FAA AVS Composite Plan & Related Research

Presented to: AMTAS

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FAA Research Process

- **Three years in advance, we in AVS propose topics for research**
  - Under Structural Integrity of Composites, we create requirements for buckets for subjects such as:
    - Structural Integrity of Bonds
    - Maintenance
    - Fatigue and Damage Tolerance
    - Advanced Materials and Testing
    - Crashworthiness
- **Year before execution we modify the requirements as necessary, based on what we have learned in the interim**

FAA Research Process

- **The FAA Technical Center turns our requirements into requests that go out to JAMS**
  - Multiple line items / projects per “bucket”
- **We have moved to a system where we expect detailed project plans with milestones and deliverables, and request written reports every year that are published by the technical center**
- **In FY16 and FY17, we had congressionally mandated additional funds which sponsor JAMS research that supports certification efficiency, more than continued operational safety**
  - We try to accelerate items identified in the Requirements

AVS Composite Plan

- **The FAA's mission is to "provide the safest, most efficient aerospace system in the world."**
  - Safety is always our first priority
- **Composite design and manufacturing oversight is performed by the Aircraft Certification Service, which in turn is part of the Aviation Safety Office (AVS) of the FAA**
  - AVS is comprised of 7 offices, including Aircraft Certification (AIR) and Flight Standards (AFS)

AVS Composite Plan

- **The FAA has created an AVS Composite Plan to identify and manage safety risks, opportunities to standardize means of compliance, and promote workforce education**
  - Seven-year plan updated annually
  - *Depends on industry deliverables (e.g., CMH-17 and SAE)*
  - Includes FAA research
- **Three focus areas**
  - Continued Operational Safety (COS)
  - Certification Efficiency (CE)
  - Workforce Education (WE)
- **Priority is assigned to tasks based on issues that pose the greatest safety threats**

Overview FY2017

Red items are directly supported by FAA research (AMTAS and CECAM coordination expected)

Green items are indirectly supported by FAA research

Continuous Operational Safety (COS)	Certification Efficiency (CE)	Workforce Education (WE)
COS A: Bonded Structure	*CE A:* Hybrid F&DT Substantiation	*WE A:* Composite Manufacturing Technology
COS B: HEWABI (High-Energy, Wide-Area Blunt Impact)	*CE B:* Advanced Composite Maintenance	*WE B:* Composite Structures Technology
COS C: Failure Analysis of Composites Subjected to Fire	*CE C:* Composite Structural Modifications	*WE C:* Composite Maintenance Technology
	CE D: Composite Quality Assurance	
	CE E: Bonded Structure Guidance	
	CE F: General Composite Structure Guidance	
	CE G: Engine Guidance	

COS Initiatives

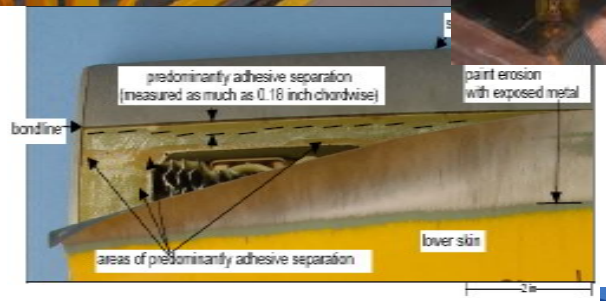
- **Three COS items in the Composite Plan:**
  A. Bonded Structure
  B. HEWABI (high-energy, wide-area, blunt impacts)
  C. Failure analysis of composites subject to fire

COS A, Bonding

- **The Bonding initiative encompasses three distinct sub-subjects**

Published as a FAA Technical Center Report (Seaton & Richter), 20148

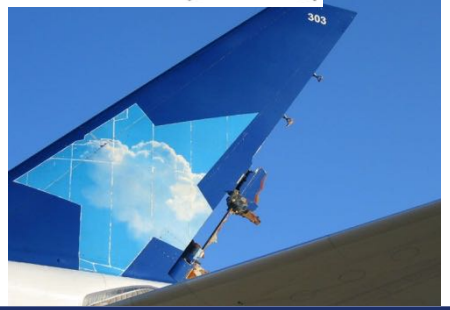
  - Bonded Repairs



From Air Force MP3 Mtg. Frank Zankar (NTSB, 2008)

  - Bond Quality Control

  - Sandwich Disbond Growth



In-flight Rudder Failure
(Large damage causing flutter)
Air Transat Flight 961 [3/6/05]

COS A, Bonding

Items in Italics are Completed

- **FAA Deliverables**
  - ➢ *PS-AIR-20-130-01 "Bonded Repair Size Limits" released 11/2014*
  - – *Published Chapter in Order 8900.1 "Flight Standards Information Management System" outlining Bonded Repair Size Limits*
  - – *Published Advisory Circular (AC) 65-33, "Development of Training/Qualification Programs for Composite Maintenance Technicians" to include specific guidance on bonded structure*
  - – Short Course for Bonded Repair Design, Substantiation, and Approval FY2018
  - ➢ AC for Bonded Structure that includes Bonded Repair Best Practices FY2021
  - ➢ AC for Sandwich Structure FY2020

COS A, Bonding

- **Industry Deliverables and Research**
  - Publication of the ACs is dependent on successful completion of the following documents by industry groups: Best Practices in Bonded Repair (SAE), CMH-17 Repair Substantiation (CMH-17 Rev H), Standards for Metal Bond Process QC (ASTM D3762), Test Standards for Disbond Growth (ASTM) and CMH-17 Risk Mitigation Guidelines (CMH-17 Rev H)
  - Numerous FAA research projects on bonded and sandwich structure are underway and planned for the next few years
  - FAA also researching current maintenance instruction practices

FAA Research Supporting COS A, Bonding (includes sandwich structure)

- Improving Adhesive Bonding of Composites through Surface Characterization
- Development and Evaluation of Environmental Durability Test Methods for Composite Bonded Joints
- Effect of Surface Contamination on Composite Bond Integrity and Durability
- Durability of Adhesively Bonded Aerospace Structure
- CACRC Depot Bonded Repair Investigation
- Environmental Factor Influence on Sandwich
- Bonded Repair Teardown

COS B, HEWABI

High-energy wide-area blunt impacts (HEWABI)

Items in Italics are Completed

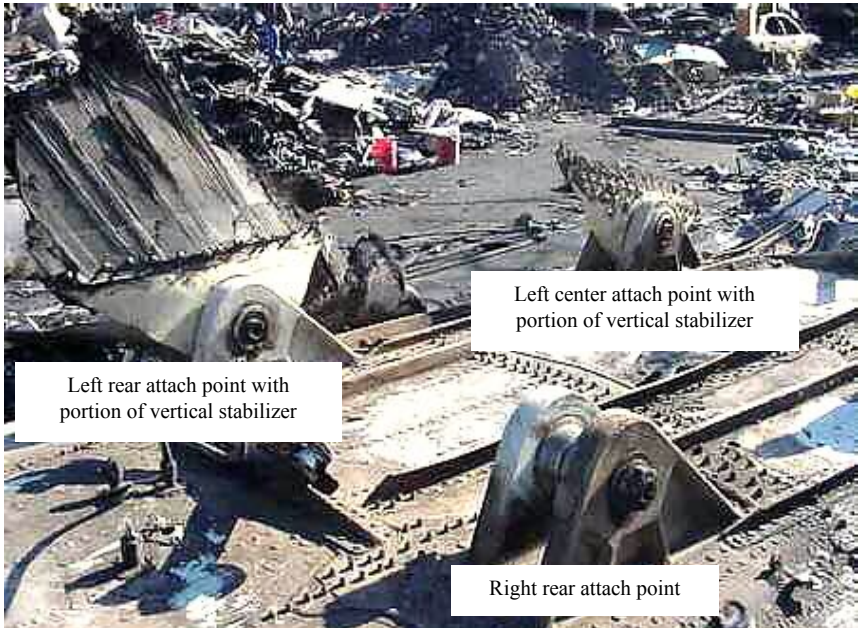
- **FAA Deliverables**
  - *PS-ANM-25-20 requiring HEWABI evaluation during the certification of aircraft structures released 8/2017*
  - Internal FAA webinar FY2017
- **Industry Deliverables and Research**
  - FAA has funded research in this area
  - The FAA will participate in the development of a chapter in CMH-17 specific to HEWABI to be used as future guidance for composite aircraft certification
- **When webinar is completed, the initiative will be closed**
  - Follow up actions in CE A

FAA Research Supporting COS B, HEWABI

- **Impact Damage Formation on Composite Aircraft Structures**
- **Non-Destructive Evaluation Methods for Detecting Major Damage in Internal Composite Structural Components**

COS C, Failure Analysis of Surfaces Subjected to Fire after Part Failure

- **Background**
  - Composite structure that failed in an accident may be subjected to fire, changing failure surfaces and potentially masking clues that could identify the root cause for part failure or the extent of damage
- **FAA Research Started (in-house at tech center)**



- **FAA Deliverables**
  - Failure Analysis Handbook FY2021

Certification Efficiency Initiatives

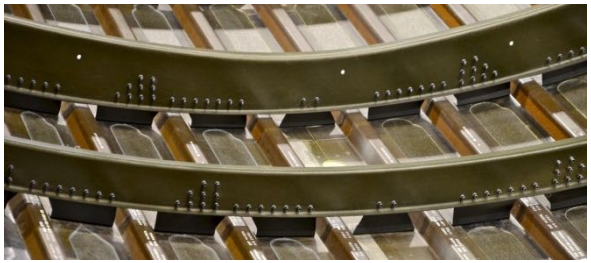
- **Certification Efficiency (CE) initiatives capture best industry practices via regulatory guidance and industry standards documents.**
- **Goal is to standardize methods to certify composite structures and repairs which will address the current industry practice of using proprietary databases and advanced procedures.**

Certification Efficiency Initiatives

- **Seven CE initiatives**
  A. Hybrid Metallic/Composite Structure Fatigue and Damage Tolerance Substantiation
  B. Advanced Composite Maintenance
  C. Composite Structural Modification
  D. Composite Quality Control
  E. Bonded Structure Guidance
  F. General Composite Structures Guidance
  G. Engine Installation Guidance
- **Additional standardization activities in the area of transport crashworthiness, fuel tank lightning protection, and composite flammability**
  – These FAA initiatives have some components specific to composites

CE A, Hybrid Structure

- **Background**
  - Fatigue and damage tolerance (F&DT) engineering protocol for composite aircraft structures differ significantly from metal engineering practices. These issues must be considered for the substantiation of most modern structures that include a combination of composite and metallic parts and assemblies.



CE A, Hybrid Structure

Items in Italics are Completed

- **Deliverables**
  - Policy on interpretation of existing amendment 25.571 for composite structure FY2019
    - *FAA "White Paper" 9/2016*
  - A new rule defining fatigue and damage tolerance requirements for the certification of composite transport aircraft FY2020
  - Associated guidance for new part 25 rule FY2020
- **Industry Deliverables and Research**
  - Publication of the policy is dependent on CMH-17 Rev H F&DT updates and ASTM test standards for laminate damage propagation
  - All deliverables linked to the three-year ARAC Tasking formed 1/26/2015 under the Transport Airplane Metallic and Composite Structures Working Group

FAA Research Supporting CE A, Hybrid Structure F&DT

- **Environmental Factor Influence on Composite Design and Certification**
- **Damage Tolerance Testing and Analysis Protocols for Full-Scale Composite Airframe Structures under Repeated Loading**
- **Failure of Notched Laminates under Out-of-Plane Bending**
- **Delamination/Disbond Arrest Features in Aircraft Composite Structures*+**
- **Evaluation of Notch Sensitivity of Composite Sandwich Structures***
- **Composite impact damage tolerance** (metrics, detectability, criticality)

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Oregon State UNIVERSITY OSU

UNIVERSITY OF WASHINGTON

THE UNIVERSITY OF UTAH

UC San Diego

***Also supports COS A, Bonding**

+ Recently completed

FAA Research Supporting CE B, Advanced Composite Maintenance

- CACRC Depot Bonded Repair Investigation – Round Robin Testing
- Bonded Repair Teardown Studies

CE D, Quality Assurance Guidance

- **Deliverables**
  - New AC that incorporates guidance on material and process specifications from AC 21-26, AC 21-31, and small airplane directorate policy PS-ACE 100-2002-006 and AC 23-20, “Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems”
    - Draft due 12/2018, Final 12/2019
- **Industry Deliverables and Research**
  - FAA-sponsored research into current process controls FY2017
    - Research is behind schedule, likely affecting date of AC release

FAA Research Supporting CE D, Quality Assurance Guidance

- **Advanced Fiber Reinforced Polymer Composite Materials Characterization**
- **Ceramic Matrix Composite (CMC) Materials Characterization**
- **Polymer-Based Additive Manufacturing (PBAM) Characterization**
- **Discontinuous Fiber Composite Structures**

CE E, Bonded Structure Guidance

- **Background**
  - There is an existing part 23 policy memo covering bonded structure material and process, control, design, analysis, testing, manufacturing, and repair techniques. The policy will be expanded into an AC for all product types and there will be a companion AC for sandwich structure.
- **Deliverables**
  - AC for Bonded Structure that includes Bonded Repair Best Practices FY2021 (Note this is the same deliverable as COS Initiative A)
  - AC for Sandwich Structure FY2020 (Note this is the same deliverable as COS Initiative A)
  - Other FAA guidance will be reviewed to determine effects from loss of prescriptive rule 23.573 in the part 23 rewrite

FAA Research Supporting CE E, Bonded Structure Guidance

- **All research associated with COS-A Bonding (see Chart 11)**
- **Adhesive Qualification Characterization**
- **Bond Process Qualification Characterization**

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CE F, General Composite Structure Guidance

- **Background**
  - With the evolving/advancing composite technology and expanding composite applications, AC 20-107 “Composite Aircraft Structure” will require revision
- **Deliverables**
  - Revision to AC 20-107, “Composite Aircraft Structure,” to incorporate advanced composite technologies and lessons learned FY2022
- **Industry Deliverables and Research**
  - Will incorporate latest information from industry documentation and FAA research (see all previous charts)

AMTAS Research Supporting CE F, General Composite Guidance

- Safety and Certification of Discontinuous Fiber Composite Structures

Since this is general guidance, AMTAS research that supports any of the other composite guidance will also have an influence on updates to AC 20-107C

CE G, Engine Installation Guidance

- **Background**
  - Polymer matrix composite (PMC) materials have been approved in several engine applications and now ceramic matrix composite (CMC) materials are being approved as well. These approvals have been managed on a case-by-case basis, adapting existing composite guidance for composite aircraft structure. Unique concerns with engine applications would benefit from documenting standardized means of compliance for both PMC and CMC materials
- **Deliverables**
  - New AC on certification of composite materials (PMC and CMC) in engine applications 12/2019 (draft due 12/2018)
- **Industry Deliverables and Research**
  - FAA research on CMCs

FAA Research Supporting CE G, Engine Installation Guidance

- **Ceramic Matrix Composite (CMC) Materials Characterization**

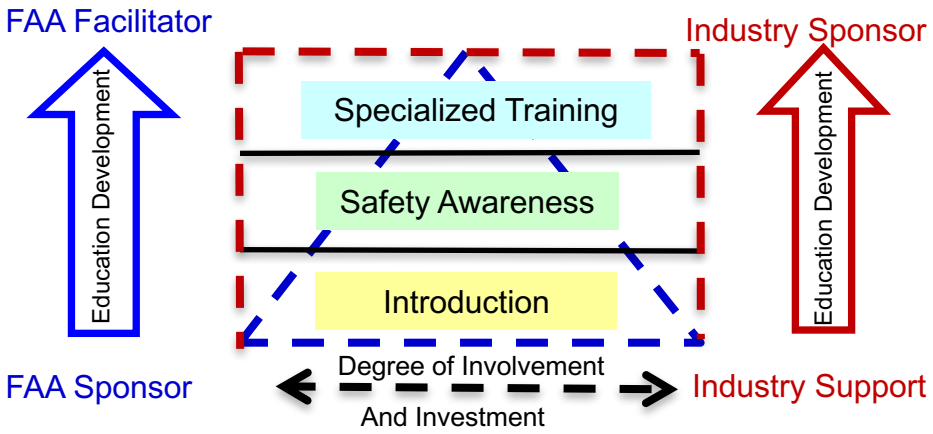
Workforce Education Initiatives

- **An essential component for COS and CE is a comprehensive educational development program**
- **Successful composite safety and certification oversight is dependent upon our workforce being knowledgeable of both basic and advanced composite technologies and terminologies**

Workforce Education Initiatives

FAA composite training strategy using existing courses, FAA Centers of Excellence & industry support

Courses to support airframe engineering, manufacturing and maintenance functional disciplines



Incl. three levels of competency:

- **Introduction ("Composites 101")**
- **Safety Awareness (courses for each functional discipline)**
  - Skills needed for FAA workforce supporting composite applications
- **Specific Skills Building (most courses developed by the industry)**
  - Specialized skills needed in the industry and some FAA experts

- **All courses can be adjusted for classroom or internet** (condensed badges/tutorials or full blackboard with discussion boards)
- **Seeking industry partnerships & safety awareness standards**

Workforce Education Initiatives

- **Three initiatives – developed by the FAA but available to industry as well**
  A. Composite Manufacturing Technology
  B. Composite Structures Technology
  C. Composite Maintenance Technology
- **Additional activities supporting "composites 101" training and Composite DER designations**
- **Includes international outreach and standardization**
  – Promote safety, technology transfer and maintaining a level playing field

WE A, Composite Manufacturing Technology

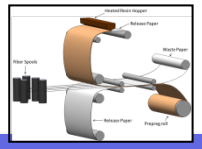
- **Background**
  - The Composite Manufacturing Technology (CMfgT) course was first offered in spring 2015
    - Offered through Wichita State University
  - It will be updated with the new quality control AC content (CE D)
- **Deliverables**
  - Updated CMfgT course with revised content, lesson plans and a job aid 6/2020

WE A, Composite Manufacturing Technology

- **FAA-Developed Course for FAA and Industry Workforce**
- **Goal:**
  - To provide FAA Manufacturing Inspectors and Designees with a technical background of composite manufacturing to a level that allows them to better and more proactively identify deficiencies on the factory floor that have safety implications.
- **Five "Badges" offered through Wichita State**
  - 4 online Badges include 12 modules that roughly correlate to composite production workflow
  - 16 hours laboratory (onsite at Wichita State University)
- **Includes an electronic job aid for later reference**

FAA's Composite Manufacturing Course

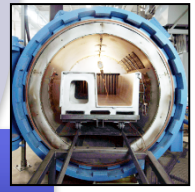
0.1. Introduction to Composites → 0.2. Composite Factory Workflow



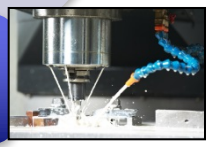
1. Raw Materials Manufacturing

2. Transport, Incoming QC and Storage

3. Tool Prep, Cutting, Layup and Bagging



4. Cure and Solidification



5. Trim and Drill

6. Inspect

7. Bonding and Part Assembly

8. Paint and Finish

9. Handling and Storage

COURSE MODULES

•10. Common Manufacturing Issues

Each Block has slide content, assessment/test, and video links

WE B, Composite Structures Technology

- **Background**
  - The Composite Structural Engineering Technology (CSET) course will be updated every four years.
    - Offered through Wichita State University
  - Update the structural DER seminar content on a recurring basis
- **Deliverables**
  - Updated CSET course with revised content, lesson plans and a job aid 12/2018
    - Significant revision and reformatting underway to remove redundancy and turn into multiple shorter courses for different subjects

FAA's Composite Structural Engineering Technology (CSET) Course

- **Top-level Course Objectives**
  - Students will describe essential safety awareness issues associated with composite structural engineering important to safe composite aircraft product applications
  - Students will describe engineering principles of composite airframe substantiation during all stages of aircraft product certification
- **Updated Course Outline**

1.0 Composite Applications
2.0 Material, Processing and Fabrication Development
3.0 Design Development
4.0 Structural Substantiation } 50% of course
5.0 Manufacturing Interface Issues
6.0 Maintenance Interface Issues
7.0 Additional Considerations
  7.1 Flutter
  7.2 Crashworthiness
  7.3 Fire safety and fuel tank issues
  7.4 Lightning protection

WE C, Composite Maintenance Technology

- **Background**
  - Revise Flight Standards Service's course "Composite Awareness for the Aviation Safety Inspector," on a five year basis (was last updated in 2015)
  - Additional directed training necessary for repair facility oversight
- **Deliverables**
  - Course development request FY2019
  - Develop a computer-based short course for Aviation Safety Inspectors that have oversight responsibilities for complex composite repair facilities FY17

Composite Plan Summary

- **The FAA is proactively identifying and attempting to mitigate risks associated with the use of composite materials in aviation products**
- **Outcomes contained in the Plan include rulemaking, guidance, and training to:**
  - ensure continued operational safety,
  - promote certification efficiency, and
  - provide workforce education
- **Efforts to integrate research advanced in 2017**

Detailed Links with AMTAS Research

- **Improving Adhesive Bonding of Composites Through Surface Characterization: Effect of Amine Blush, Peel Ply History, and Other Material or Process Key Issues on Bond Quality, UW**
  - Evaluate material and processing variables that lead to amine blush, peel ply and other bonding challenges in typical industry manufacturing environment and identify key process parameters and key characteristics that need to be controlled in materials and processes to avoid potential understrength or weak bonds
  - Document findings, including results from experimental measurements, to establish protocol and criteria that avoids known bond surface phenomena from degrading structural performance
- **Development and Evaluation of Environmental Durability Test Methods for Composite Bonded Joints, University of Utah**
  - Investigate the a composite bond standard for cleavage loading and environmental strength/durability testing that meets the needs of existing applications, ***integrating knowledge coming from other AMTAS researchers working on bonding***
  - Document the key factors to control quantitative data analysis and results from mode I fracture tests performed with joints having different levels of structural bond integrity in supporting development of an international composite bond test standard

Detailed Links with AMTAS Research

- **Effect of Surface Contamination on Composite Bond Integrity and Durability, Florida International University**
  - Understanding the failure modes dependent on local and continuous bond surface contamination leading to weak or “understrength” bonds and the overall effects on fracture properties that relate to bond structural performance and long-term durability (including local cleavage bond failures and crack migration)
  - Documenting industry bonding practices, including process enhancements that mitigate the risk of different levels of contamination on weak or understrength bonds, with an emphasis of getting such information into CMH-17 (Rev. H)
- **Durability of Adhesively Bonded Aerospace Structures, Washington State University**
  - Investigate the various test and analysis methods used to evaluate environmental effects and history/time-dependent static/durability performance of adhesives (with a range of toughness) used in existing aviation applications. Characterize viscoelastic and plastic behavior up to loads approaching failure.
  - Document key factors (design – bond-line thickness, temperature, ***stress level***) contributing to environment and *load history/time-dependent ratcheting effects* in studying structural bond integrity, including ***screening test recommendations***

Detailed Links with AMTAS Research

- **Evaluation of Notch Sensitivity of Composite Sandwich Structures, University of Utah**
  - Sandwich disbond test standards supporting the ongoing CMH-17 efforts for Rev. H
  - ***Evaluation*** of analysis used by industry for Category 2 and 3 large in-plane damage capability of *sandwich structures*, including complex structural loading
  - ***Development*** of building block test standards & related data analysis procedures to gain the structural data needed to support sandwich structural damage tolerance
- **Effects of Moisture Diffusion in Sandwich Composites, UW**
  - Perform analysis & tests to understand the moisture and liquid transport phenomena in sandwich composites as it affects loads, core degradation and fracture properties
  - Document key factors (temp, MC) to be considered for loads causing disbond growth, changes in core material fracture properties, and sandwich design substantiation
- **Failure of Notched Laminates under Out-of-Plane Bending** (and an assessment of progressive damage material props)**, Oregon State University**
  - ***Evaluation*** of industry progressive damage analyses for large damage capability (*stiffened structures* subjected to combined loads), while assessing basic tests of material properties used in these analyses (initial matrix compression emphasis)
  - ***Development*** of building block test standards and related data analysis procedures to gain the structural data needed to support structural damage tolerance

Detailed Links with AMTAS Research

- **Building Block Testing Supporting Crashworthiness, UU**
  - Evaluate laminated composite structural coupons & elements used to absorb energy under dynamic loading in support of industries' desire to apply an analysis supported by test approach to crashworthiness assessments
- **Safety and Certification of Discontinuous Fiber Composite Structures, UW**
  - Investigate the structural performance of discontinuous fiber material forms for applications selected by industry and document unique characteristics.
  - Evaluate analysis and tests used to quantify the effects of defects for such composite materials, documenting the strengths and limitations of available models, including those needed for size effects of quasi-brittle materials.
- **Delamination/Disbond Arrest Features in Aircraft Composite Structures, UW (In memory of Dr. Kuen Y. Lin)**
  - Evaluate best industry design practices used for bonded structures, which include structural redundancy. Perform tests and analysis to evaluate effectivity of mechanical fasteners to arrest disbond growth and the associated dependence on loads, design detail and process variables.
  - Document work to support industry use of fasteners in arresting disbonds.