Low Cost Agile Manufacturing

Aerospace Composites Forum – 19-20 July 2022

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Agenda

- AF Vision for Low Cost Autonomous Vehicles
- Brief Program History – Where are we now?
- Low Cost Attritable System Goals and Objectives
- Composite Structures Projects / Programs Overview
- How to get involved?

Vision for Low Cost Autonomous Systems

- UAS offboard augmentation of manned A/C (*increased risk tolerance & a force multiplier*)
- Low cost allows large procurements (*mass*)
- Single mission configuration (*less complex*)
- No depot maintenance (*treat as a commodity*)

Design for Manufacturing in an “attritable” design paradigm:
*Tailored Specs/Criteria **enable** Expanded Manufacturing Approaches to **yield** Cost, Rate & Agility Advantages*

Initiative / Program History

- Low Cost Attritable Aircraft Technology (LCAAT)
    - Initiated Nov 2014 – missions analysis, clean sheet design, design for manufacturing
    - OUSD, SAF/AQR and AFRL
- Low Cost Attritable Strike Demo (LCASD)
    - Kratos award: XQ-58A - High sub-sonic; >3,000nm range
    - Runway independent & ~$3M/vehicle
    - Multiple flight tests executed to-date

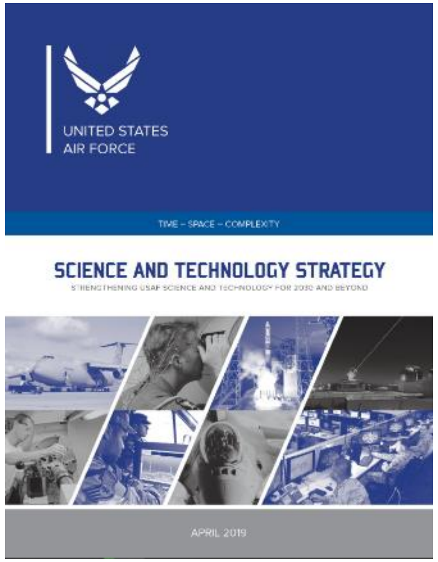
XQ-58A – 5 March 2019 First Flight

- Design for manufacturing activities 2016-Present
    - Innovative Manufacture of a BQM-167 Aerial Target
    - Low Cost Responsive Tooling
    - Wing Structural Design and Manufacturing
    - Braided Inlet Duct
    - Design for Manufacture of Attritable Aircraft Primary Structure
- Autonomous Collaborative Platforms (ACP): AFRL Capability Portfolio (2020)
    - Low Cost Attritable Aircraft Platform Sharing (LCAAPS) - 2 awards
    - Off-Board Sensing Station (OBSS) - 2 design awards (Ph1), then build/fly options (TBD)

Where are ACP today?

- AF 2030 S&T Strategy Document
  - Identifies 5 critical strategic capabilities
  - Complexity, Unpredictability and Mass
- AFRL Skyborg Vanguard
  - Autonomous flight algorithms
  - Multiple ground & flight tests
  - Vanguards may lead to a Program of Record
- Off Board Sensor Station (OBSS) program
  - Two Ph I airframe design programs in progress
  - Downselection expected fall 2022
  - Ph II – Detailed design, fabrication & flight test

"To become more agile, the Air Force must augment its high-end platforms with larger numbers of inexpensive, low-end systems. Swarms of low-cost, autonomous air and space systems can provide adaptability, rapid upgradability, and the capacity to absorb losses…"



Low Cost Autonomous Systems will become part of tomorrow's Air Force

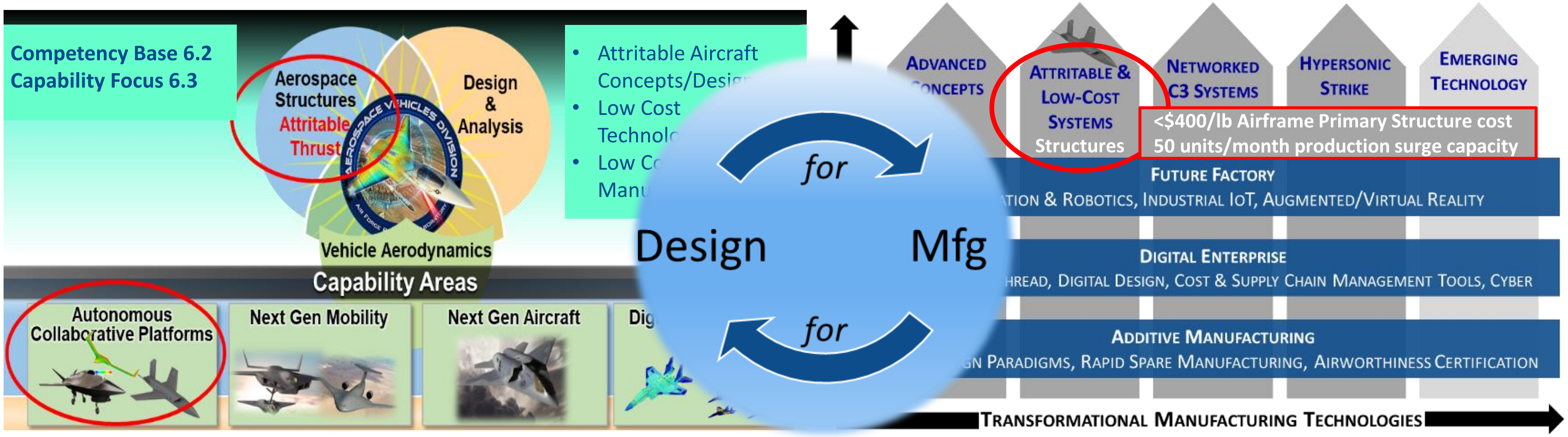
Low-Cost Attritable Structures at AFRL

Air Force Research Laboratory

- **Aerospace Systems Directorate**
- Airman Systems
- Directed Energy
- Information
- **Materials & Manufacturing Directorate**
- Munitions
- Sensors
- Space Vehicles

RQV - Aerospace Vehicles Division

RXM - Manufacturing & Industrial Technologies Division



ManTech Low-Cost Attritable Systems – Goals & Areas of Emphasis

OPERATIONAL VISION:

- RESILIENT, MULTI-DOMAIN HIGHLY PROLIFERATED SYSTEMS OF SYSTEMS TO ENHANCE WARFIGHTER CAPABILITIES AND MINIMIZE RISK TO EXQUISITE SYSTEMS

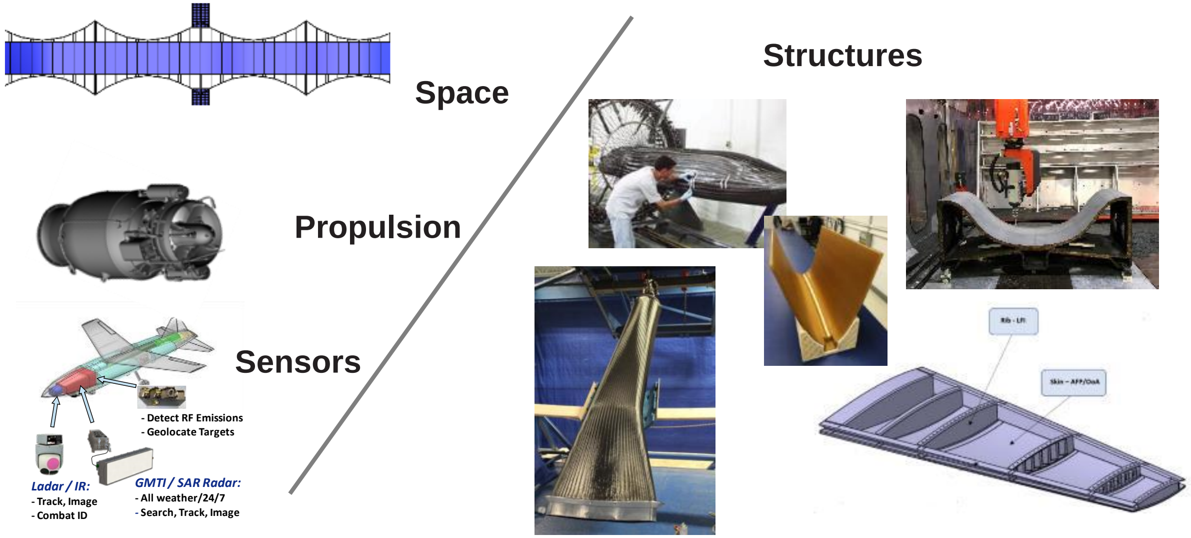
Disaggregated Air & Spacecraft Variants w/ Mission Specific Configurations

Structures Manufacturing Goal & Objectives:

Goal: <$400/lb UAV structural fabrication costs w/ 50 units/month production surge capacity

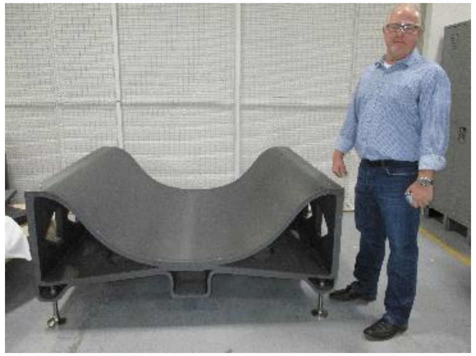
Objectives:

- 50% cost and procurement time reduction for AM tooling
- Reduce component processing times from 8 hours to ~30 minutes using non-conventional processes
- 50% cost and 70% cycle time reductions using automated processes
- Develop common vehicle design and associated TDP w/ data management architecture



AFRL

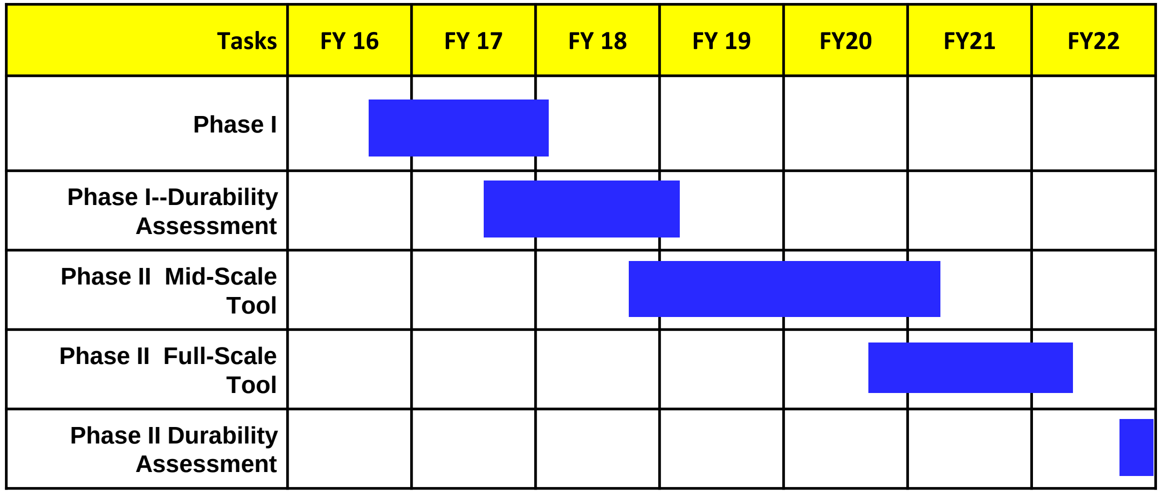
Low Cost Responsive Tooling



Thermwood printed tool - PESU 1810

Contractors: Boeing, Thermwood, AES, Cincinnati Inc,

Project Schedule



Description

Leverage carbon fiber filled polymer AM process for the fabrication of large scale composite tooling

Delivering

- 1 Mid-Scale Tool for 250F durability evaluation
- 1 Full Scale Tool for 350F durability evaluation
- HandyScan 700 & MaxShot Photogrammetry Systems

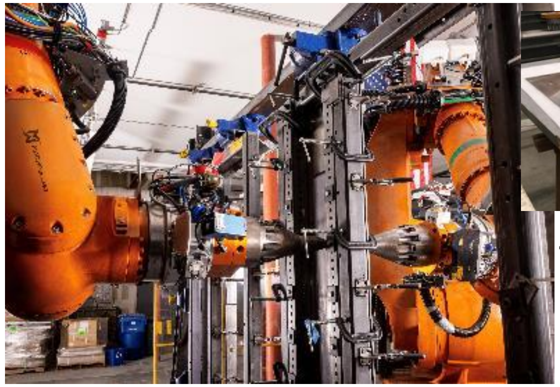
Technical Approach

- Evaluate multiple FDM processes/materials
- Evaluated multiple adhesives and sealers
- Characterized surface roughness and vacuum integrity
- Evaluate tool durability at AFRL

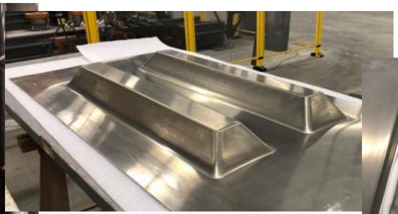
Benefits to the Warfighter

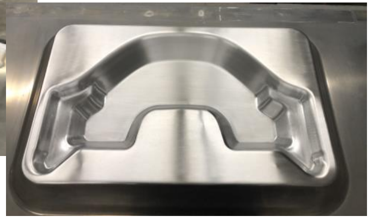
- Reduced cost tooling
  - 20-70% based on tool size and complexity
- Reduce cycle time from days to hours
  - 50-65% based on tool size and complexity

Rapid Metal Tooling for High Rate, Low Cost Composites

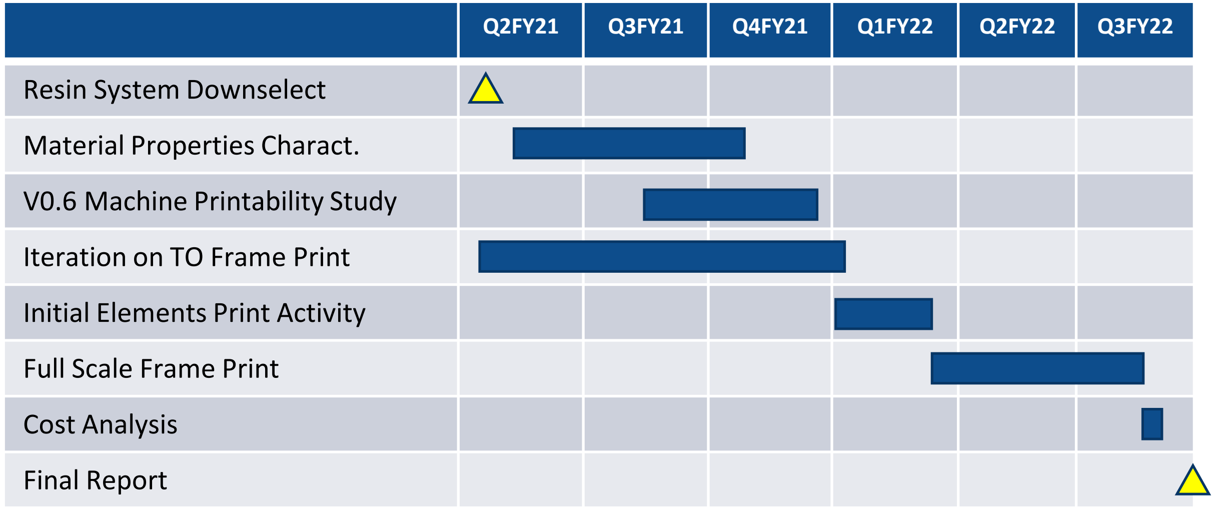


Machina's opposing robots form sheet metal





Tools fabricated for :
Hat Stiffeners
Fuselage Builhead
Scaled Wing Skin



Description

- Leverage Machina's opposing robotic systems for fabrication of inexpensive, rapid reaction tooling

Delivering

- Hat Stiffener, fuselage bulkhead and wing skin tools meeting ± 0.020" tolerance requirement

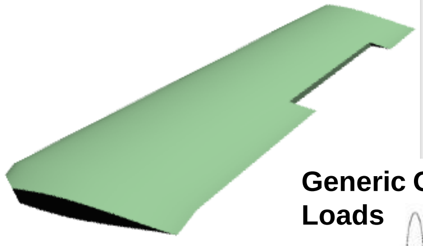
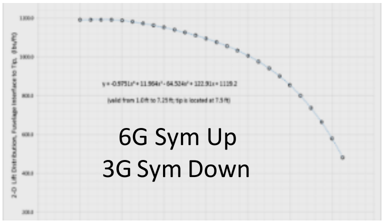
Technical Approach

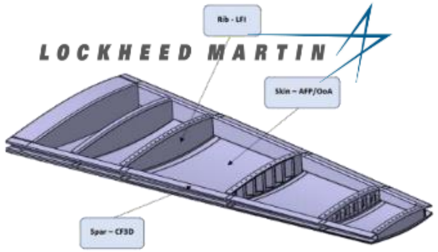
- Supply Machina with CAD's for multiple parts
- Iterate forming process to meet tolerance requirements
- Low temp heat treatment for stress relaxation
- Deliver tools to TARMACS and CC for demo's
- Cost and cycle time analysis

Benefits to the Warfighter

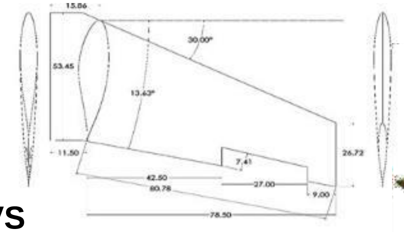
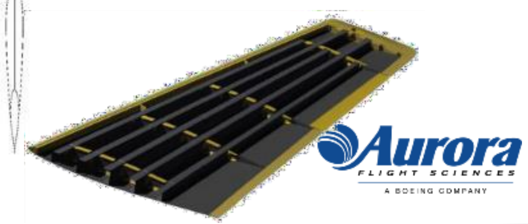
- Extremely inexpensive tooling material (sheet metal)
- Single day fabrication of complex tools with isotropic material response
- Complex tool shapes available
- Sustainment community interest

Wing Structural Design and Manufacturing (WiSDM)



Generic OML Design & Loads

AFRL PM: Ray Fisher, RQVS

Lockheed Martin's Approach:

- *Fully automated drilling & fastening*
- *Continuous fiber AM spars*
- *Long Fiber Injection (LFI) ribs*
- *AFP skins on BAAM AM Tools*

Aurora's Approach:

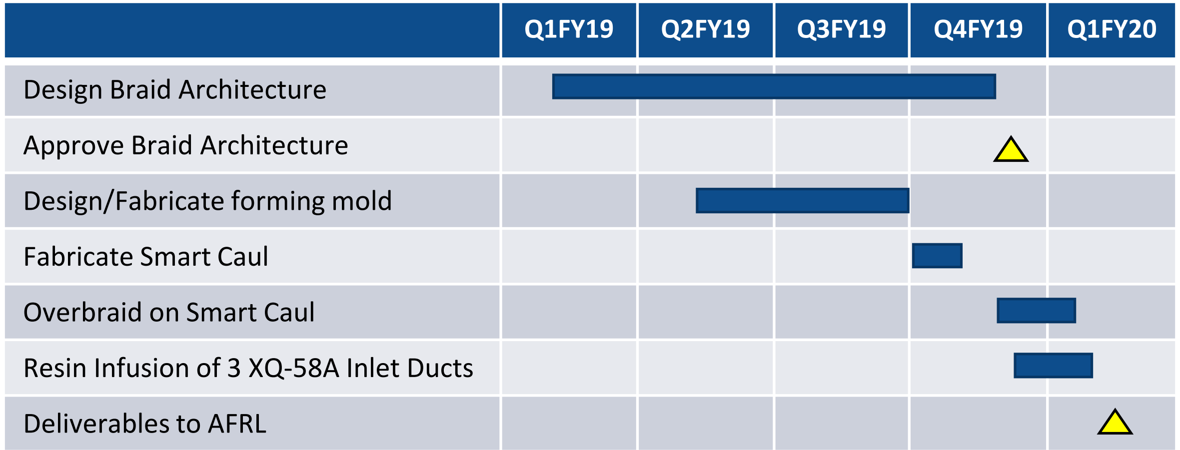
- *Manual Co-bonded assembly w/ AM Pi-Clips*
- *Polymer AM "Pi Clips" (low stiffness consequence)*
- *'Ultra Low' capital equipment investment*
- *No automation - Labor dependent – Replicated Factory*

Description	Delivering
Design for manufacturing demonstration w/ low-cost & non-traditional aerospace composite processes	Wing fabrication cost analysis and manufacturing demo articles for ground static testing

Technical Approach	Benefits to the Warfighter
Evaluate two approaches for wing desig/mfg • Minimized capital equip, hand assembly (Aurora) • Automate (AFP, AM, LFI & robotic assembly) • Mfg wing structure, deliver cost & manhour data • Static wing performance testing	• Auto Inspired Long Fiber Infusion process to be matured by joint AFRL/Lockheed Martin program – aero focus • Maturation of continuous carbon fiber AM tech for future complex shape fabrication

Braided / VARTM Inlet Duct Manufacturing Demonstration

Project Schedule



Contractors: CRG, SpinTech, A&P, Kratos

Description

Design and manufacturing demonstration using non-traditional aerospace composite processes

Delivering

- Full scale braided inlet duct - DMAAPS program
- Cost and cycle time analysis

Technical Approach

Replace multi-piece metal tooling, hand layup and autoclave processes with:

- Shape Memory Polymer (SMP) mandrel
- Braided inlet duct preform
- Vacuum Assisted Resin Transfer Molding (VARTM)

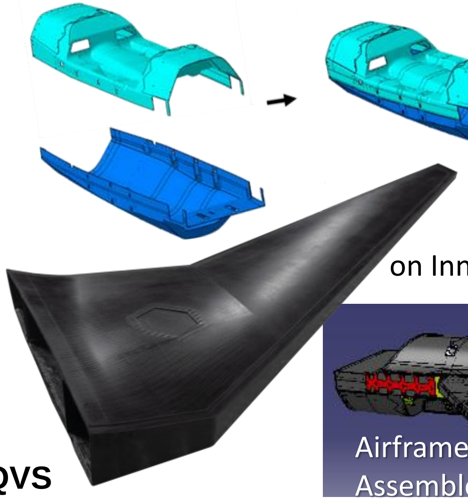
Benefits to the Warfighter

- 67% reduction in man hours required
- 57% reduction in cost for 100th part
- Understanding of Smart tool durability
- Data for AFRL/FMC cost model mods

Design for Manufacture of Attritable Aircraft Primary Structure (DMAAPS)

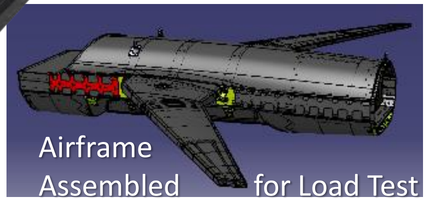
Fuselage Overbraid on Mandrel

AFRL PM: Ray Fisher, RQVS



2-pc VaRTM Fuselage

Braided Wing: 1-pc from RTM with 3 SmartTools on Inner mold line (IML)



Program Priorities

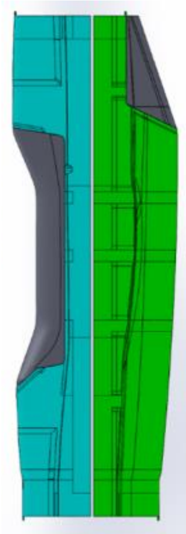
- Mature Braided Textile & Infusion Process to:
  - Minimize Cost Versus Pre-Preg Baseline
  - Speed manufacture & assembly hours
- Deliver Assembled Demonstration Airframe
- Static Test Airframe to Design Ultimate Load

Description	Delivering
Application of automated overbraiding, SMP tools & VARTM techs for large fuselage and wing structures	• Overbraided fuselage & wing structures • Cost and cycle time data

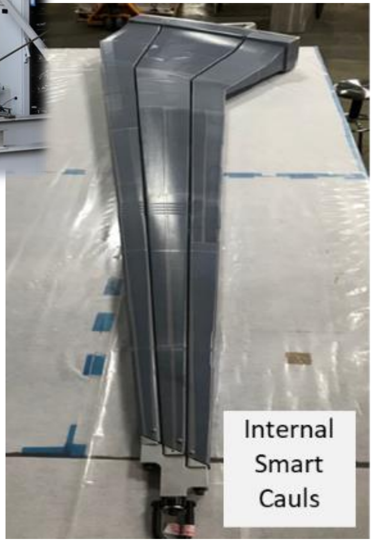
Technical Approach	Benefits to the Warfighter
<u>Dry fiber with resin infusion</u>: no special storage - long shelf life. <u>Braiding</u>: enables rapid, semi-automated coverage of textiles to produce large area preforms. <u>Innovative tooling</u>: (wing) full IML/OML molding for large scale curing of unitized structures.	Enable manufacturing in the attritable design paradigm (low cost, rapid and scalable) to yield UAS assets which can be utilized with “attrition tolerance

Design for Manufacture of Attritable Aircraft Primary Structure (DMAAPS)

Fuselage (l to r): braid mandrel w/ inserts before braiding, upper and lower preform split @ mid waterline for VaRTM (green and blue), upper preform going into VaRTM tool.



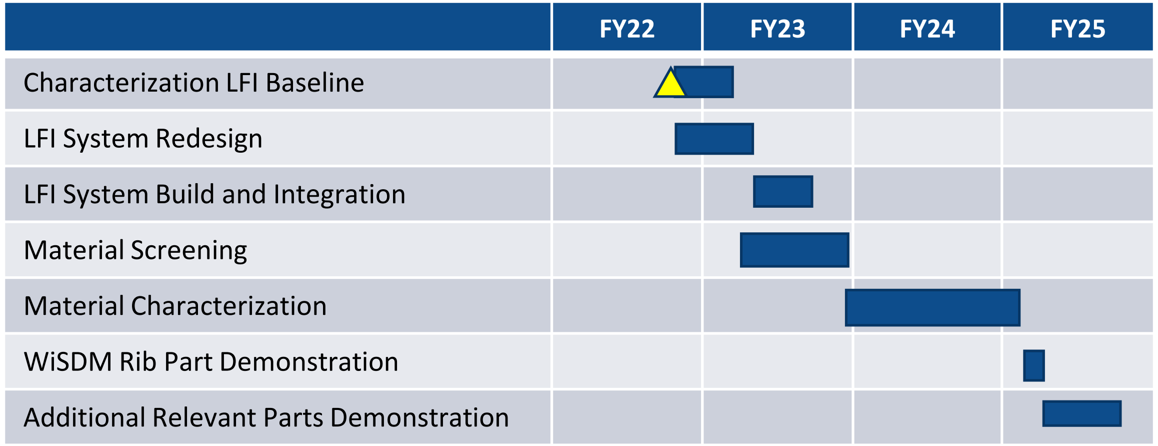
Wing (l to r): 3-pc internal SMP mandrel/tool, braided textile applied over mandrel/tool and loaded in lower RTM tool, demolded one-piece composite wing



Long Fiber Injection

Krauss-Maffei's LFI Machine @ Romeo Rim

Wing Rib Matched Metal Molds - WiSDM



Description

- Develop and demo an automated process for small - medium carbon composite part fabrication

Delivering

- Modified KM fiber cut/mix head
- Multiple complex part demonstrations
- Quantified cost & cycle time benefits

Technological Approach

- Partner with multiple AFRL & Industry entities
- Redesign cut/spray head for carbon fiber & new resins
- Integrate @ Krauss-Maffei and screen materials
- Characterize material properties
- Demo relevant parts: ribs, bulkheads, etc.

Benefits to the Warfighter

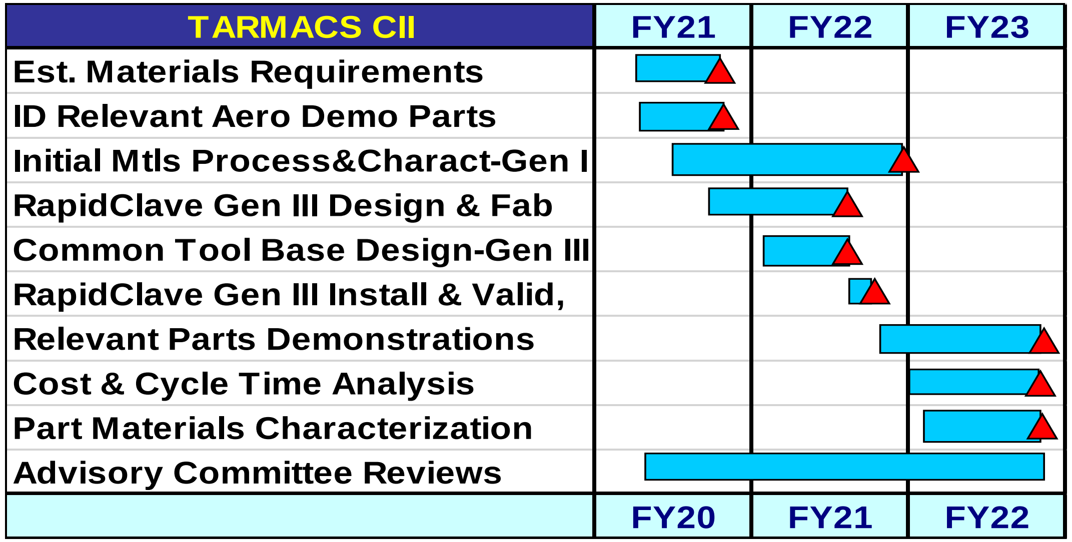
- 70+% Structures Cost Savings
- 80+% Cycle Time Reduction
- Consistent Part Quality
- Weight Neutral
- Minimize process skill labor needs

Technology for Agile Rapid Manufacturing of Aerospace Composite Structures (TARMACS) CII

Globe Gen II RapidClave

Sub-30 min cure of continuous fiber Class A components

C7 Corvette



Contractors: Globe Machine Mfg, UDRI

Description

- **Leveraging commercial composites fabrication process for rapid, low cost curing of complex, aerospace composite geometries**

Delivering

- **Gen III RapidClave System w/ ML controls**
- **Multiple parts demos using quick cure resin(s)**
- **Assessments of novel tooling options**

Technological Approach

- **Establish Industry/Navy/Academic Advisory Committee**
- **Use RapidClave Gen I machine for initial mtl studies**
- **Design Gen III machine based on anticipated requirements**
- **Investigate multiple rapid cure resins**
- **Demo on relevant aerospace parts, characterize mtl prop.**
- **Gather cost/cycle time reduction data**

Benefits to the Warfighter

Vastly Reduced Composite Part Cycle Times

- **80%+ reduction in processing time**
- **30%+ reduction in composite part costs**
- **Highly automated – minimized labor**
- **Quality neutral**

How do I Get Involved?

- Share information with AFRL on your technology
  - Craig Neslen, AFRL/RXMS, craig.neslen@us.af.mil, 937-684-0939
  - Ray Fisher, AFRL/RQVS, burton.fisher@us.af.mil, 937-656-8834
- Be aware of AF SBIR topic calls
  - Issued 3 times a year
  - www.afwerx.af.mil
  - www.afsbirsttr.us
- Reach out to USAF contractors/subcontractors
  - Airframers, e.g., Lockheed Martin, Boeing, Northrop Grumman, Kratos, General Atomics
  - Tier 1 suppliers