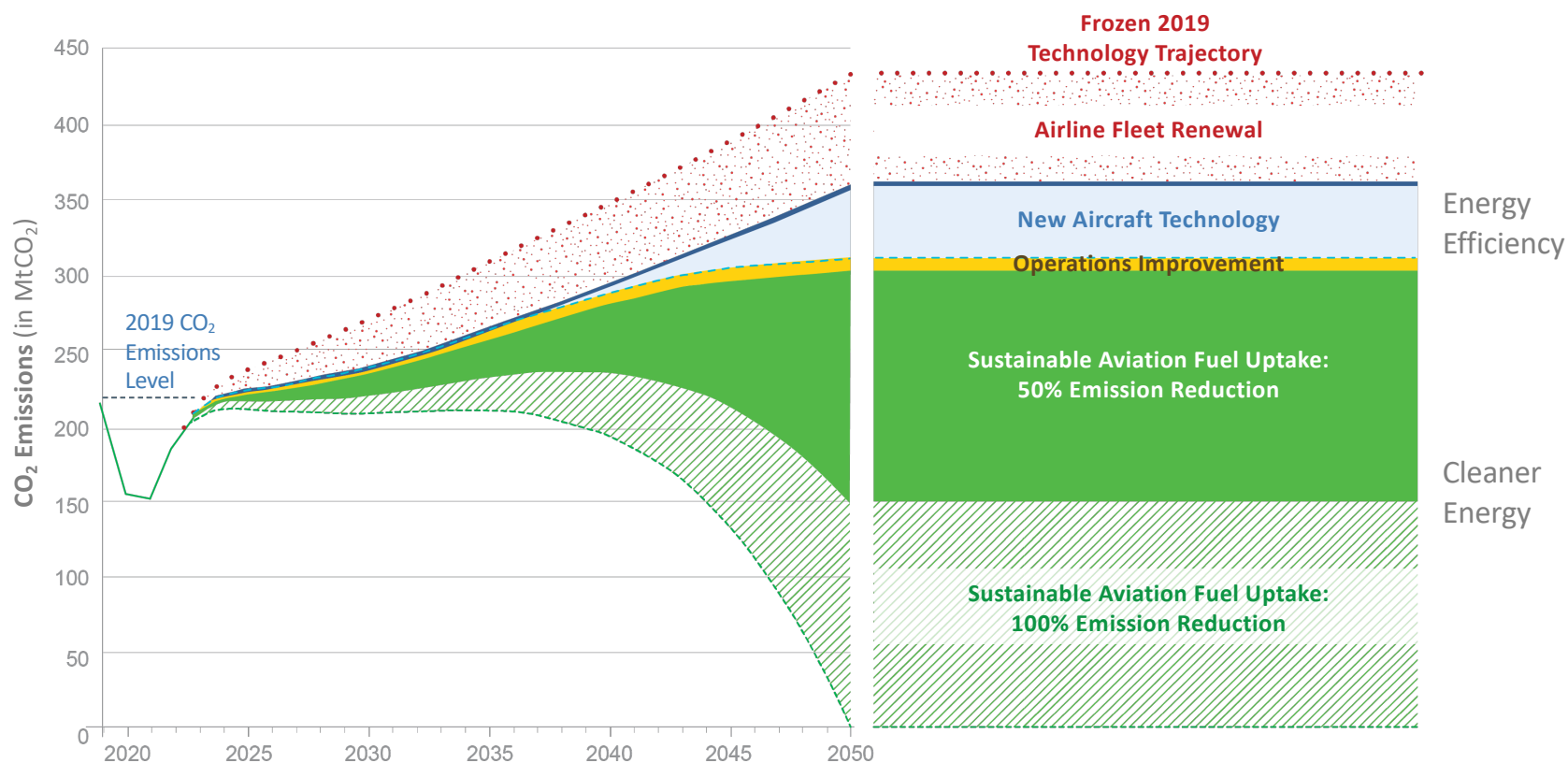
Hi-Rate Composite Aircraft Manufacturing (HiCAM)

ICAS 2024

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U.S. Aviation Climate Action Plan – 2021

Net-zero greenhouse gas emissions by 2050



https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf

The U.S. is working with the global community to achieve net-zero greenhouse gas emissions by 2050 with reduced non-CO₂ (e.g. contrails), noise, and local air quality impacts

Sustainable Flight National Partnership



Accelerating Toward Net-Zero Greenhouse Gas Emissions and Reduced Non-CO₂ Climate Impact in the 2030s

Advance engine
efficiency and
emission reduction

Enable integrated
trajectory optimization



Advance airframe
efficiency and
manufacturing rate

Enable use of 100%
sustainable aviation fuels

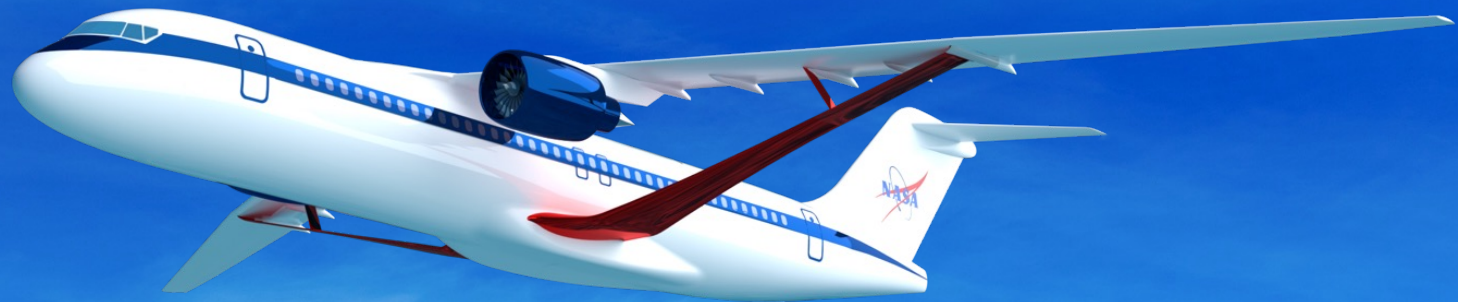
Next-generation transports using up to 30% less fuel, current & future fleet flying optimal trajectories, and engines burning SAF with greater than 50% reduction in lifecycle GHG emissions



Composite Aircraft Structures: Sustainability

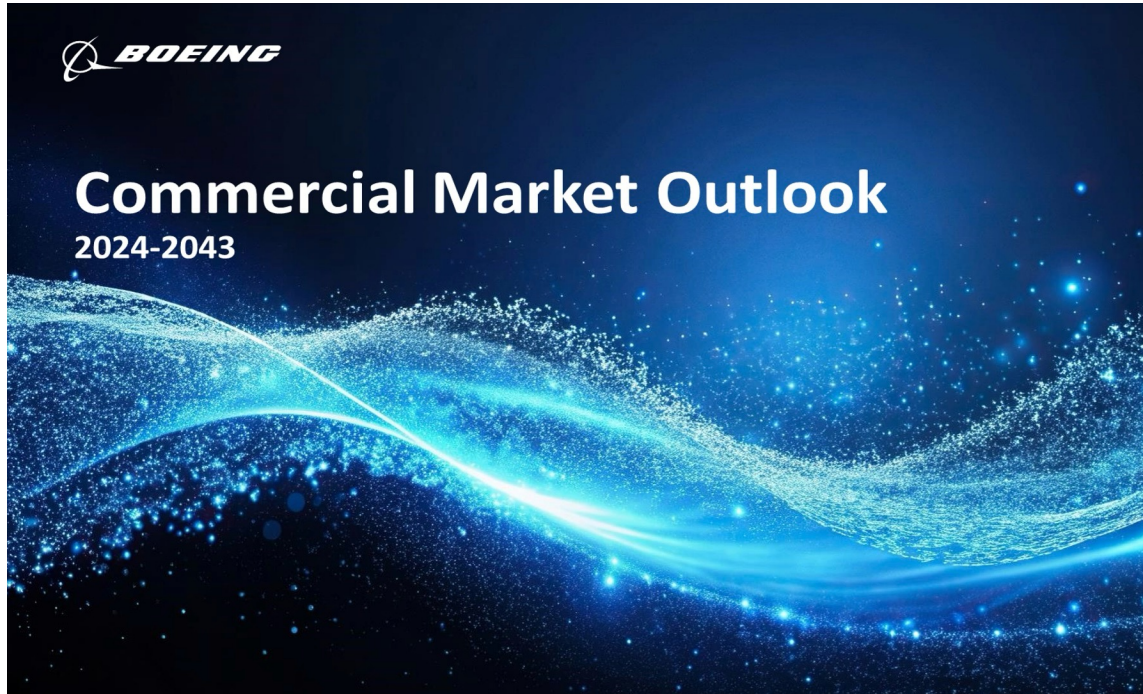
Next-generation transports burn up to 30% less fuel (source of 97% of CO₂ from aviation)

- Composites airframe
 - 25% lighter
 - Enables low drag configs
 - Reduced cost (fuel, maintenance)
 - Production is expensive – desire 50% cost reduction for composites fab
- 5-8% fuel burn reduction



- Sustainable Manufacturing
 - Composites: 2x environmental impact, yet offset in weeks of operation
 - Energy efficiency, renewable energy sources
 - Reduced consumables, waste products, scrap
 - Recycling: Down-cycle fibers
 - Sustainable fibers and polymers

Transport Aircraft Market Demand Drives Manufacturing Rate



Boeing & Airbus desire next single aisle production 80-100/month

Historic production rates/month

- Metals : 60 80 = 1.3x
- Composites : 10-14 80 = 6x

Airlines need 43,975 new airplanes over 20 years

- Replacing 70% of current fleet
- Nearly doubling fleet size



Hi-Rate Composite Aircraft Manufacturing (HiCAM)

Challenge: Meet aircraft demand; improve fuel efficiency

Goal: Demonstrate manufacturing approaches and associated technologies for large composite primary airframe structures that enable high-rate production (up to 80 aircraft per month) with reduced cost and no weight penalty versus 2020 technology for composite structures for early 2030s single-aisle aircraft production

Objectives:

- Affordable, high-rate composite manufacturing tech
- Model-based engineering tools for high-rate concepts

Approach:

- Baseline: B787/777x aircraft production system
- Compete thermosets, resin infusion, thermoplastics
- Assess system production cost and component weight
- Demonstrate capability for full-scale component(s)



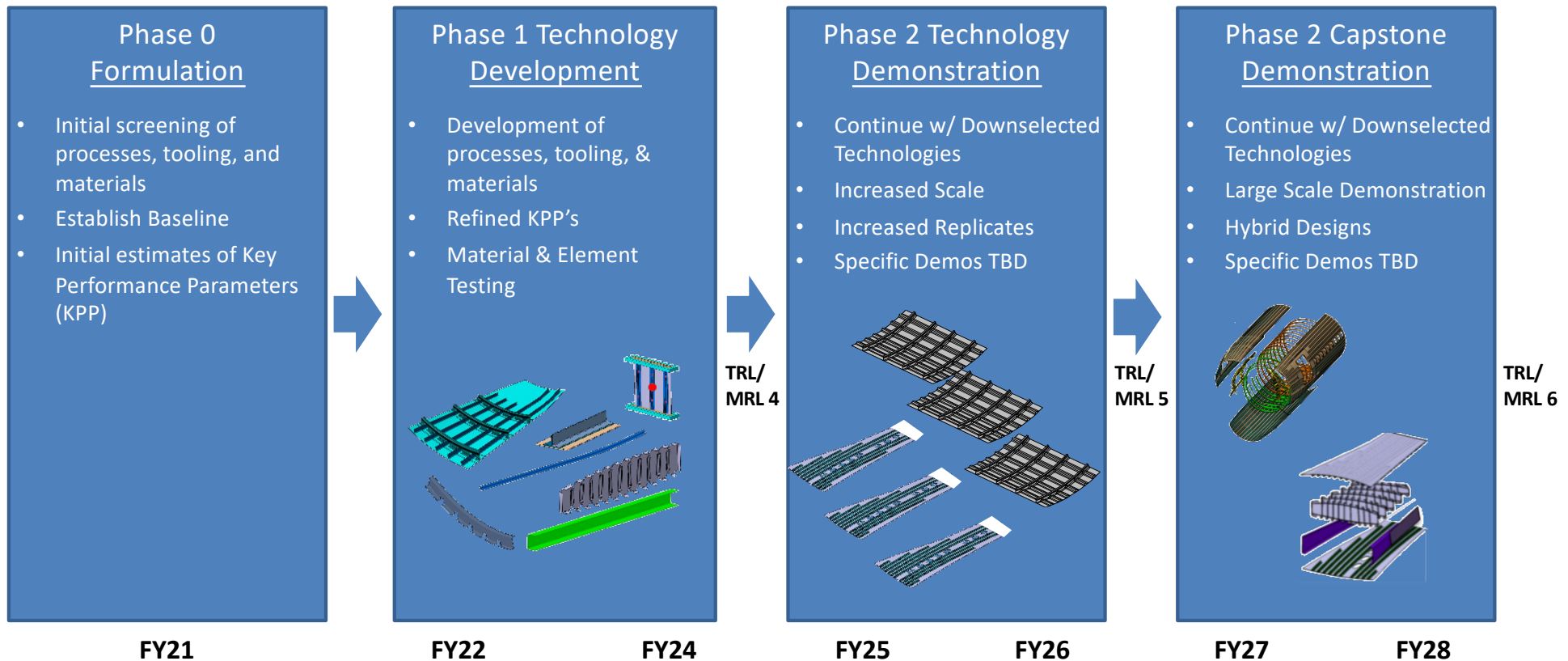
Advanced Composites Consortium



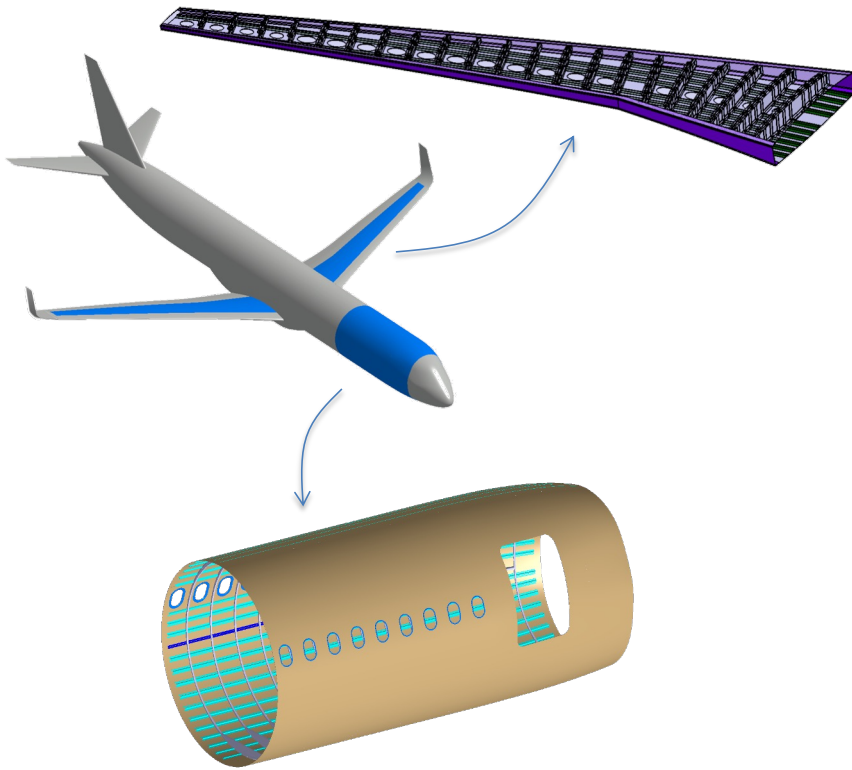
Addresses industry needs for rate, cost, and weight

Public-Private Partnership with 50:50 cost share

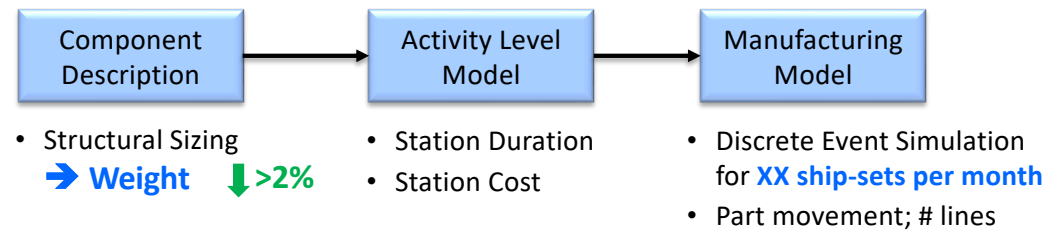
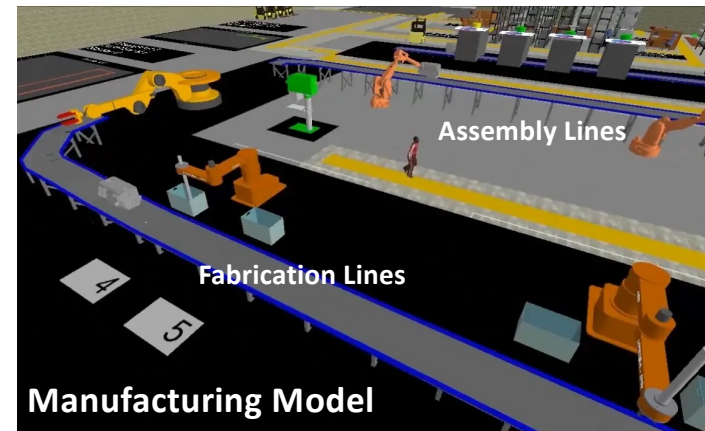
Project Timeline



Technology Assessment Process: Key Performance Parameters & Goals



- Generic narrow body reference config.
- Aircraft loads; common sizing tools



GOALS

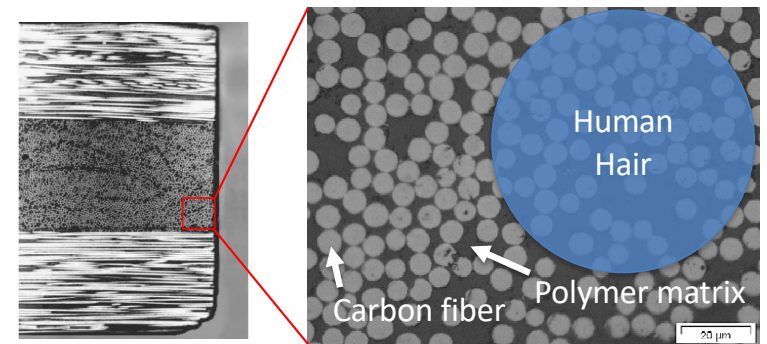
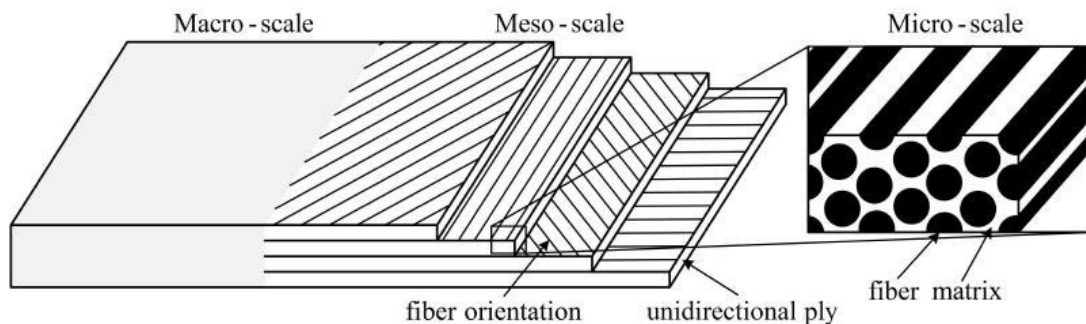
Compare:

- Baseline (787, 777 wing)
- Next-Gen thermosets
- Resin infused composites
- Thermoplastic composites

- **Production Rate, XX** 80/month
 - **Non-Recurring Cost***
 - **Recurring Cost**
 - **Factory Area**
- ↓>50%, net cost per ship set

* Assume allocation to 3600 shipsets

Laminated Composites: Manufacturing Approaches



Thermoset Prepreg

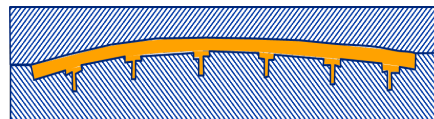
- Layer of fiber, pre-impregnated with uncured epoxy (soft, tacky)
- Stored in a freezer until used
- Stacked to form laminates
- Vacuum bagged, cured in autoclave (P, T, ~8hrs)



Thermoset epoxy: cure chemical transformation, permanent crosslinks between polymer chains, non-reversible solid form

Resin-infused Composites

- Layers of dry fiber (no epoxy)
- Vacuum bagged or placed in a closed tool



- Infused with 2-part thermoset epoxy
- Cured in oven or heated tool

Thermoplastic Composites

- Plastic polymer matrix, molten when heated, harden upon cooling
- Reversible: reheat, reshape, recycled
- Stored at room temp
- Assembled by fusion (P, T, ~minutes)
- Processing: Autoclave, vacuum bag in oven, in situ consolidation, stamp forming, injection molding, continuous compression molding, welded assembly



NextGen Thermosets (NGT)

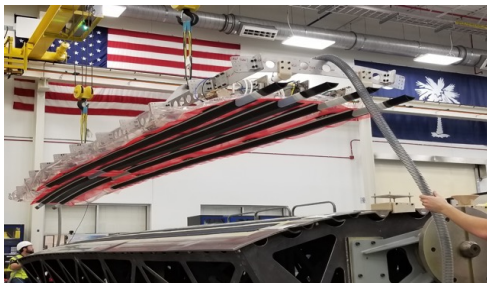
- *Evolution of the state of the art, baseline production system*



High Rate Lamination (AFP 4.0)

- Higher performance fiber
- 4-8X faster lamination rates

Automated Stringer Forming (ASF)



Automated Part Handling

- Pick-n-Place
- Improved Factory Flow

Autoclave

- 3x faster cure flow time



Progress

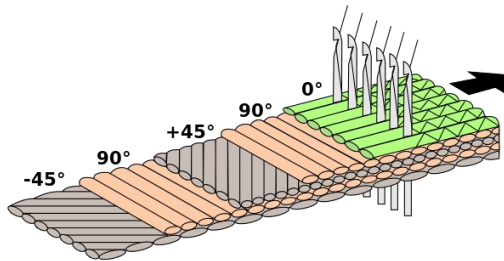
- AFP trials w/laser heating, in situ inspection
- Coupon tests: IM+, rapid cure
- ASF: 10' stringer
- Lamination process dev. for low, med, high contour panels; spars, frames
- Accelerated cure trials

Upcoming

- 4'x8' stringer-stiffened panels, fuselage and wing
- Skin-stinger element tests

Efficient, Reliable M&P / Equipment → Shorter Cycle Time → Less Capital, Labor → Lower Cost

Resin Infused Composites (RIC)

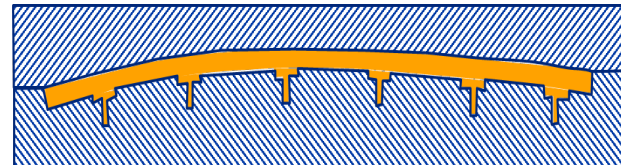
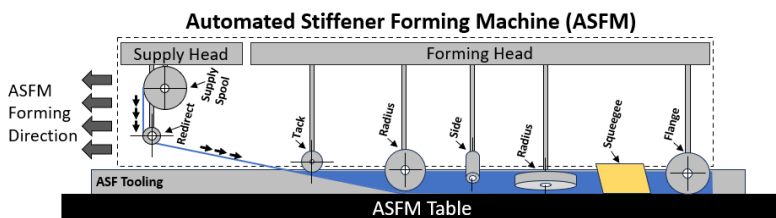


Multi-axial NCF stacks, IM+ Fiber

- Faster material laydown, highly drapable (10x faster)
- Higher strength carbon fibers (reduced weight)

3D Pick & Place

Automated Fabrication of Stringers, Spars and Frames



Closed Mold Tooling

- Controlled surfaces, precision/shimless assembly

Self Heated Tools, Out of Autoclave Cure

- Free standing press
- Fast cure toughened resin system (less time on tool)

3D Structural Reinforcement (Stitching)



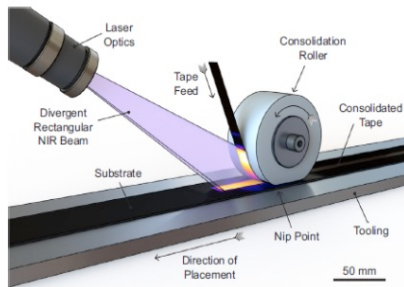
Progress

- Wing:
 - NCF dry fiber preform with low bulk: stiffeners, kinked spar, skin panels
 - Infusions: flat panels; spar section
 - Process development for fast cure
- Fuselage:
 - Dry-fiber placement, in situ inspection
 - Frame preforming
 - Infusion simulation
 - One-sided stitching, characterization
 - New isothermal rapid cure resin dev.

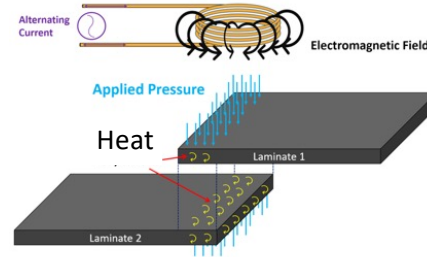
Upcoming

- 2-stringer panels
- Spar section

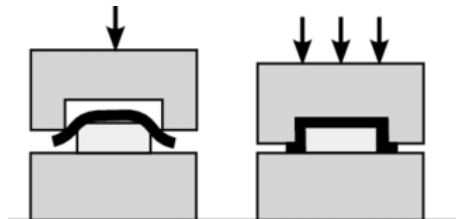
Thermoplastic Composites (TPC)



Laser-assisted AFP

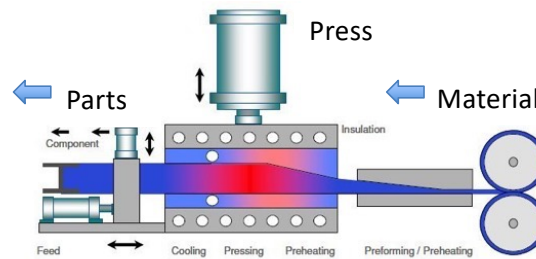


Welding or Co-Fusion Assembly

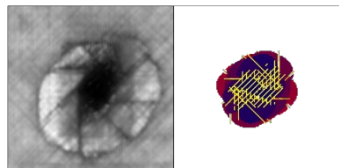


Stamp Forming

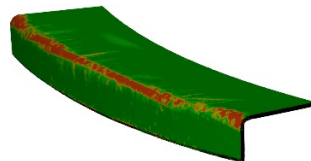
Rapid cycle times, typically minutes vs hours



Continuous Compression Molding (CCM)



Structural Sizing Tools



Manufacturing Process Models



Paint Finishes

Progress

- In situ consolidation – abandoned due to low strength, low rate
- High-rate laser AFP with in situ inspection
- ASF with in situ consolidation - success
- Stamp forming of stringer, frames, and ribs
- Evaluation of welding techniques: ultrasonic, induction, conduction
- Draft roadmap for welding certification
- Evaluation of strength prediction tools

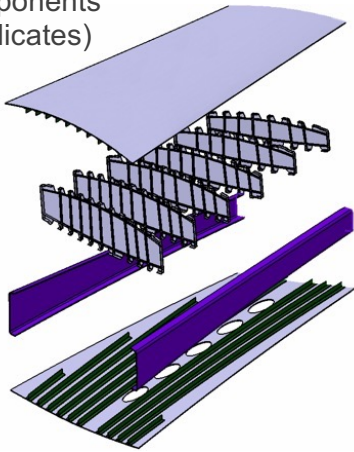
Upcoming

- Stamp forming skin
- 4'x6' stiffened panels:
 - skins: vbo, stamp formed
 - welded or confusion joining

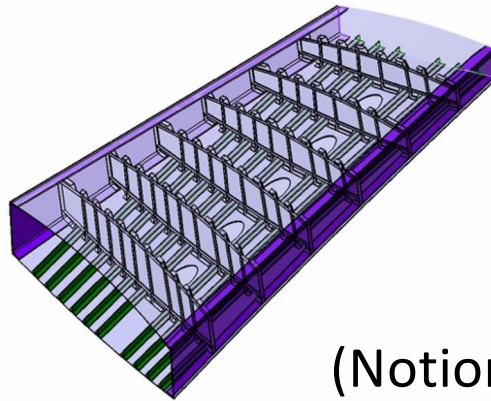
HiCAM Phase 2: Large-Scale Demos for Wing and Fuselage (FY25-FY28)

Wing box section near engine pylon

Subcomponents
(~10 replicates)



Assembled Component (~3 replicates)

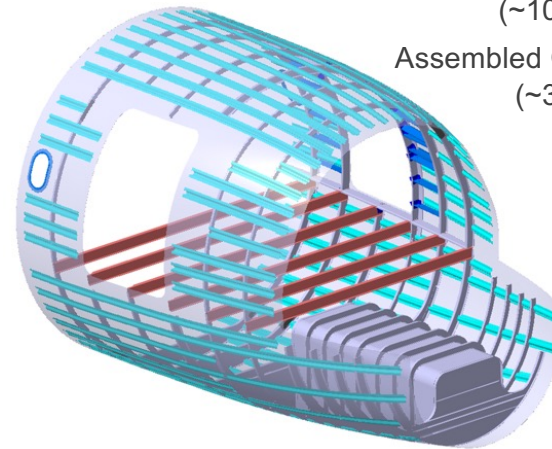


(Notional)

Fuselage forward section

Subcomponents
(~10 replicates)

Assembled Component
(~3 replicates)



- Demonstrate manufacturing rate and quality at component scale with representative complexity
- Validate design tools and strength at panel scale
- Assess best manufacturing systems for transition to next airplane program



Summary

- Lightweight composite airframe improves aircraft efficiency, helps the environment
- High-rate (lower cost) manufacturing technologies being developed for narrow-body market
- Competing manufacturing approaches evaluated; demonstrated at panel scale (TRL/MRL4)
- Select technologies to be scaled up for large scale wing and fuselage assembled components

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Hi-Rate Composite Aircraft Manufacturing Project

The Hi-Rate Composite Aircraft Manufacturing (HiCAM) project addresses an aviation industry need for more rapid production of composite aircraft to meet increasing global demand for lightweight transport aircraft. As part of the Sustainable Flight National Partnership, HiCAM partners with industry to increase the rate of composite aircraft manufacturing, reduce costs, and improve performance.

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Robert Martin

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[Learn More About HiCAM](#)