Hi-Rate Composite Aircraft Manufacturing (HiCAM) Project Overview

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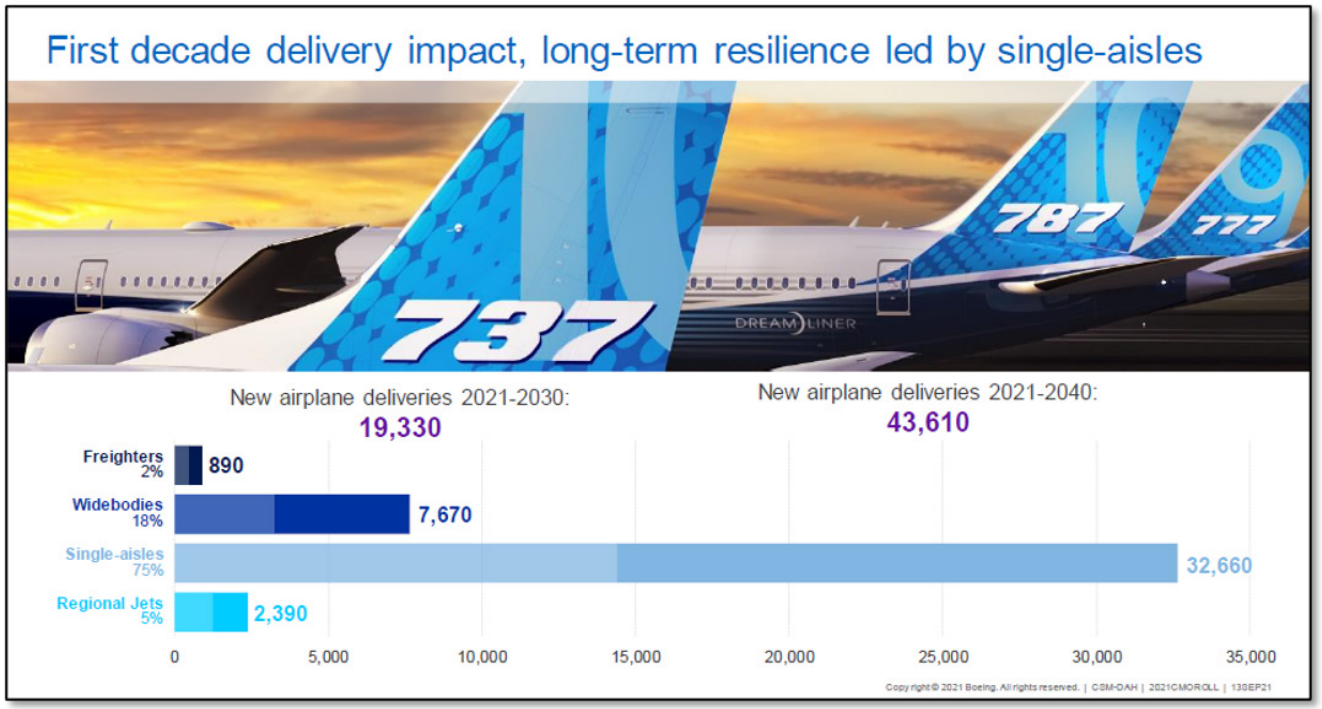
Boeing & Airbus market outlook are similar

- By 2040, > 43,000 deliveries
  - replace 80% current & double fleet size
  - Single-aisle, 2nd decade demand ~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

Sept 2021 Boeing Commercial Market Outlook



Increased Emphasis on Sustainability:

- Reduced emissions (reduced weight, drag)
- Reduced operating cost (fuel, acquisition, maintenance)

Market driving: earlier deliveries (high production rate), cost reductions, & performance improvements

Next Single-Aisle Transport Market Needs

Metals versus Composites (currently)

	Production Rate	Acquisition Cost	Weight	Thin wing for reduced drag	Maintenance Cost	Other: higher cabin pressure, bigger windows, modern
Metals	Better	Better	Worse	Worse	Worse	Worse
Composites	Worse	Worse	Better	Better	Better	Better

- Metals approach (production, design) mature and previously optimized for single-aisle aircraft
- Best opportunity to capture the market: composites, improve rate and cost without sacrificing other attributes

Composites Production Rate and Cost Drivers:

- Long cycle times, labor intensive methods, high cost and lead time for large specialized equipment and tooling
- Not plausible to scale current composites production system 6x
  - Supply chain: limited skilled labor and specialized equipment; Difficult to ramp and adjust with demand
  - Scaling current composites production doesn't reduce acquisition cost
  - Technology needed to improve production efficiency (increasing rate, while reducing cost)

Industry states significant cost reduction needed to enable composites at 80 aircraft per month

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 technoogy for composite structures for early 2030s single-aisle aircraft production

Production Rate per Month

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

Image Credit: Boeing

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:

- Set production rate target = 80 aircraft per month
- Baseline: scaled B787/777x composite aircraft production system
- Complete thermosets, thermoplastics, resin transfer molding
  - System-level assessments of production cost and component weight
- Demonstrate capability for full-scale airframe component(s)
- Transition to industry by participation

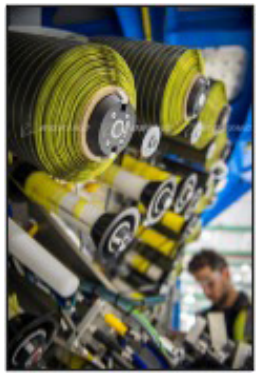
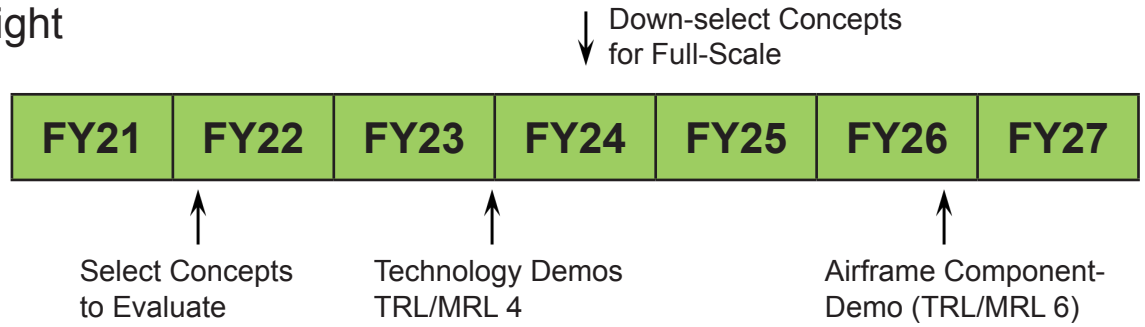
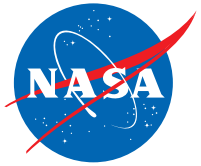


Image Credit: Boeing



Addresses industry needs for rate, cost, and weight

High-Level Requirements, Performance Metrics & Success Criteria



Requirements

1. Airframe components shall comply with Airworthiness Standards required for aircraft certification
2. Maturity: TRL* and MRL**
   a. Manufacturing technologies matured to TRL 6, MRL 6 by Project Closeout
   b. Related MBE tools matured to TRL 6 by Project Closeout

Performance Metrics

KPP	HiCAM Full Success	HiCAM Min Success
Composite Production Rate	80 shipsets per month	60 shipsets per month
Component Net Cost per Shipset	Cost reduction > 50% of baseline	Cost reduction > 30% of baseline
Component Weight	>2% lighter than baseline	<2% heavier than baseline
MBE Tool Accuracy	Predicts experimental values within stakeholder-defined tolerance	Simulates experimental trends

Capstone demonstration will anchor and validate technology models that show ~80 aircraft a month is achievable with cost and weight reductions

* Technology Readiness Level (TRL), NPR 7123.1C

** Manufacturing Readiness Level (MRL) Deskbook, Version 2020 https://www.dodmrl.com/MRL%20Deskbook%20V2020.pdf, with emphasis on the following threads: Manufacturing Technology Development, Producibility Program, Cost Analysis, Manufacturing Process Maturity, Process Yields and Rates

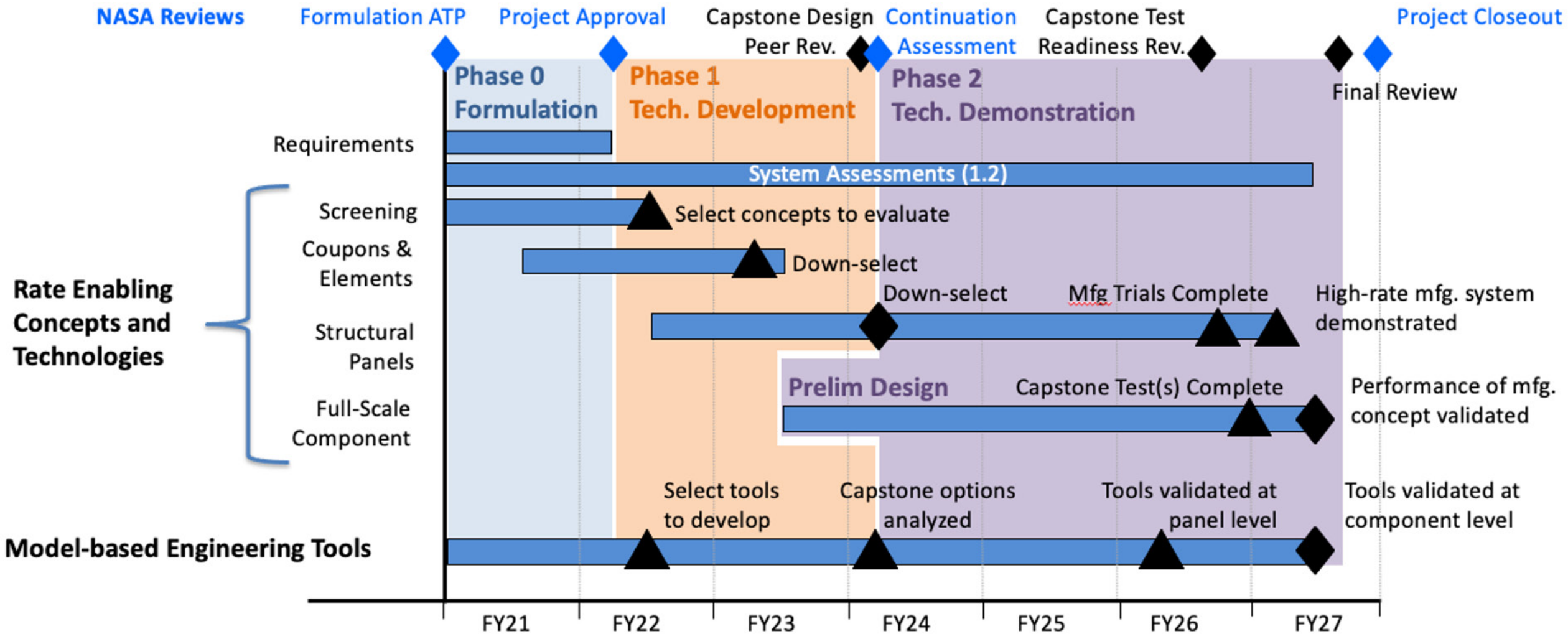
Stakeholders and Partners

HiCAM focus: large composite primary airframe structures

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 applicaitons	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
FAA, preview emerging technology	FAA / Aviation Safety (AVS), WJH Technical Center

- Secondary stakeholders: AAM, space, energy, automotive, environmental protection
  - Common interest in high-rate, low-cost manufacturing technology for more unitized, lighter weight structures
  - Leverage recent advances, coordinate with current programs

Schedule & Proposed Budget



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
NIAR Wichita State University National Institute for Aviation Research
University of South Carolina
ELECTROIMPACT
CGTECH
CONVERGENT Manufacturing Technologies
HEXCEL
'TORAY' Toray Advanced Composites
SOLVAY Progress beyond

- May add members in future

Executive Steering Committee (ESC)

Technical Oversight Committee (TOC)

Cooperative Research Teams (CRT)

Technical Content and Approach

System Requirements and Baseline Definition

- Baseline components: configuration and requirements
- Factory production models
- Metrics to assess, trade, down-select technologies

Preliminary screening of content for HiCAM

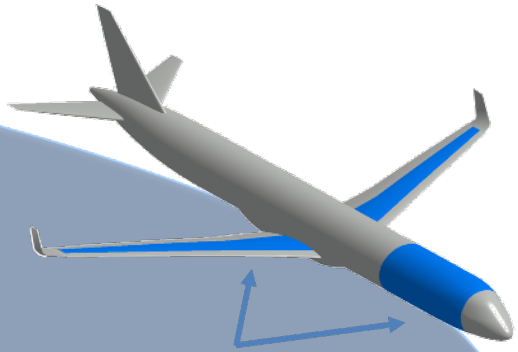
- Potential impact of manufacturing technologies
- MBE tool capability
- Technology development roadmaps

HiCAM: Validated manufacturing technology and MBE tools

Contributes to Sustainable Flight National Partnership

- Enables composite applications, advanced concepts
- Introduces design for manufacturing

Manufacturing rate (airplanes/month)



HiCAM Components

Image Credit: Spirit

Image Credit: Boeing

Down Select

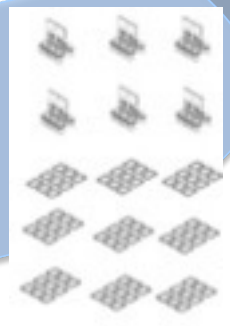
Thermoset

Thermoplastic

Resin Infused

Stitched or Hybrid

Panels



Coupon & Elements

Technology Demonstration: Full-scale Aircrame Component(s)

Technology Development