U.S. AIR FORCE

USSF

AFRL

Composite Structures: Military Aircraft Applications

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Why Do Research in Structures?

New Aircraft

Existing Fleet

Strategy to Task

Mission Challenges

Commander's Intent

AF Futures
COCOMS
MAJCOMS

AIR FORCE OPERATIONAL IMPERATIVES

1. Defining resilient space order of battle and architectures.
2. Achieving operationally optimized ABMS / AF JADC2.
3. Defining the Next Gen Air Dominance systems of systems.
4. Achieving moving target engagement at scale.
5. Defining optimized resilient basing, sustainment, and communications in a contested environment.
6. Evaluating readiness of the DAF to transition to a wartime posture against a peer competitor.
7. Defining the B-21 Long Range Strike family of systems.

Department of the Air Force's "seven operational imperatives"

- Frank Kendall: "My highest personal goal as Secretary has been to instill a sense of urgency about our efforts to modernize and to ensure that we improve our operational posture relative to our pacing challenge; China, China, China,"

- https://www.af.mil/News/Article-Display/Article/2953552/kendall-details-seven-operational-imperatives-how-they-forge-the-future-force/

Department of the Air Force's "seven operational imperatives"

- Defining Resilient and Effective Space Order of Battle and Architectures
- Achieving Operationally Optimized Advanced Battle Management Systems (ABMS) / Air Force Joint All-Domain Command & Control (AF JADC2)
- Defining the Next Generation Air Dominance (NGAD) System-of-Systems
- Achieving Moving Target Engagement at Scale in a Challenging Operational Environment
- Defining optimized resilient basing, sustainment, and communications in a contested environment
- Defining the B-21 Long Range Strike Family-of-Systems
- Readiness of the Department of the Air Force to transition to a wartime posture against a peer competitor.

- https://www.af.mil/News/Article-Display/Article/2953552/kendall-details-seven-operational-imperatives-how-they-forge-the-future-force/

Optimized Resilient Basing: High-Speed VTOL

- High-Speed VTOL Challenge, the effort is a collaboration between AFWERX, the Air Force's innovation hub, and US Special Operations Command (SOCOM). The HSVTOL program seeks to develop an aircraft that could eventually replace the Air Force's CV-22 Osprey, one that can fly on the order of 400 kt (740 km/h) and conduct a range of missions such as personnel infiltration, tactical mobility and aeromedical evacuation.

- https://evtol.news/news/air-force-picks-11-companies-for-high-speed-vtol-program

Next Generation Air Dominance

- While still highly classified, the Air Force has gradually begun to reveal limited details about NGAD, which it describes as a “family of systems” that will collaboratively gain air dominance in combat. The NGAD family will include at least one crewed aircraft and an **undisclosed number of uncrewed aircraft**, along with other technologies that could include optionally crewed platforms, missiles, pods, and offboard capabilities, some of which could operate from space. Some flying escorts will carry sensors or more weapons, while others will provide electronic or ground attack capabilities so that NGAD can get through enemy defenses to hold at risk any target in the battlespace.

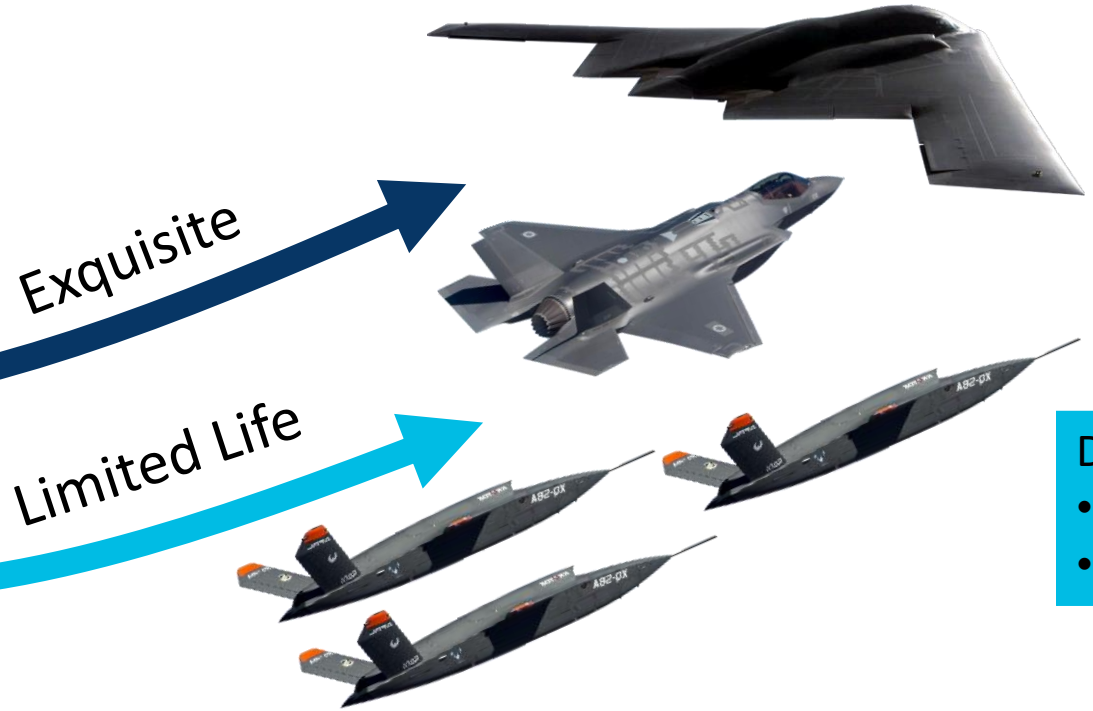
- https://www.airforcemag.com/article/piecing-together-the-ngad-puzzle/

B-21 Long Range Strike Family-of-Systems

- “We are assessing the potential to introduce a **lower cost, complementary, uncrewed aircraft** into the B-21 to provide an enhanced level of capability,” Undersecretary of the Air Force Gina Ortiz told reporters at the announcement of the service’s 2023 budget request.

- https://warriormaven.com/air/b-21-raider-stealth-bomber-drones

Demand signals: Materials and Processes



Demand for **Increased Performance**
- Higher temperature materials
- Lighter weight structures
- Complex geometries / bonding

- **Next Gen Exquisite Engines**
  - CMCs, Higher temperature PMCs
- **Large, Unitized Structures**
  - Link design optimization to processing to performance models for PMCs
  - Certification and life prediction, NDE/I

Demand for **Affordability**
- Low cost material options
- Design for Limited life

- **Attritable, Low Cost Structures**
  - Superior new AM PMCs
  - Link novel PMC M&P models w/ design tools
  - Cost vs. Performance trades
  - Risk-based Certification, NDE/I

Demand for **Increased Performance**
- Higher temperature materials
- Lighter weight structures

- **Near Term High Speed Structures**
  - C-C, CMCs for leading edges, apertures, TPS, acreage
- **Next Gen High Speed Structures**
  - AM CMCs, C-C, UHTCs, HT PMCs

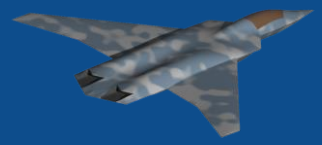
Demand Signals: Structural Design

Autonomous Collaborative Platforms

Technical Needs

- Cost is highest priority
- Continue to understand "What is attritability?"
- Take advantage of emerging low cost manufacturing technologies
- Weight reduction

Next Generation Systems



Technical Needs

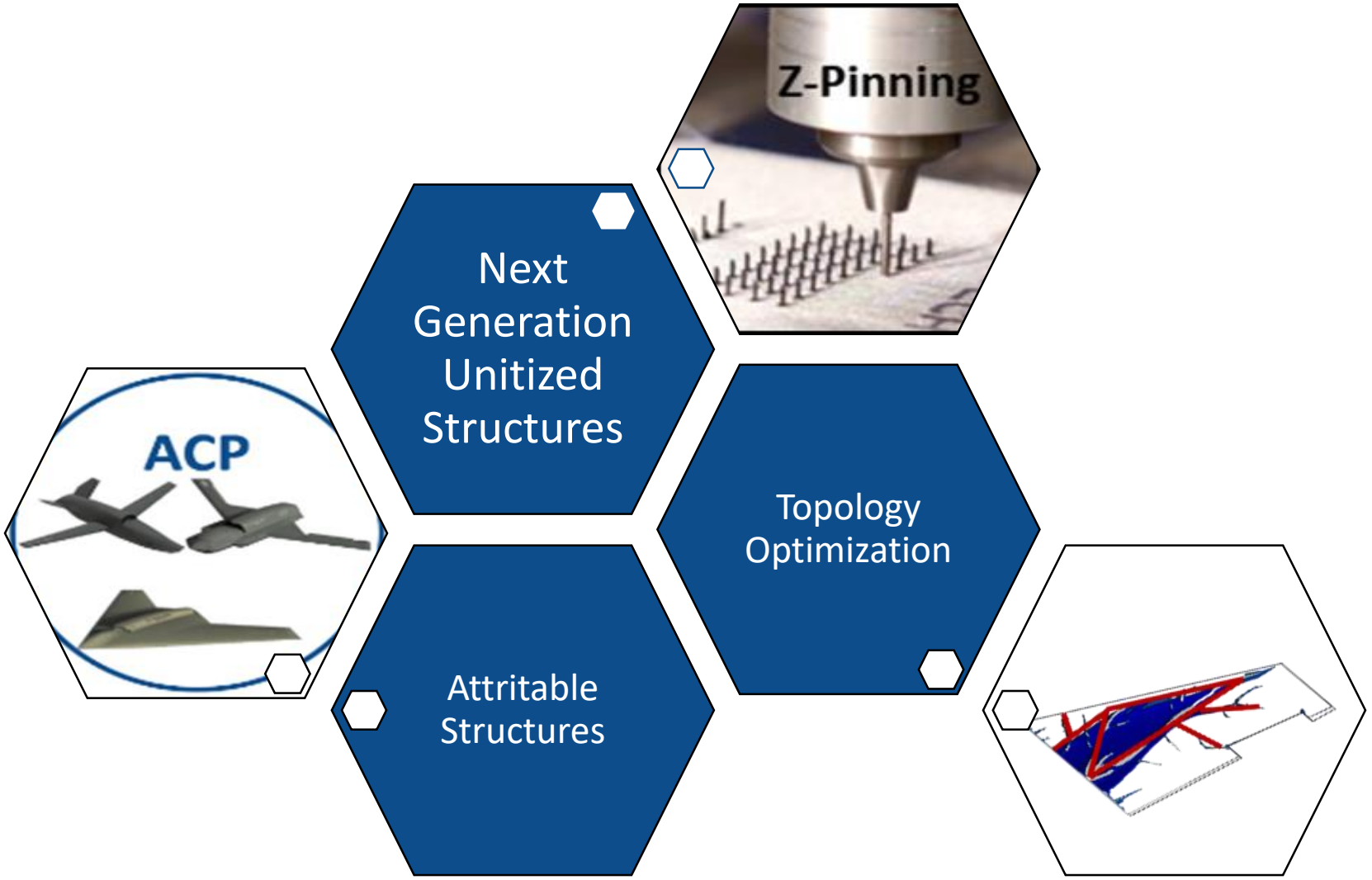
- Lightweight, low-cost structures (manufacturing and service life)
- Compliant (morphing) structures
- Multifunctional structures

Tactical Tanker/Mobility

Technical Needs

- Rapid low cost manufacturing of structures
- Hot wash exhaust structure
- Topology optimization at large scale

Structures Competency Technical Focus Areas

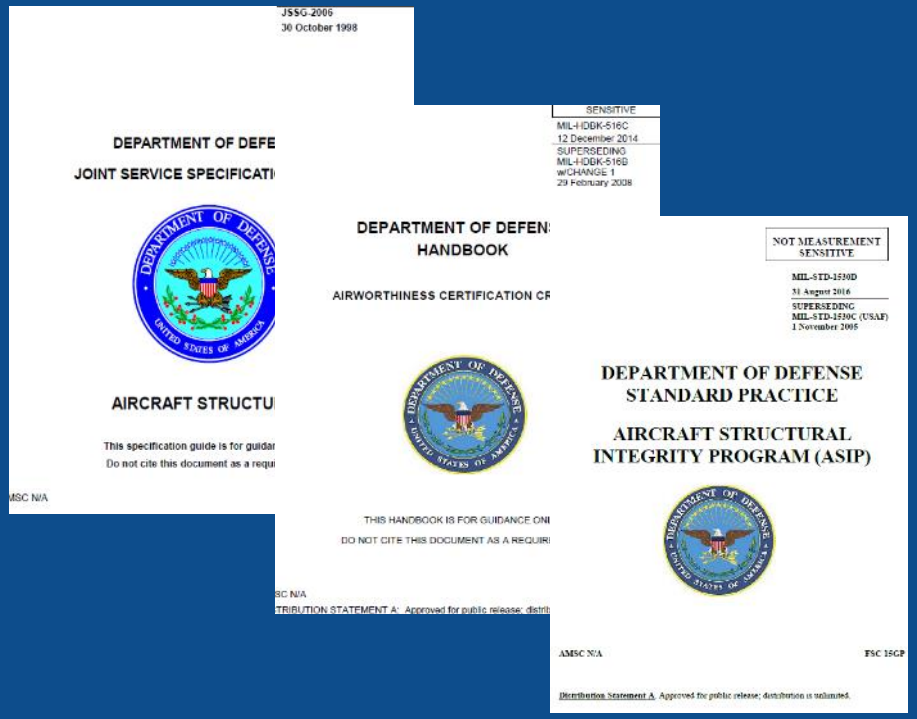


Low Cost, Agile Manufacturing and Processing

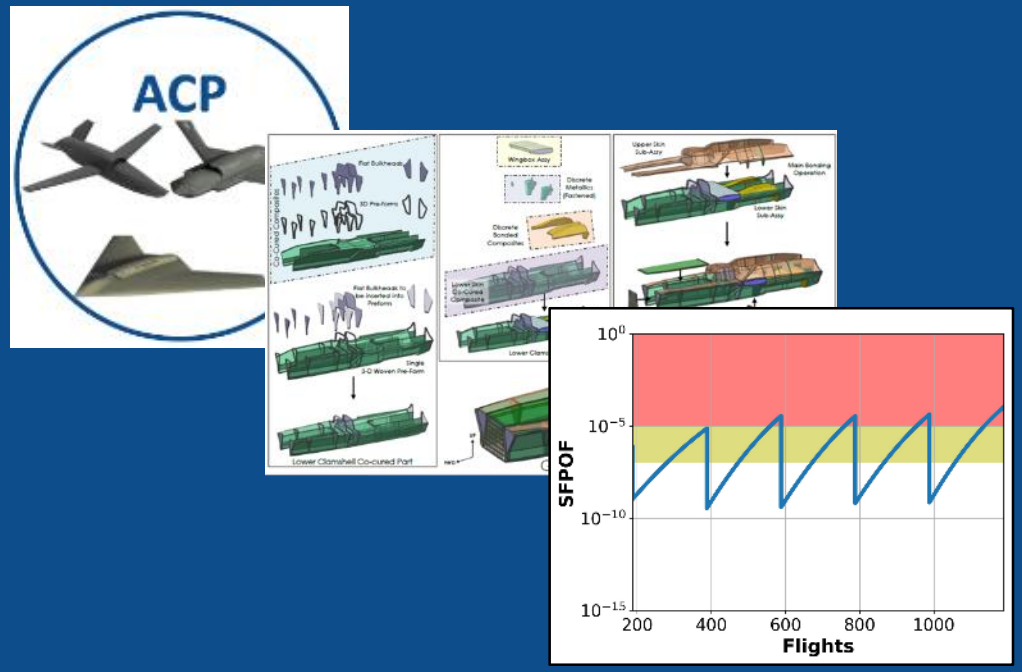
- Problem
  - Current composite manufacturing methods too costly for attritable aircraft concepts.
- Gaps
  - Long lead time for tooling
  - High touch labor
  - Don’t’ take advantage of designs enabled by eliminating depot maintenance.
- 2030 End State
  - Robust understanding of low cost manufacturing process capabilities enabling 50% reduction in design cycle time

What is Attritability?

- **2021-22: Airworthiness of Attritable Airframes (A^3) Study**
  - **Product: Recommended attritable airframe requirements document**



- **2023-24 Effect of Attritable Airframe Requirements**
  - **Product: quantified effect of reduced requirements on the cost, performance, and safety of attritable airframes**

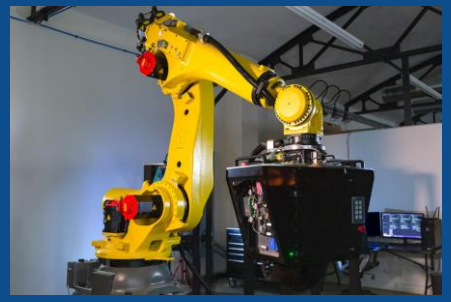


Design for Materials and Manufacturing

Life Cycle Segment	Attributes	Non-Traditional Qualities
Design & Development	Rapid Design Rapid Development	• **Designed for Limited Life** • **Limited and Fixed Requirements** • Rapid Acquisition Cycle – months not years • Quick Tech Refresh - buy new versus upgrade the old
Engineering & Manufacturing Development (EMD)	Rapid/Low Cost Manufacturing	• **Non-traditional materials & manuf (auto & marine)** • **Commercial Off-The-Shelf (COTS)** • Development variants from common architecture
Production & Deployment	Low Acquisition Cost	• Unit Flyaway Cost < $3M for 100 A/C (w/o mission sys) • **Scalable and Responsive Manufacturing**
Operations and Support	Cost Effective Operations and Support	• Unmanned & Re-Usable • Non Trad/CTOL Launch & Recovery • Open System Payloads • Minimal Operational & Sustainment Footprint • **No Depot & Limited Field Maintenance**

Design for Materials and Manufacturing Path Forward

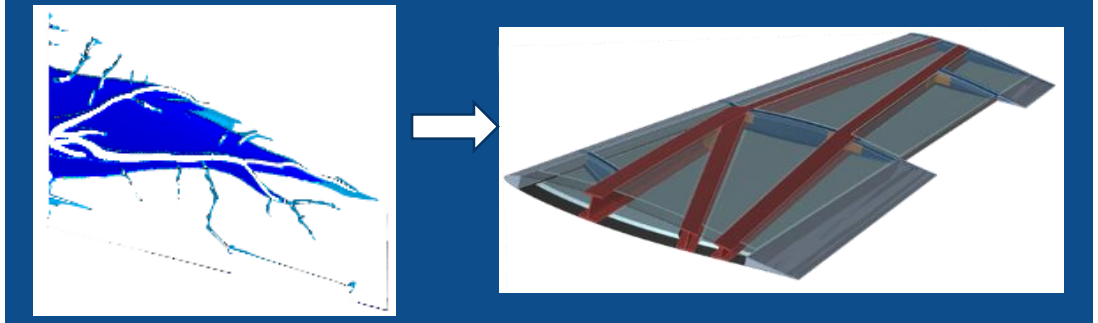
- **2021-24: Low-Cost Agile Manufactured Structures**
  - **2021 Product: Plan for 2022 CRAD effort with expected ROI**
  - **2024 Product: Verified new manufacturing processes for attritable structures**



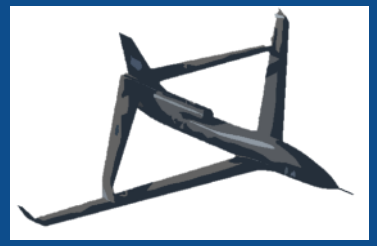
- **FY22-24: Additively Manufactured Metal Airframe Structure (University Engagement)**
  - **Product: Understanding of the impact of AM on primary structure design**

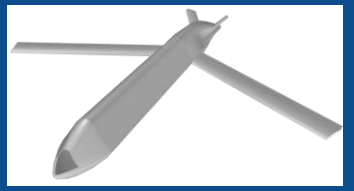
Foundational Efforts for Topology Optimization

- 2020: WiSDM Topology Optimization Wing
  - Product: full scale wing designed through T.O., weight and cost comparisons, structural test data



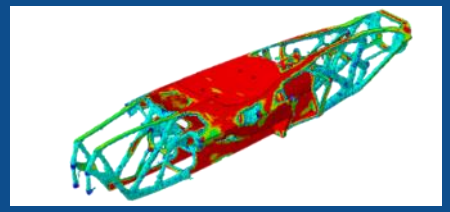
- 2020-2023: Printed Composites for Attritables & Rapidly Deployables (PiCARD)
  - Product: Low cost drone concept through printed composites, topology optimization structural design, alternative composite cure methods, over-braided wing skins, a modular fuselage chassis, structurally integrated antenna

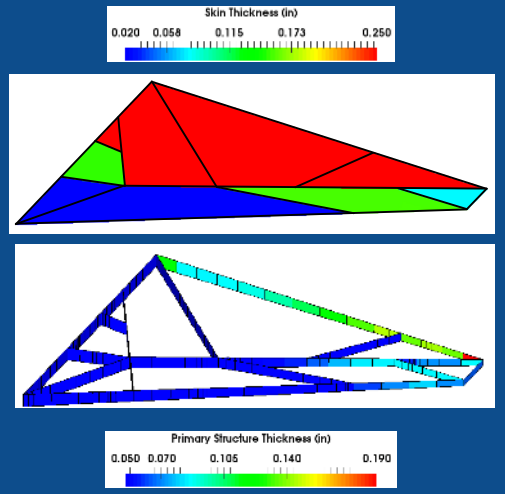




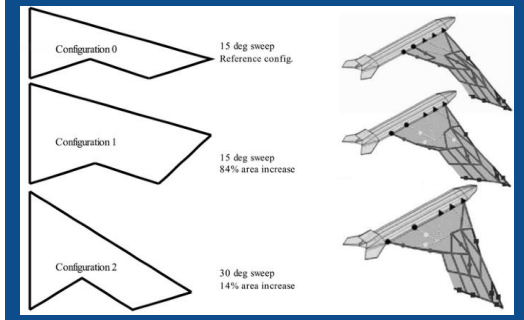
Topology Optimization Path Forward

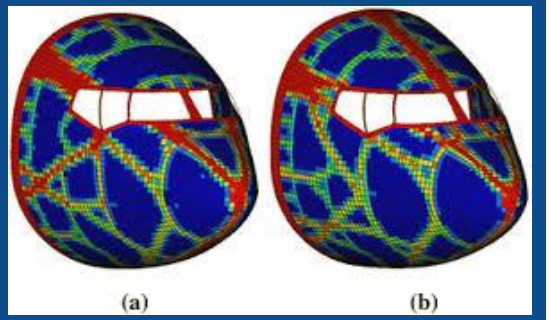
- **2021-22: Physics - Informed Structural Topology Optimized Layout (PISTOL)**
  - **Product: Advanced T.O. tools demonstrated on a full scale structural article**



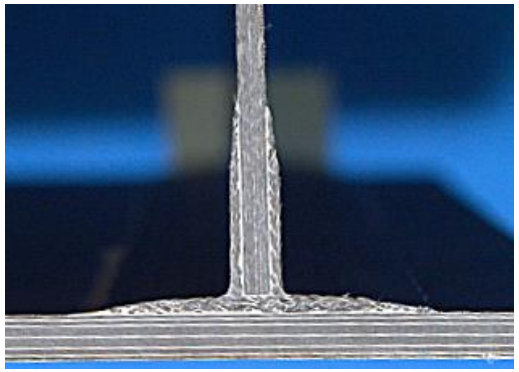


- **2022 and beyond: Future CRAD or CRADA on Topology Optimization**
  - **Product: Topology optimization at scale, with structural test and flight test**





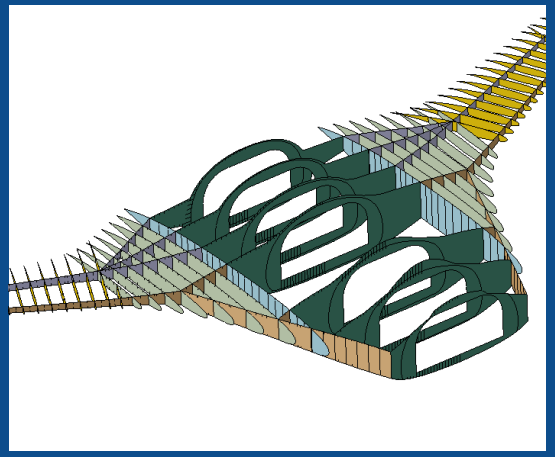
Joining



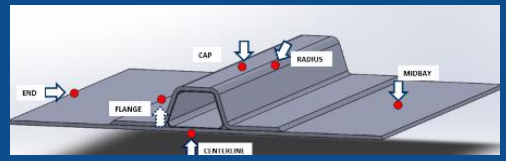
- Problem
  - Despite years of development, bonded joints are not ready for prime time
- Gaps
  - Ability to inspect all joints throughout the lifecycle
  - Surface preparation quality control
  - Properly trained workforce
  - Lack of ability to predict durability
- 2030 End State
  - Verify bond quality and strength for all composite joints throughout the lifecycle

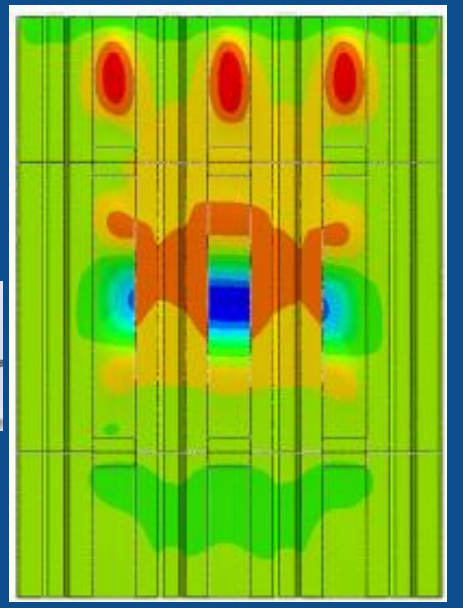
Next Generation Unitized Structure Designs

- **2018-23: Fail-Safe Technologies for Bonded Unitized Composite Structures (FASTBUCS)**
  - **Product: Fail-safe damage arrest certification approach for bonded unitized composite structures**



- **2018-2023: Impact Damage Analysis Tools (IDAT)**
  - **Product: Validated commercial FEA tool to assess the durability and damage tolerance of unitized composite structures for impact damage**





Summary

- Structures research still important for the Air Force. Cannot rely on the commercial aircraft industry to meet our requirements.
- Enabling step function improvements in cost, performance, and time to market of military aircraft
- Making attritable aircraft a reality: airworthiness, design, materials, manufacturing
- Not forgetting next generation systems
  - ISR: morphing, multifunctional, low cost
  - Mobility: Hot exhaust wash, rapid low cost manufacturing, topology optimization