Hi-Rate Composite Aircraft Manufacturing (HiCAM)

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Composites: Transport Market Demand & Opportunity

Boeing & Airbus market outlook

- By 2040, > 43,000 deliveries
  - ➔ Industry desires single-aisle aircraft at 80 per month production rate
- Historic aircraft production rates per month
  - – Metals (B737, A320) : 60 1.3x = 80
  - – Composites (B787, A220): 10-14 6x = 80

Increased Emphasis on <u>Sustainability</u>:

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

To enable wide-spread use of composites in single-aisle market:

- High-rate production
- Production cost <50% of current composites

Sustainable Flight National Partnership

Next-Generation Capability on the Path to Net-Zero Greenhouse Gas Emissions by 2050

Advance engine efficiency and emission reduction

Enable integrated trajectory optimization

Advance airframe efficiency and manufacturing rate

Enable use of 100% sustainable aviation fuels

Accelerate toward net-zero greenhouse by 2050 through up to 30% energy efficiency improvement in next-generation transports, 100% sustainable aviation fuel, and optimal trajectories.

Hi-Rate Composite Aircraft Manufacturing (HiCAM)

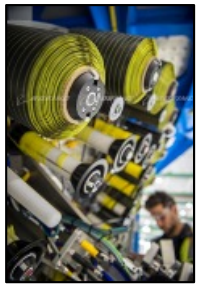
Goal: Demonstrate manufacturing approaches and associated technologies for large composite primary airframe structures that enable high-rate production (up to 80 aircraft per month) with reduced cost and no weight penalty versus 2020 technology for composite structures for early 2030s single-aisle aircraft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

Production Rate per Month

- Metals SOA: 60
- Composites SOA: 10-14
- Requirements: 80

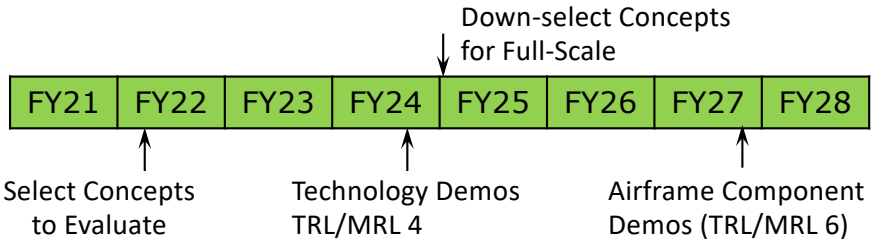
Objectives:

- Mature affordable, high-rate composite manufacturing technologies, with reduced labor, equipment, and tooling costs
- Develop model-based engineering tools for high-rate concepts



Approach:

- Baseline: scaled B787/777x composite aircraft production system
- Compete thermosets, thermoplastics, resin transfer molding
- System assessment of production cost and component weight
- Demonstrate capability for full-scale airframe component(s)



Addresses industry needs for rate, cost, and weight

Partnerships, Cost Share, and Tech Transfer Strategy

Primary stakeholders	Current Partners
U.S. transport aircraft OEMs, and Tier 1 suppliers	Boeing, Spirit Aerosystems, Northrop Grumman, ATC
Other composites aerostructures for defense and engine applications	Collins Aerospace, GE Aviation, Lockheed Martin, Aurora Flight Sciences
Composite material suppliers	Hexcel, Toray, Solvay
Manufacturing and inspection equipment	Electroimpact
Engineering software developers	Collier Research Corp, CGTech, Convergent MT-U.S.
Universities – aero R&D, future workforce	Wichita State Univ., Univ. of South Carolina, Miss. State Univ.
FAA, preview emerging technology	FAA / Aviation Safety (AVS), WJH Technical Center

NASA Role: catalyst to ***accelerate*** advancement; Leadership, Resources, Expertise on R&D teams: material processing, fabrication technology, non-destructive inspection, structural design, damage tolerance

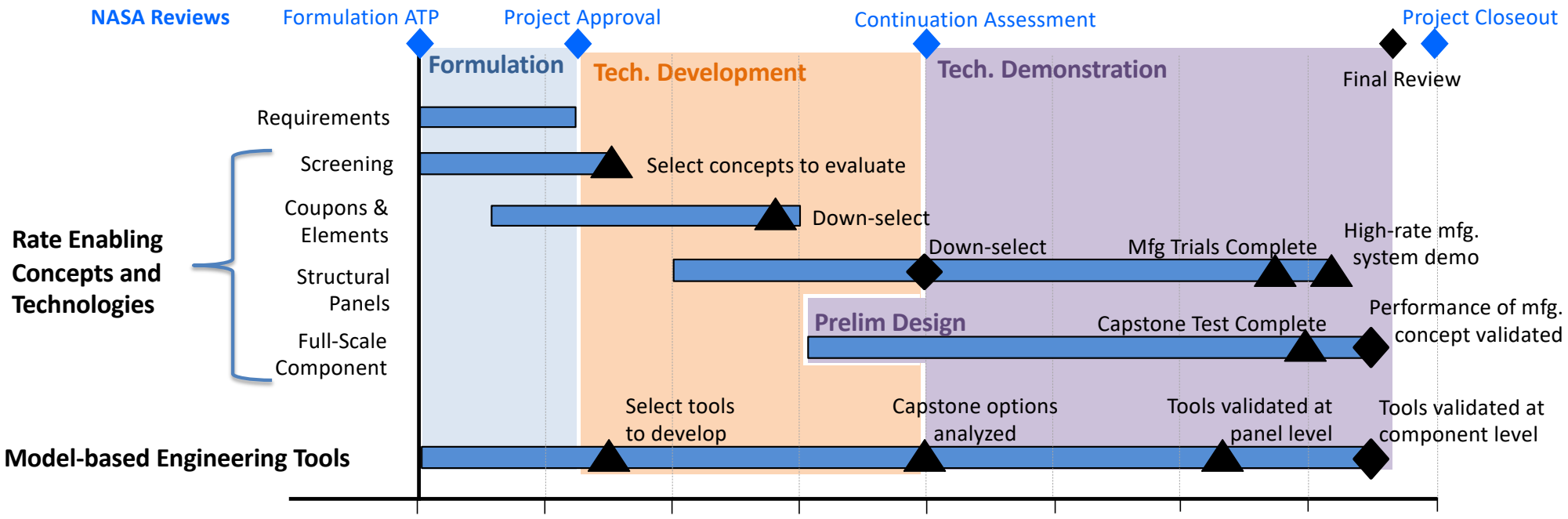
Cost Share: 50:50 of all partners

- Shared investment, risk
- Partner 'skin in the game'

Tech transfer:

- By participation
- Commercially available products
- Publications, broader application

HiCAM Schedule & Budget



NASA Budget ($M)	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	Total
Per President's Budget Request	12	32	26	34	33	28	14	7	**184**
Planned PPP invest = Partner match	8	25	19	26	24	19	11	4	**136**

Total 320M

Augmented budget, Mar. 2023: FY22,23 Appropriations; FY24 President's Budget Request

- Includes major demonstrations for Wing and Fuselage applications

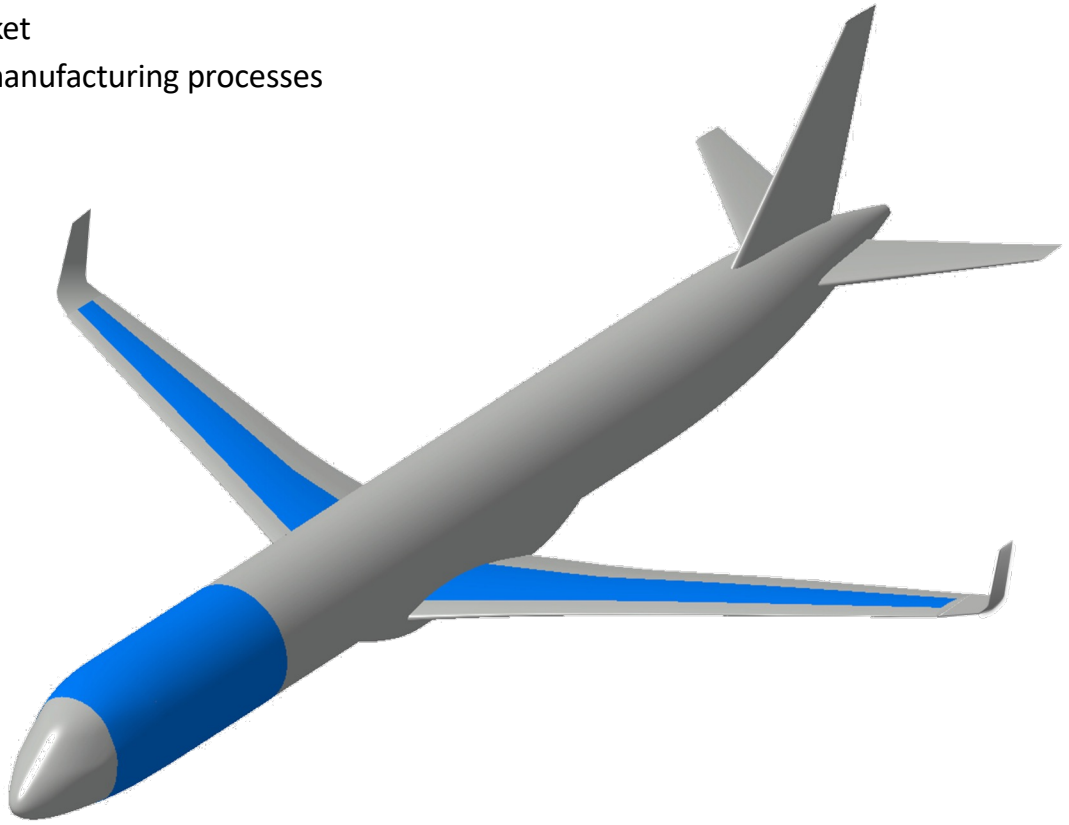
Baseline and Requirements Definition

- Baseline Components:
  - HiCAM Reference Aircraft for high-rate production market
  - Today's "state of the art" composite construction and manufacturing processes (embodied in B787/777x)

- Design Requirements and Objectives
  - Commercial airplane requirements
  - Standard Design Objectives, Requirements, and Constraints
  - Input to HiCAM Requirements document for all HiCAM technologies

- Structural Sizing Plan & Baseline Sizing
  - Common Methods, Commercial Tools
  - Consistent structural sizing for competing concepts

- Potential capstone tests



Key Performance Parameter (KPP) Calculation & Success Criteria

Component Description

- Geometry Definition
- Manufacturing Definition

Structural Sizing

Weight

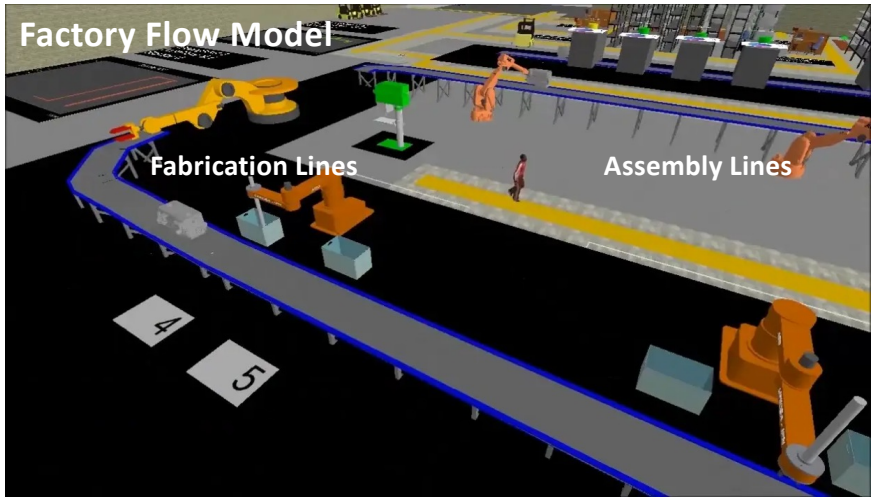
Activity Level Model

- Station Definition
- Station Duration
- Station Cost

- **Production Rate**
- **Non-Recurring Cost**
- **Recurring Cost**
- **Factory Area**

Manufacturing Model

- Simio Discrete Event Simulation for **80 ship-sets per month**
- Parts & tooling moving through stations; determines # lines
- Accounts for uncertainty, rework



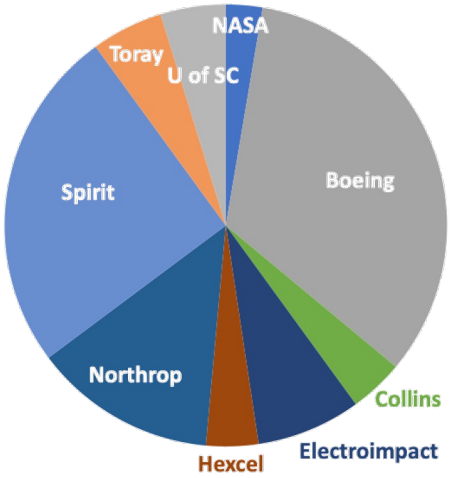
KPP	Full Success	Min Success
Production Rate	80 shipsets/month	60 shipsets/month
Net Cost per Shipset	Cost reduction > 50%	Cost reduction > 30%
Weight	>2% lighter	<2% heavier

- Designs, manufacturing models, and KPPs for Baseline & competing approaches
  - Next Gen Thermosets
  - Resin Infused Composites
  - Thermoplastic Composites
- KPPs estimate opportunity; must also consider development risks

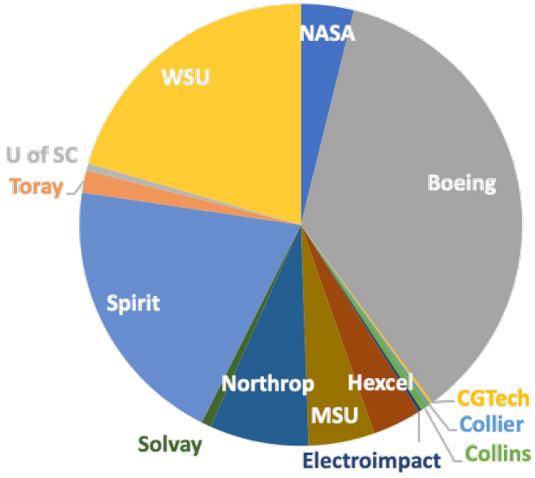
HiCAM Teams for 'Technology Development' Phase, FY22-FY24

- Mature competing manufacturing approaches; Demonstrate TRL/MRL 4; inform down-select for large-scale demonstration
- Three Integrated Product Teams (IPTs) – Charts portray cost of research performed by Partner

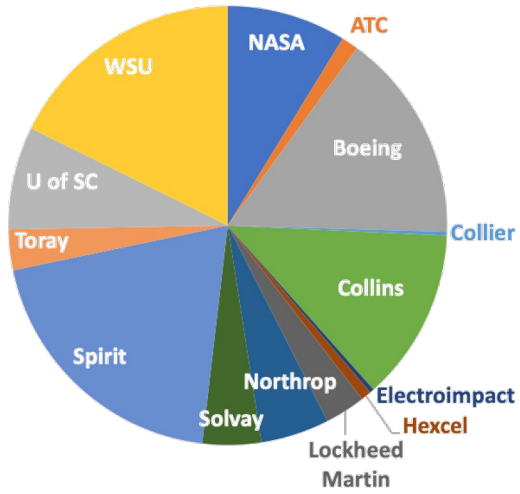
Next-Gen Thermosets IPT



Resin Infused Composites IPT



Thermoplastic Composites IPT



- Teams for Cross-cutting supporting technologies (3 to 6 cost-sharing partners)

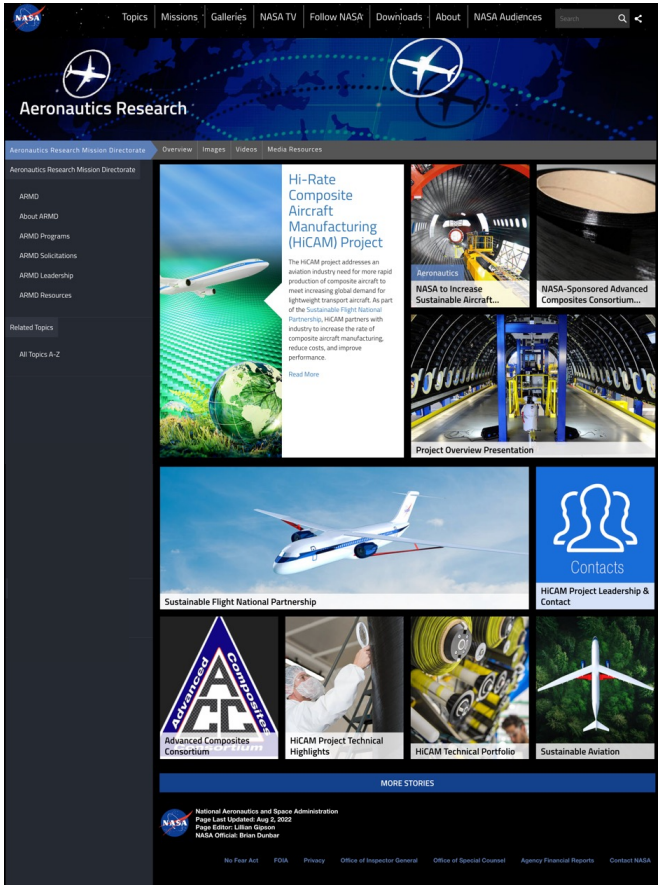
Non-Destructive Evaluation | **Manufacturing Process Models** | **Structural Sizing Tools** | **Design for Manufacturing** | **Technology Assessment Process**

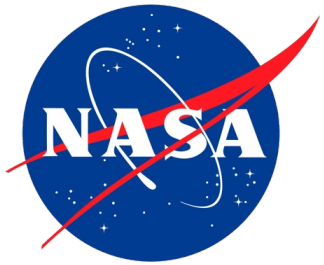
- ~$100M total, including ~$50M partner cost-share (50:50) committed

Summary

- Tasks and results supporting Formulation laid a solid foundation
- Assembled Integrated Product Teams
- Developed integrated technical plans
- Negotiated cost-sharing agreements with 15 partners
- FY23 focus on technology maturation, & preliminary capstone design
- Contributing to ARMD and SFNP by enabling composite applications and advanced concept vehicles for economic and environmental benefit

Follow HiCAM: https://cms.nasa.gov/aeroresearch/programs/aavp/hicam

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