

National Aeronautics and Space Administration

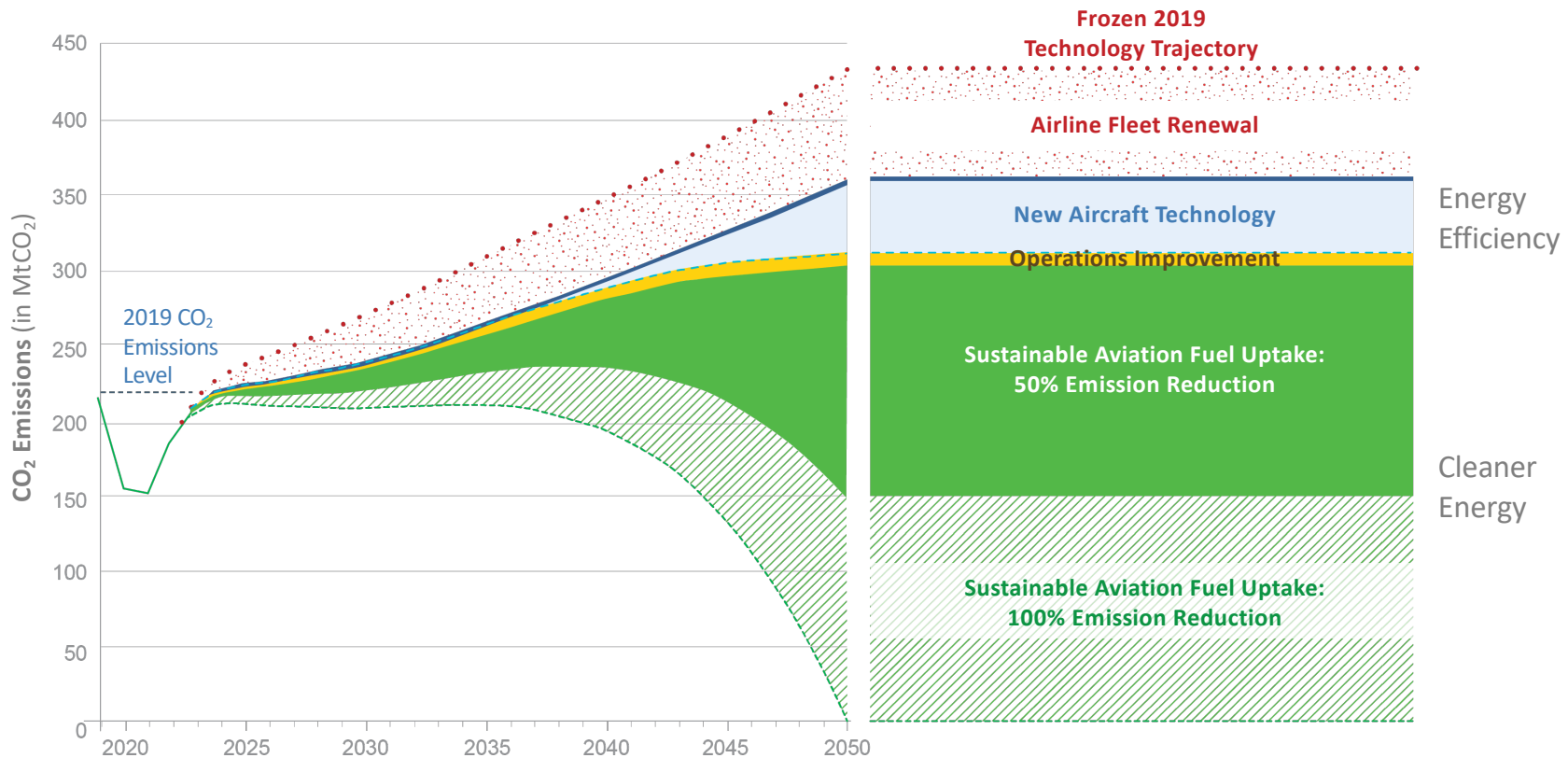


NASA HI-RATE COMPOSITE AIRCRAFT MANUFACTURING (HiCAM) PROJECT OVERVIEW and Other Related Topics

Rick Young, HiCAM Project Manager, NASA

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

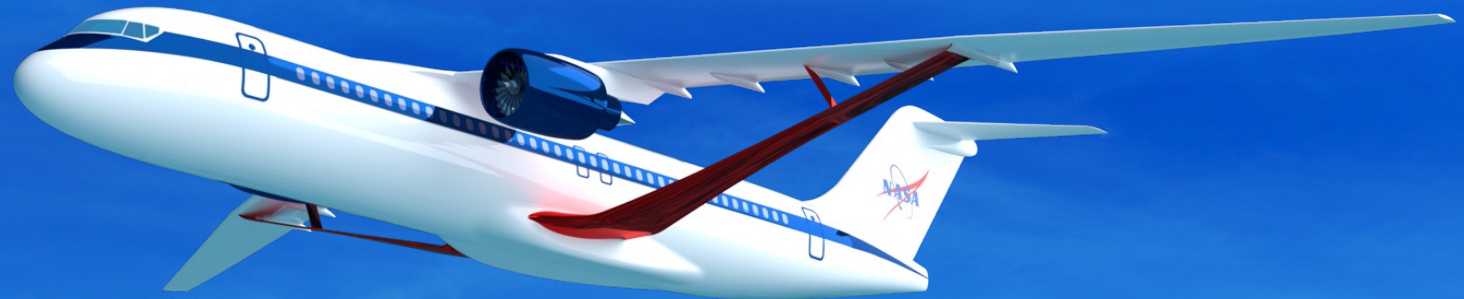
Next-generation transports using up to 30% less fuel, current & future fleet flying optimal trajectories, and engines burning SAF with greater than 50% reduction in lifecycle GHG emissions



Composite Aircraft Structures: Sustainability

Emissions

- Next-generation transports burn up to 30% less fuel (source of 97% of CO₂ from aviation)
 - Composites airframe
 - Wings: ~34-40% lighter; Enables low drag configs
 - Fuselage: ~5-10% lighter than metallic
- } 5-8% fuel burn reduction



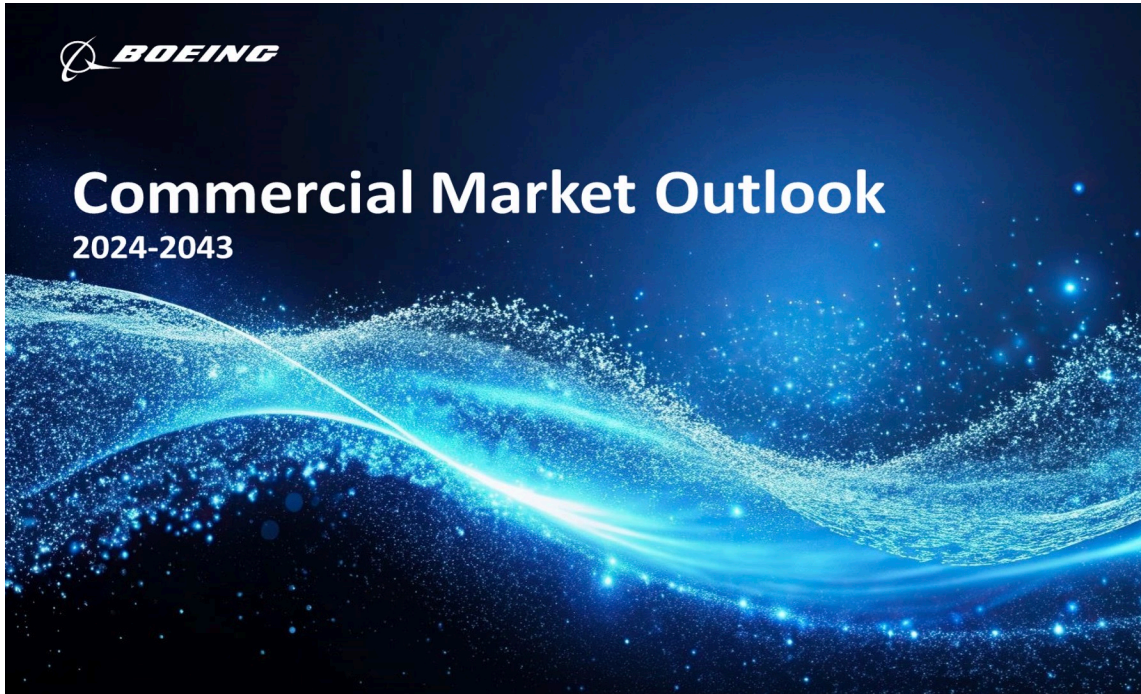
Lifecycle sustainability:

- Composite mfg. & disposal has 2x emission impact; yet “negligible”, offset by in-use benefit in weeks
→ Sustainable mfg – second order

Economic Sustainability:

- Reduced cost (fuel, maintenance)
- Composites production is expensive – desire 50% cost reduction for composites fab

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)



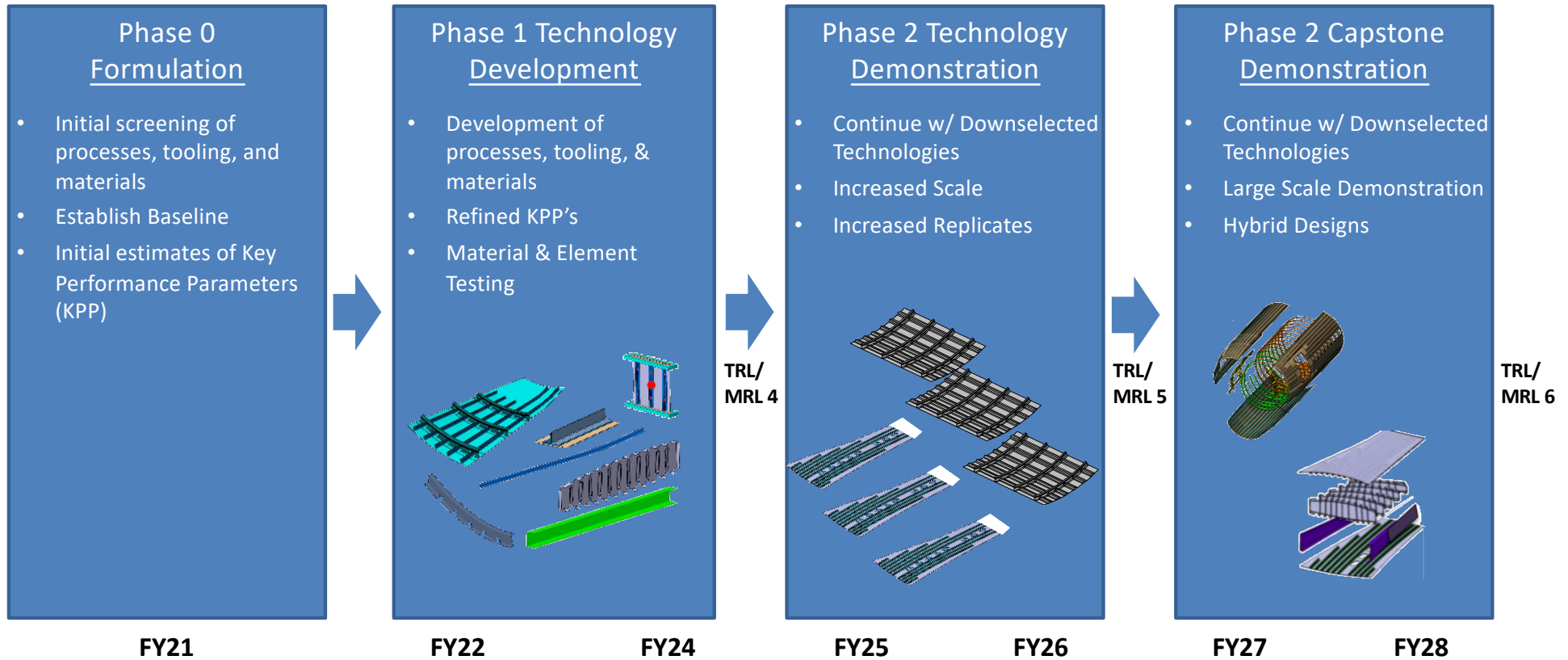
Advanced Composites Consortium



Addresses industry needs for rate, cost, and weight

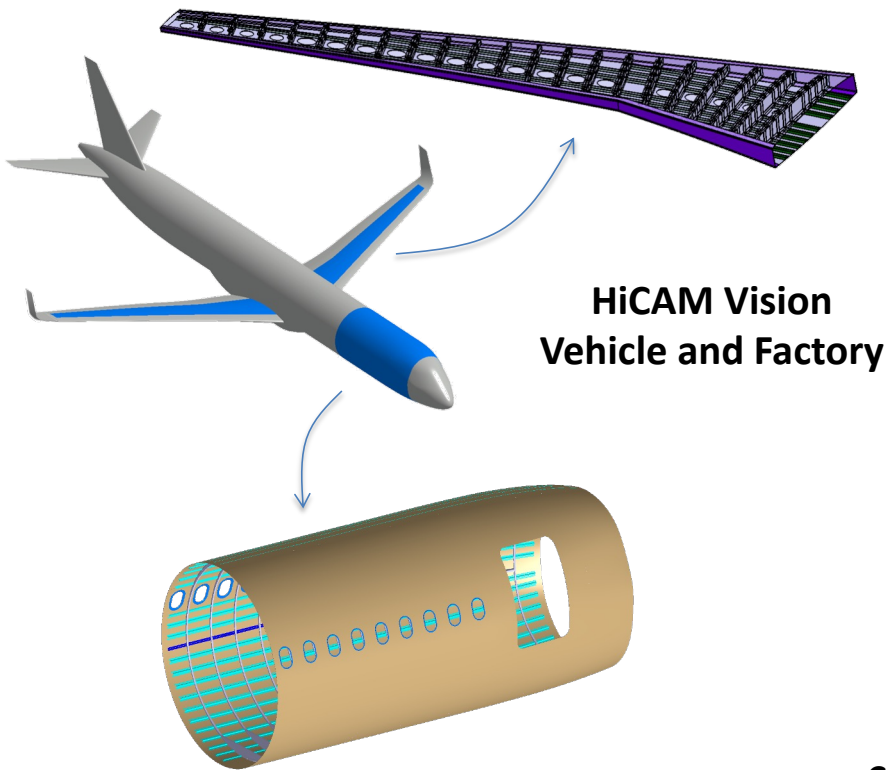
Public-Private Partnership with 50:50 cost share

Project Timeline

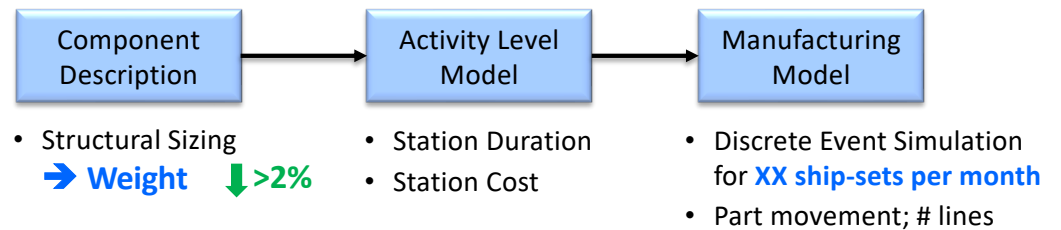
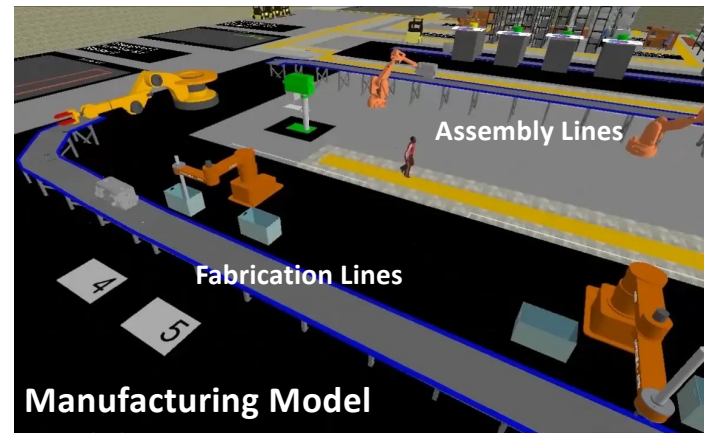




Technology Assessment Process: Key Performance Parameters & Goals



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



GOALS

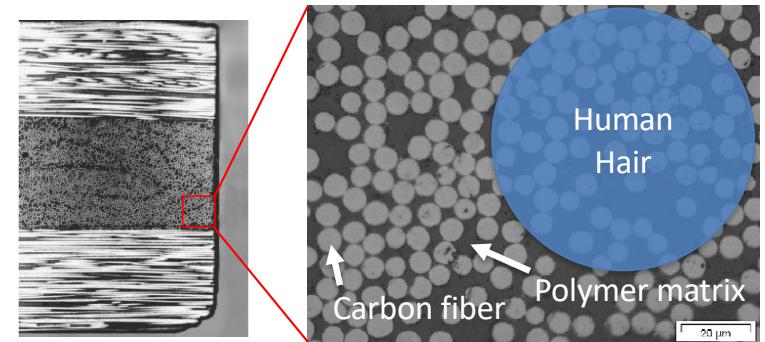
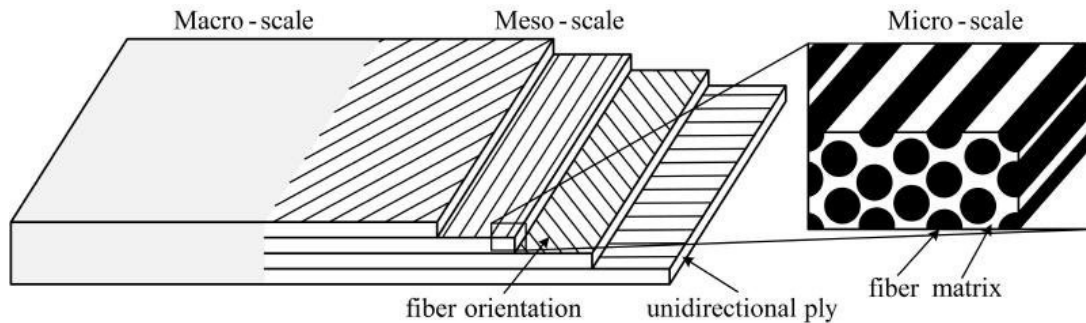
Compare:

- 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

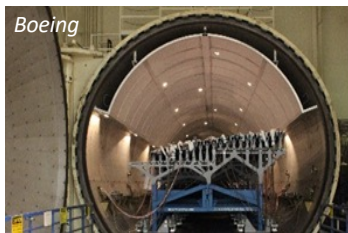
* Assume allocation to 3600 shipsets

Laminated Composites: Manufacturing Approaches



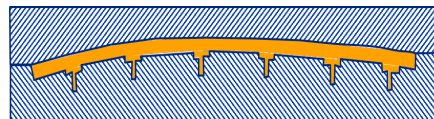
Thermoset Prepreg

- 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)



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

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

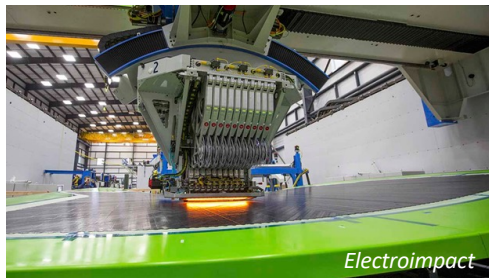
Thermoplastic Composites

- 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)

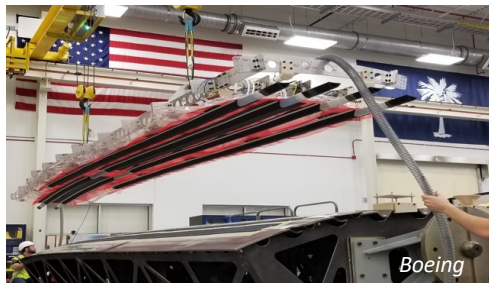
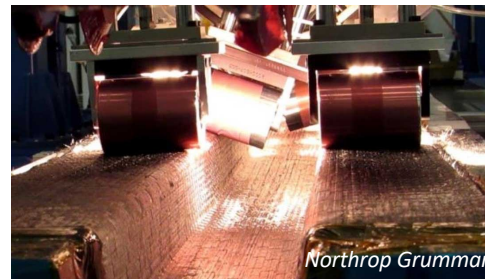
- Evolution of the state of the art, baseline production system



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

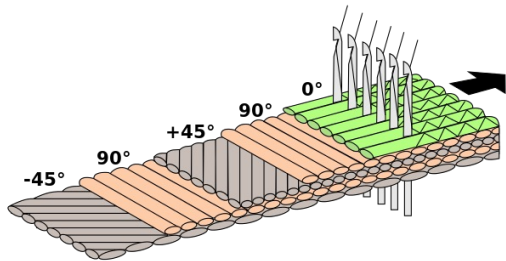
- AFP trials w/laser heating, in situ inspection
- Coupon tests: IM+, rapid cure
- ASF: 10' stringer
- Lamination process dev. for low, med, high contour panels; spars, frames
- Accelerated cure trials

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)

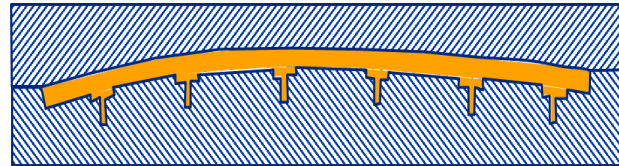
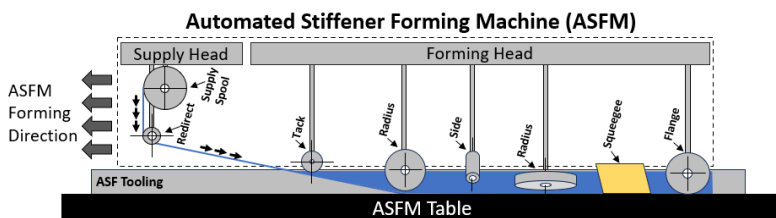


Multi-axial NCF stacks, IM+ Fiber

- 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)



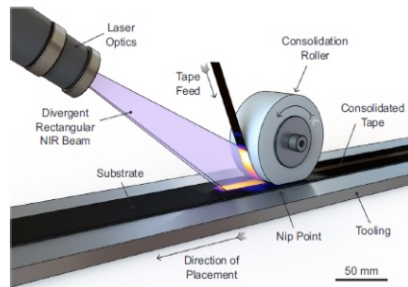
Progress

- 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.

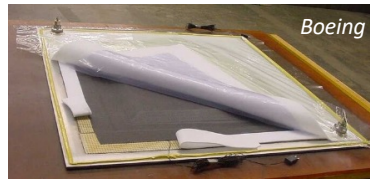
Upcoming

- 2-stringer panels
- Spar section

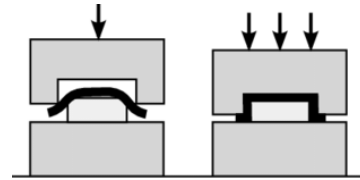
Thermoplastic Composites (TPC)



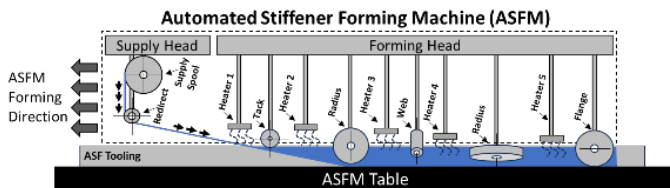
Laser-assisted AFP



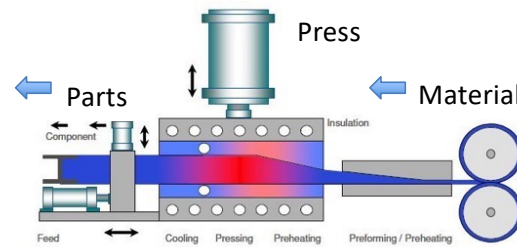
Vacuum Bag (VBO) Consolidation



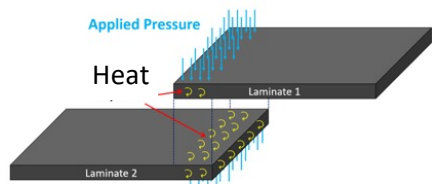
Large Stamp Forming
Minutes vs hours



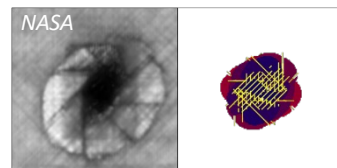
Automated Stiffener Forming



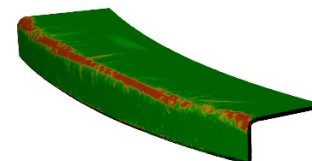
Continuous Compression Molding (CCM)



Welding or Co-Fusion Assembly



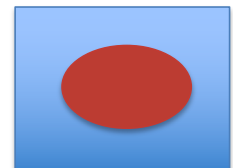
Structural Sizing Tools



Manufacturing Process Models



Paint Finishes



Repairs

Progress

- In situ consolidation – 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 co-fusion joining

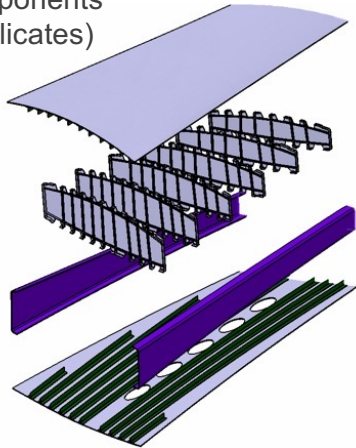


HiCAM Phase 2: Large-Scale Demos for Wing and Fuselage (FY25-FY28)

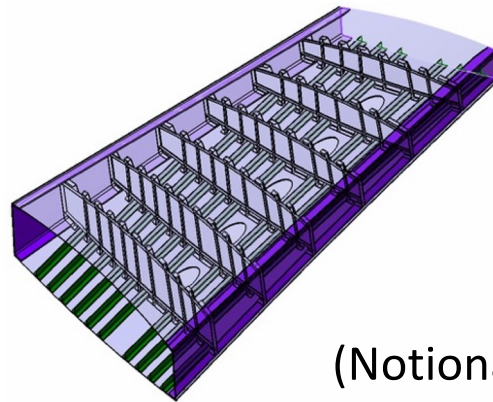
- Down-select manufacturing tech based on impact, readiness, and likelihood to transition to next airplane program
- Consider hybrid concepts
- Demonstrate manufacturing rate and quality at component scale with representative complexity
- Validate design tools and strength at panel scale
- Assess best manufacturing systems for transition to next airplane program

Wing box section near engine pylon

Subcomponents
(~10 replicates)



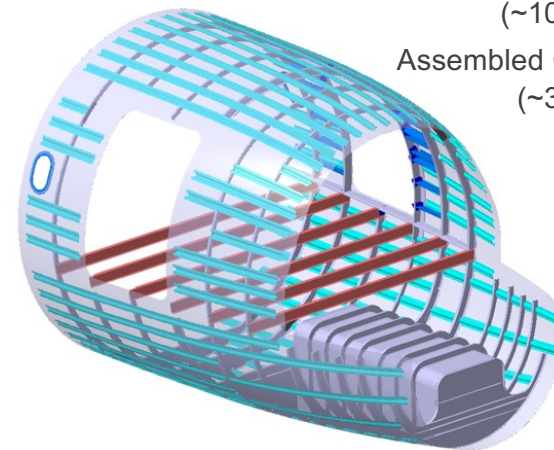
Assembled Component (~3 replicates)



(Notional)

Fuselage forward section

Subcomponents
(~10 replicates)



Assembled Component
(~3 replicates)

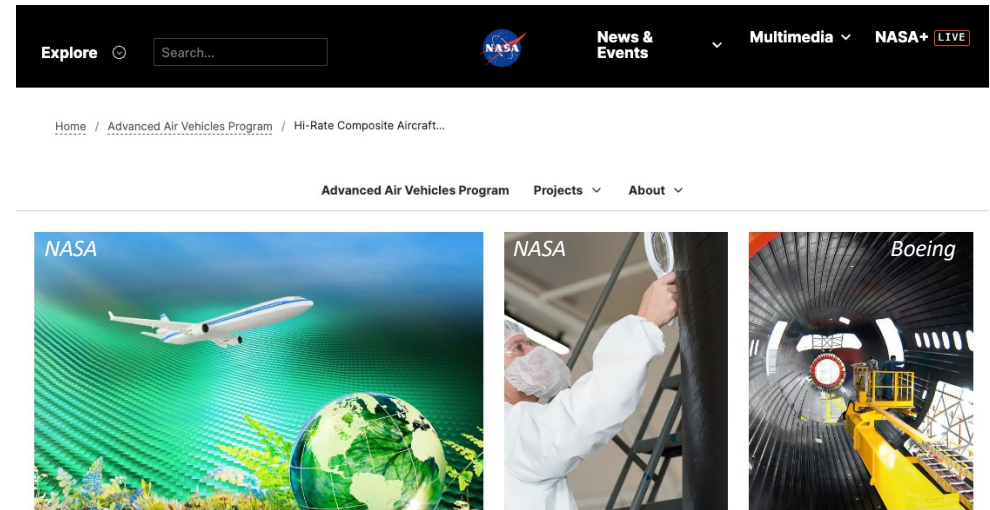


HICAM Summary

- 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

Follow HiCAM:

<https://www.nasa.gov/directorates/armd/aavp/hicam/>



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.

[Learn More About HiCAM](#)

PROJECT MANAGER
Dr. Richard Young

DEPUTY PROJECT MANAGER
Robert Martin

COMMUNICATIONS LEAD
Tamara Croom



Other Related Topics

- Resin Infusion Development in UK
- Thermoplastics development in Europe versus U.S.
- Perspectives on Sustainability
- Beyond the next single aisle airplane



HiCAM Leadership Visits UK, May 13-17, 2024

Spirit Aerosystems, Belfast

- Bombardier C-series (2018) / A220 wing fabrication and assembly, 10/month,
- SOP large scale resin infusion with autoclave cure



Spirit Aerosystems

- Fabrication, trim, inspection, assembly including shimming
- 30% waste with dry non-crimp fiber mat → dry AFP, 5% waste
- Big opportunities
 - Out of autoclave processing
 - Automated stiffener forming
 - Optimized assembly



Spirit Aerosystems

<https://youtu.be/tDDrgGSiW3A>

<https://www.compositesworld.com/articles/plant-tour-spirit-aerosystems-belfast-northern-ireland-uk>



HiCAM Leadership Visits UK, May 13-17, 2024 (cont.)

Spirit Aerosystems, Prestwick

- Resin infused A320 spoiler production
 - Automation with Pick and Place & shuttle systems
 - Resin infusion, heated press cure
 - <https://www.youtube.com/watch?v=yqUdH2LL-Eg>
- Wing of Tomorrow program (lower skin panels)
 - Scaling up, size and thickness (140 plies)
 - Resin infusion, out of autoclave heated tool
 - Automated stiffener forming



Spirit Aerosystems



17m heated tool

Spirit Aerosystems

GKN Global Development Center, Bristol

- Wing of Tomorrow program (spar)
 - Resin infused, closed heated tool
 - 1m, 5m, 17m scale up articles



GKN

Wing of Tomorrow (2015-2023) complete → SusWingS: New program for industrialization for rate



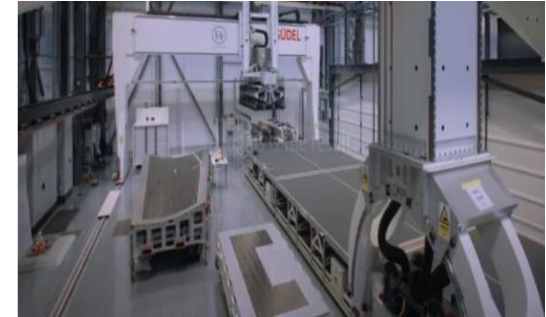
HiCAM Leadership Visits UK, May 13-17, 2024 (cont.)

High Value Manufacturing Catapult (HVMC) Centres

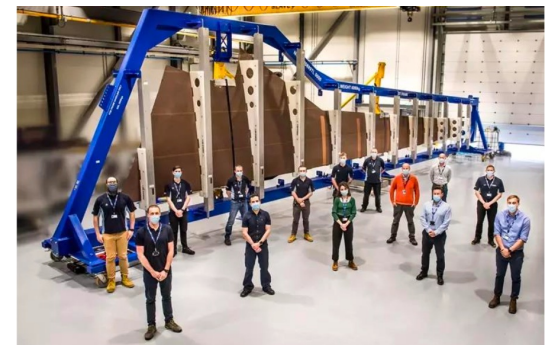
- **Advanced Manufacturing Research Center, Sheffield (2001)**
 - >120 partners, including Boeing, RR, McLaren, Airbus
 - Mix of funded open R&D, collaborative, industry sponsored
 - Factory of the Future, Factory 2050
 - COMPASS – Composites at Speed and Scale (under construction), first R&D project is with Boeing
- **National Composite Centre, Bristol (2011)**
 - World 1st industrialized UHR composite deposition for dry fibre, moulded and resin infused
 - Consortium partners include Airbus, Spirit, GKN, NG, GE, RR

Observations:

- Heavy investment in UK in resin infused composites for large scale and high rate
- Actively working/tracking sustainable manufacturing
- Working cyrotanks for H2-fueled aircraft, longer term with SAF as near term
- AAM prototypes; nobody investing in manufacturing yet



AMRC



NCC



Status of U.S. Thermoplastics Capability, Relative to Europe

U.S.

After overhype & failures in 1980's, U.S. development slowed

....

2018: Boeing intro thermoplastics in "elementary structural parts" on the 787's fuselage and wing, replacing metal and thermosets

HiCAM: High-rate concepts for large structures

2022 TRL 2: Material evaluations, Characterization

2024 TRL 4 Stiffened panels, 4 ft x 8 ft

2028 TRL 6 Assembled Components

2023: AMMRC, U.S. thermoplastics development center, receives "EDA Tech Hub" designation; not yet funded

2024: ASPERA Welded Thermoplastic Composite Demonstrator: fuselage panel, AFP, VBO, stamp forming, welded assembly, TRL4; JEC Innovation Award



Spirit Aerosystems & partners

Assessment of U.S. Thermoplastics:

- U.S. is several years behind; aggressive plans but lacks experience
- Difficult to scale to largest fuselage or wing structures
- HiCAM to navigate risk versus reward, with time constraint for FSA

Europe

Airbus and the Dutch (Fokker) continued to invest heavily in development of thermoplastic composites

1990's: Fokker 50, supplying Gulfstream floor panels

2002 (A340), 2007 (A380): 1000's small parts, 10% airframe

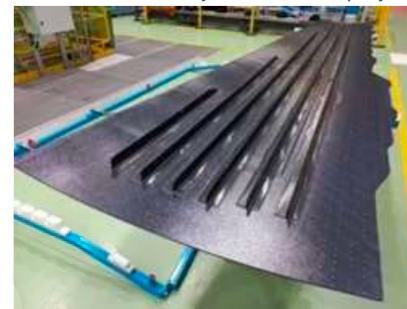
2009: Thermoplastic Composites Research Center (TPRC)

2014: Thermoplastic composites for high volume small components in fuselage on the Airbus A350

2018: A320 pressure bulkhead demo, welded assembly

2017-2024: CleanSky2 Program

Clean Sky 2 OUTCOME project



Outer wing box cover, 4m regional aircraft, in situ consolidation, integrated stringers, TRL5, 2023

Clean Sky 2 MFFD project



Multifunctional Fuselage Demonstrator, 8m, in situ consolidation, welded assembly, TRL5, 2024



American Aerospace Materials Manufacturing Center (AAMMC)

U.S. Developmental Center for Thermoplastic Composites

- Focus on large part applications, RL 6-9
- Expand domestic capabilities; supply chain demand, 20x
- Spokane region economic development

501c, Consortium Members:

- Industry: [Boeing](#), [Raytheon \(Collins\)](#), [Lockheed Martin](#), [Spirit](#), [Northrop Grumman \(ATK\)](#), [ATC](#), [Electroimpact](#), [Toray](#), [Syensqo*](#), [Blue Origin](#), [Accudyne](#)
- Federal Agencies and Labs: USAF/AFRL, DOE: PNNL, ORNL; NASA
- Education, Workforce, Economic Dev., Venture Dev., Govt. & Tribal

DOC-EDA Tech Hub, Notice of Opportunity

- Oct. 23, 2023: Phase 1, one of 31 designated Tech Hubs
- July 2, 2024: Phase 2, Not among 12 Tech Hubs awarded implementation \$
- Eligible for future rounds of funding



In Spokane WA at vacated Triumph facility

* HiCAM partners

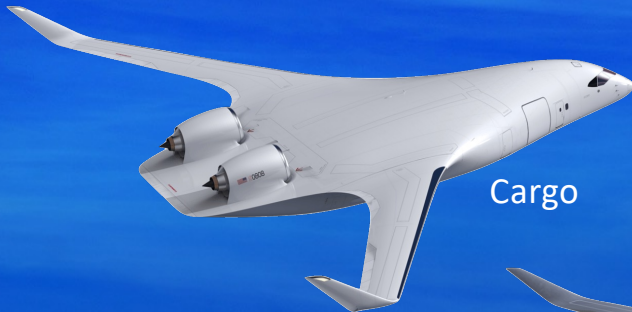
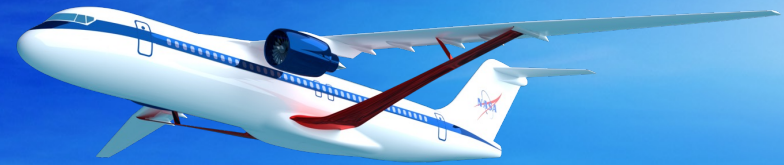


Aviation Sustainability

- Aircraft use 80% less fuel than at start of jet age – 60 passenger miles per gallon = Prius with one passenger
- Today, aviation's share of global emissions = 2.5%
- 97% aviation-related emissions from fuel burn → 3% everything else including manufacturing and disposal
- Sustainable manufacturing is second order, but still important
- Recycling, end of life
 - Reuse of structures
 - Reuse of materials → Down-cycling
- Natural fibers for sustainable manufacturing, challenges:
 - Strength
 - Scatter
 - Degradation during use
 - Opportunities, but manage expectations



Beyond the Next Single Aisle Airplane



Cargo

AAM



Joby



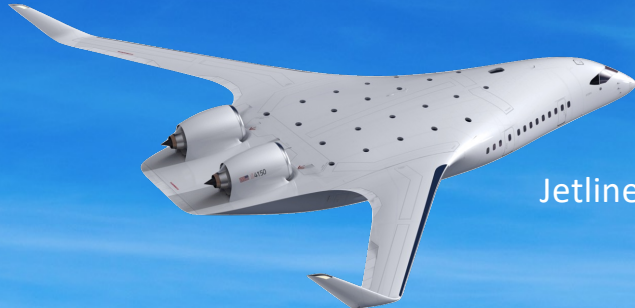
wisk



Jetzero



Tanker



Jetliner



Collaborative Combat Aircraft

- “Loyal Wingman”
- “affordable mass”
- “attritable aircraft”

