National Aeronautics and Space Administration

Hi-Rate Composite Aircraft Manufacturing (HiCAM)
Commercial Transport Needs

Dr. Rick Young

NASA Aeronautics – Strategic Thrusts

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Innovation in Commercial Supersonic Aircraft
- Ultra-Efficient Subsonic Transports

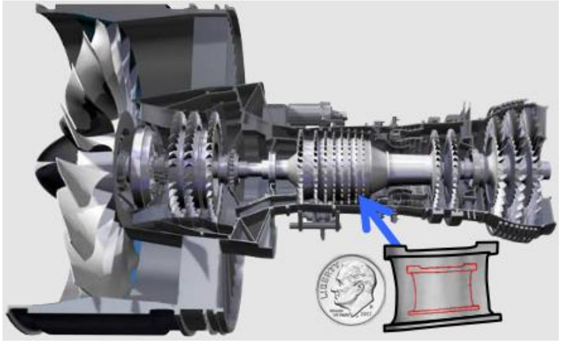
AAM Mission

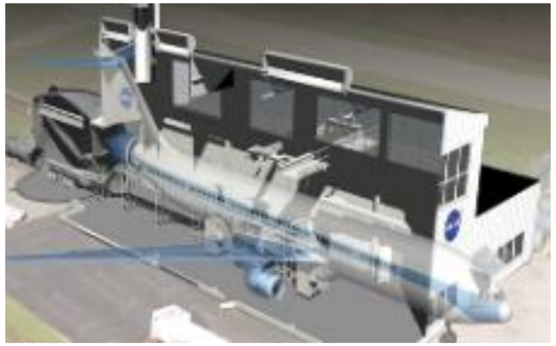
- Safe, Quiet, and Affordable Vertical Lift Air Vehicles
- In-Time System-Wide Safety Assurance
- Assured Autonomy for Aviation Transformation

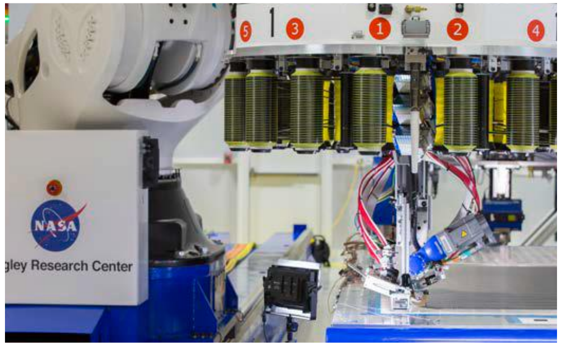
Thrust 3: Realize revolutionary improvements in economics and environmental performance for subsonic transports with opportunities to transition to alternative propulsion and energy

ARMD Key Subsonic Technologies


Transonic Truss-Braced Wing


Small Core Gas Turbine


Electrified Aircraft Propulsion



High-Rate Composite Manufacturing

Transport Market Demand & Opportunity

Boeing & Airbus market outlook

- By 2040, > 43,000 deliveries
  - replace 80% current & double fleet size
  - Single-aisle, 2nd decade: ~150 per month
    - ➔ Industry desires 80 per month as the production rate for HiCAM studies
- Historic aircraft production rates per month
  - Metals (B737, A320)   : 60   1.3x = 80
  - Composites (B787, A220): 10-14   6x = 80

Increased Emphasis on Sustainability:

- Reduced emissions (reduced weight, drag) ➔ Composites: low weight, enables low-drag configs
- Reduced operating cost (acquisition, fuel, maintenance)

Transport Market driving: (1) High volume, earlier deliveries ➔ high-rate (80/month) production
(2) cost reductions ➔ <50% of current cost
(3) performance improvements

Potential AAM market: similar drivers, vehicle rate approaching automotive (1000x)

Hi-Rate Composite Aircraft Manufacturing (HiCAM)

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

- Mature, affordable, high-rate composite manufacturing technologies with reduced labor, equipment, and tooling costs
- Model-based engineering tools for high-rate concepts
- Large-scale demo by 2026 (TRL/MRL 6)

Key Partners: Advanced Composites Consortium (ACC)

Tier 1 Members

- NASA
- Boeing
- GE Aviation
- Aurora Flight Sciences
- Federal Aviation Administration
- Lockheed Martin
- Collins Aerospace
- Spirit AeroSystems

Tier 2 Members

- Northrop Grumman
- Collier Research Corporation
- ATC Advanced Thermoplastic Composites
- Electroimpact
- NIAR Wichita State University National Institute for Aviation Research
- U of SC South Carolina
- Mississippi State University
- CGTech
- Hexcel
- Toray Toray Advanced Composites
- Solvay Progress beyond
- Convergent Manufacturing Technologies - US

Executive Steering Committee (ESC)

Technical Oversight Committee (TOC)

Cooperative Research Teams (CRT)

Phase 0: Tasks Supporting Formulation

	System Requirements, Assessment Process		Manufacturing Technology Assessments							Model-Based Engineering Tool Assessments		
			NDE	Resin Infusion		Thermoplastic			Thermoset			
PWP / CRT Members	P0-1.1 Req. Def	P0-1.2 Tech Assess Process	P0-2.1 NDE	P0-2.2 Rapid Cure Resins	P0-2.3 Resin Infusion	P0-2.4 Thermoplastic Forming	P0-2.5 Thermoplastic Assembly	P0-2.6 Thermoplastic AFP	P0-2.7 NextGen Thermoset	P0-3.1 Process Models	P0-3.2 Structural Sizing Tools	P0-3.3 Design for Manufacturing
NASA												
ATC Mfg.												
Boeing												
CGTech												
Collier Research												
Electroimpact												
GE												
Hexcel												
Northrop (NGSC)												
Rohr (Collins/RTX)												
Solvay												
Spirit												
Toray												
U of SC												
WSU (NIAR)												

- 12 Cooperative Research Teams, comprised of 3 to 10 members
- Total Value $16M (including $8M partner cost share)

Results from Tasks Supporting Formulation

System Requirements and Baseline Definition

- Baseline Components:
  - HiCAM Reference Aircraft for high-rate production market
  - Today's "state of the art" composite construction processes
- Design Requirements and Objectives
  - Commercial airplane requirements
  - Standard Design Objectives, Constraints
- Structural Sizing Plan & Baseline Sizing
  - Common Methods, Commercial Tools
  - Consistent structural sizing for competing concepts

Large-scale Demo Options

- Conceptual Designs
  - Fuselage Barrel Segment, Wing Box, Precursor Articles
- Test Plans: Types and Quantities
- ROM Schedules and Cost Estimates

Calculation of Key Performance Parameters (KPP)

- Component Definition: geometry, manufacturing definition
- Structural Sizing → **Weight**
- Manufacturing Models
  - Activity Level Model; Station Definition, Precedence, Duration, Cost
  - Discrete Event Simulation; parts & tooling moving through stations; determines # lines for 80 ship-sets per month

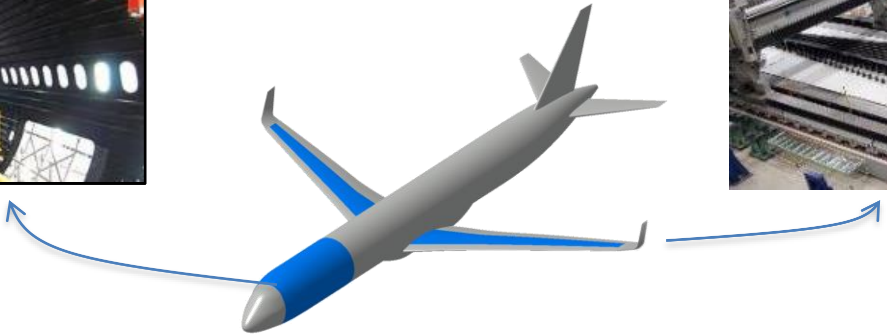
Manufacturing Models →
- **Production Rate (80/mo)**
- **Non-Recurring Cost ($B)**
- **Recurring Cost ($M)**
- **Factory Area (M sq ft)**

Quantitative Technology Assessments for Competing Manufacturing Approaches

- Compare to baseline production system (787 technology)
- Potential impact on KPPs (future state)
- Current state assessment: TRL, MRL
- Technology development roadmaps

HiCAM Scope

- Large composite primary airframe structures



Competing Manufacturing Approaches

- Next Gen Thermosets
  - Evolutionary, lower risk
  - AFP: heating, inspection
  - Automated stiffener forming
  - Shorter autoclave cycle time
  - Paint prep
- Resin Infusion
  - Out-of-autoclave
  - Rapid cure resins
  - Near net shape
  - Integrated structures
  - Unstitched and stitched
- Thermoplastics
  - AFP, out-of-autoclave
    - Tack, secondary oven
    - *In situ* consolidation
  - Stamping, cont. compression molding, stiffener forming
  - Welding, bonding, repair

Shorter Cycle Time ➔ Less Equipment, Labor ➔ Lower Cost

Commercial Transport: Composites Technology Needs

- **High-rate, low-cost manufacturing concepts (labor, equipment; material cost is small factor)**
  - Low processing time = less equipment, labor ➔ 'new' materials to enable rate
  - Consolidation choices: on the fly, secondary process, oven or autoclave (forgiving)
  - Reduced part count (?)
    - Complex unitized versus simple parts & rapid assembly
    - Joining (co-processing, bonding, welding)
  - Automation: quality, factory flow
  - Factory design for rate (movements, inspection, rework)
  - Design for manufacturing, inspection
  - Flaw acceptance: fast, not perfect, but safe
- **Lighter weight**
  - always desired, but secondary importance
- **Computational methods**
  - Concepts lacking historical experience
    - Simulation for rapid development, learning
    - Sizing tools for aircraft program application
  - Many variables, simulation to predict trends
- **Collaboration**
  - Multiple company teams, supply chain: leverage expertise, resources (funds, facilities)
  - Integration of manufacturing, inspection and design
- **Manufacturing project team focus**
  - Limited scope, defined requirements & objectives
  - Technology assessment process, quantitative key performance parameters
  - Constrained timeline to drive decisions, down-selects