Composite Safety & Certification Initiatives Progress and Plans for Bonded Structure

Presented at 10/26/04 FAA Bonded Structures Workshop

FAA

Larry Ilcewicz
CS&TA, Composites

- Overview of CS&CI
  - Technical thrust areas, approach and milestones
- Progress with bonded structures
  - Applications of bonding to aircraft structures
  - 2004 bonded structures initiative
  - Workshop objectives
  - Synopsis of progress to date
- Critical bonding issues
  - Material & process qualification and control
  - Design development and structural substantiation
  - Manufacturing implementation and experience
  - Repair implementation and experience
- Support during & after the workshop

Ongoing Composite Safety & Certification Initiatives*

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Objectives

1) Work with industry, other government agencies, and academia to ensure safe and efficient deployment of composite technologies being pursued for use in aircraft

2) Update policies, advisory circulars, training, and detailed background used to support standardized composite engineering practices

** Efforts started in 1999 to address issues associated with increasing composite applications*

Current CS&CI Technical Thrust Areas Pursued by FAA and NASA

FAA

NASA

Advancements depend on close integration between areas

Material Standardization and Shared Databases

Damage Tolerance and Maintenance Practices

- Critical defects (impact & mfg.)
- Bonded structure & repair issues
- Fatigue & damage considerations
- Life assessment (tests & analyses)
- Quantitative NDE/Service POD
- Equivalent levels of safety

Structural Substantiation

- Advances in analysis & test building blocks
- Environmental effects
- Manufacturing integration

FAA and NASA R&D is currently active in most of these areas

Bonded Joint Processing Issues

Advanced Material Forms and Processes

Flammability & Crashworthiness

Support from cabin safety research groups

Significant progress, which has relevance to all aircraft products, has been gained to date

FAA Approach to Composite Safety and Certification Initiatives

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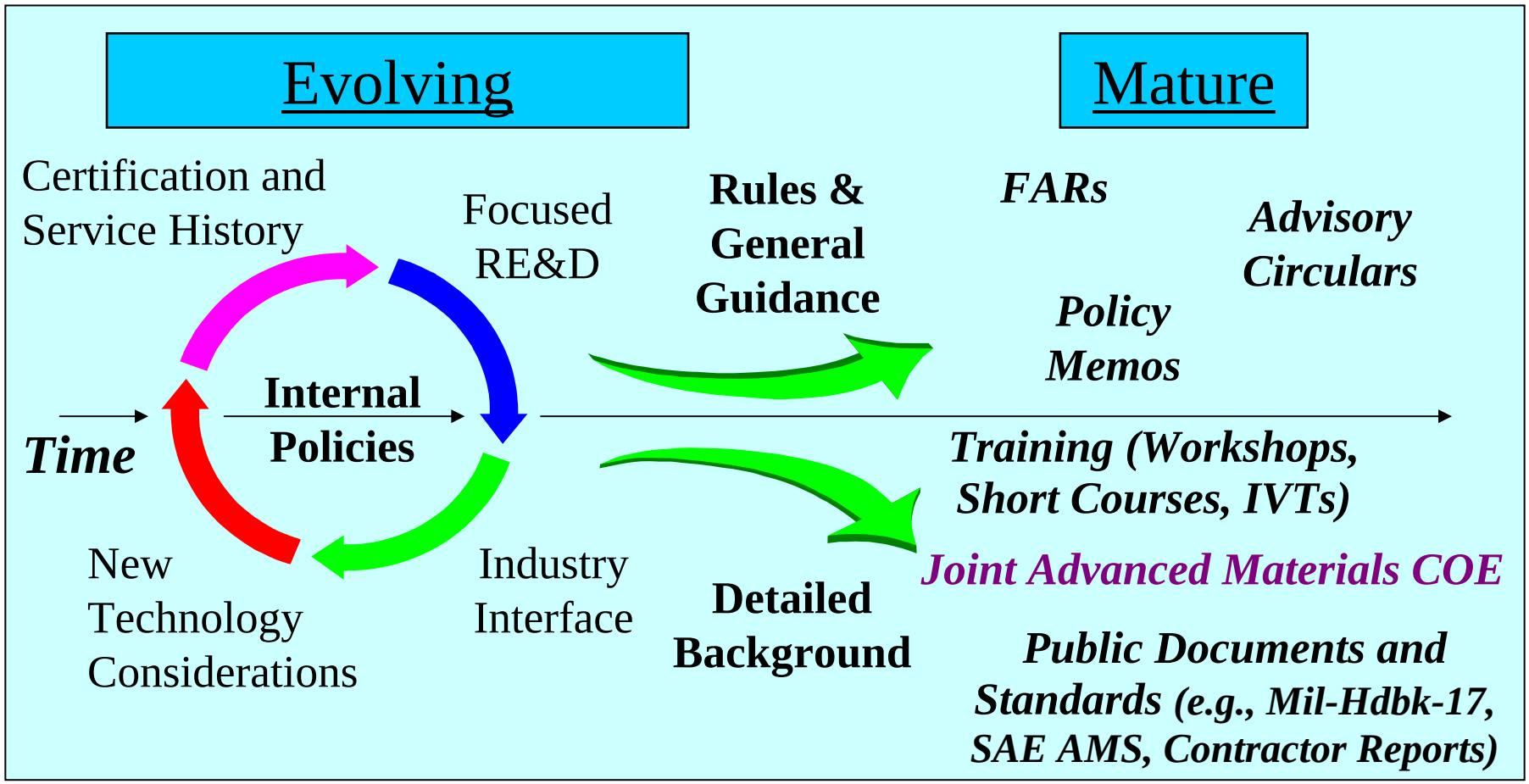

FAA Composite Team Members

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Represented Group	Team Member Name	FAA Organization Number & Routing
FAA Tech. Center	*Curtis Davies*	*AAR-450 (FAA Technical Center)*
	Peter Shyprykevich	*AAR-450 (FAA Technical Center)*
International	John Masters	AEU-100 (Brussels Aircraft Certification Staff)
Directorates	*Lester Cheng*	*ACE-111 (Small Airplane Directorate)*
	Mark James	ACE-111 (Small Airplane Directorate)
	Richard Monschke	ASW-111 (Rotorcraft Directorate)
	Richard Yarges	ANM-115 (Transport Airplane Directorate)
	Hank Offermann	ANM-115 (Transport Airplane Directorate)
	Jay Turnberg	ANE-110 (Engine & Propeller Directorate)
Flight Standards	William Henry	AFS 350 (Aircraft Maintenance Division)
ACOs, MIDOs & CMOs	Randy Blosser	ANM-100D (Denver ACO)
	Roger Caldwell	ANM-100D (Denver ACO)
	Mark Freisthler	ANM-120S (Seattle ACO)
	Fred Guerin	ANM-120L (Los Angeles ACO)
	Angie Kostopoulos	ACE-116C (Chicago ACO)
	David Ostrodka	ACE-118W (Wichita ACO)
	Richard Noll	ANE-150 (Boston ACO)
	Dick Vaughn	ANM-108B (Seattle CMO)
	David Swartz	ACE-115N (Anchorage ACO)
CS&TA	*Larry Ilcewicz*	*ANM-115N (CS&TA, Composites)*

Composite Team has placed an emphasis on a need to address bonded structure issues (metal & composite)

Present at this workshop

Important Teammates

FAA

- NASA has been a leader for composite applications
  - Significant research support since 1970/1980s
  - AA587, A300-600 accident investigation

NASA

- Partnerships with industry are essential, e.g., Mil-17, SAE P-17, CACRC, ASTM, SAMPE, AGATE, SATS, RITA, SAS/IAB/AACE

SAE INTERNATIONAL

COMMERCIAL AIRCRAFT COMPOSITE REPAIR COMMITTEE — ata — IATA — SAE

Training
Standardization
Shared databases
Engineering guidelines

MIL COMPOSITE MATERIALS HANDBOOK

ASTM INTERNATIONAL

- FAA Joint Advanced Materials Center of Excellence (JAMCOE)
  - Univ. of Washington (Edmonds C.C., Washington State Univ., Oregon State Univ.)
  - Wichita State Univ. (Univ. Of Delaware, Tuskegee Univ., UCLA, Northwestern, Purdue)

FAA Strategic Plan: Safety Continuum

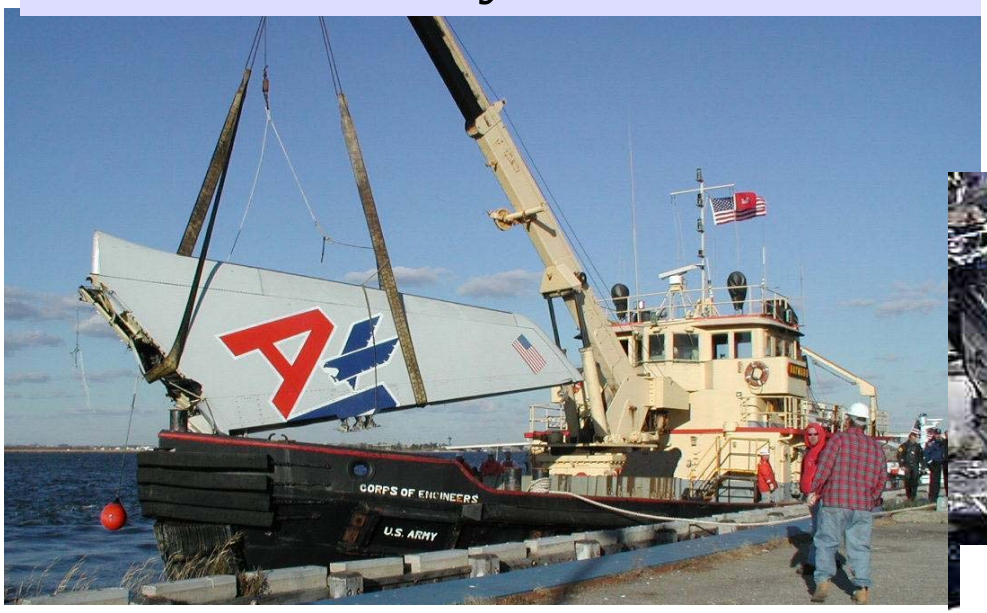
FAA

Safety management system linking certification standards, maintenance and operations

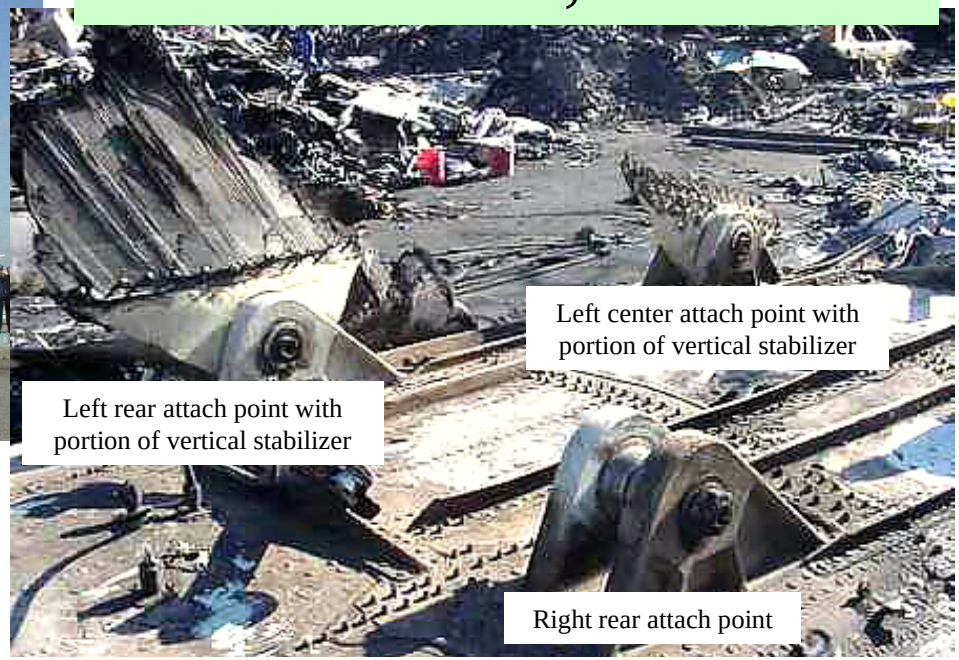
American Airlines Flight 587, Airbus A300 Accident, 11/12/01

FAA

Recovery of Vertical Fin from Jamaica Bay, New York



Fuselage Attachment Structure at Accident Site in Belle Harbor, New York



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Accident Investigations

- Detailed studies indicate there are generally many factors that combine to contribute to an accident
  - Precursors are often evident but are usually not obvious because they must combine with other factors
- Safety management must combine the skills of many disciplines
  - A systems approach with airplane level awareness can help mitigate the risk of accidents
  - Critical relevant information must be disseminated (i.e., lessons learned)
  - Industry standards groups can help promote consistent engineering practices and practical guidance

Major Milestones for Bonded Structure Policy, Guidance & Training in 2004 + 2007

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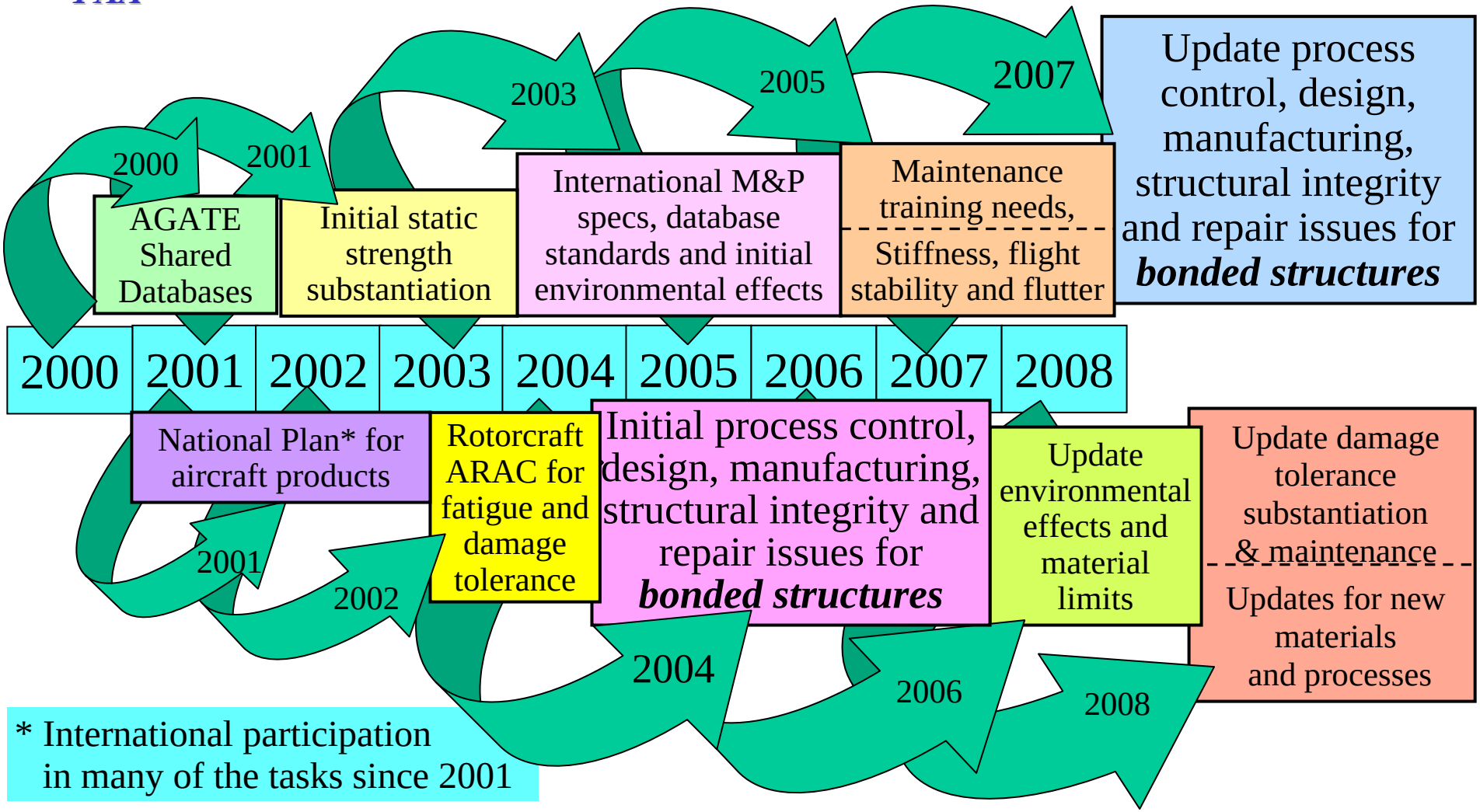

* International participation in many of the tasks since 2001

Use of Bonding for Structural Joining & Attachments in Commercial Aircraft

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Small airplanes

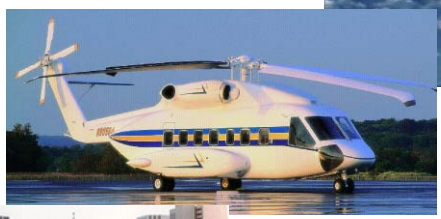
- Long history of metal bonding in primary load bearing applications for some small airplanes/jets
- Extensive bonding in new prop-driven airplanes (composite sandwich skin panels and major joints to close wing torque box, attach main spars & fuselage skin splices)
- Business jets use bonded sandwich in fuselage (major fuselage splices include bolted redundancy)

Rotorcraft and propellers

- Combination of bolted and bonded structures in airframe and dynamic parts (major splices are bolted, many bonded attachments)

Transport aircraft

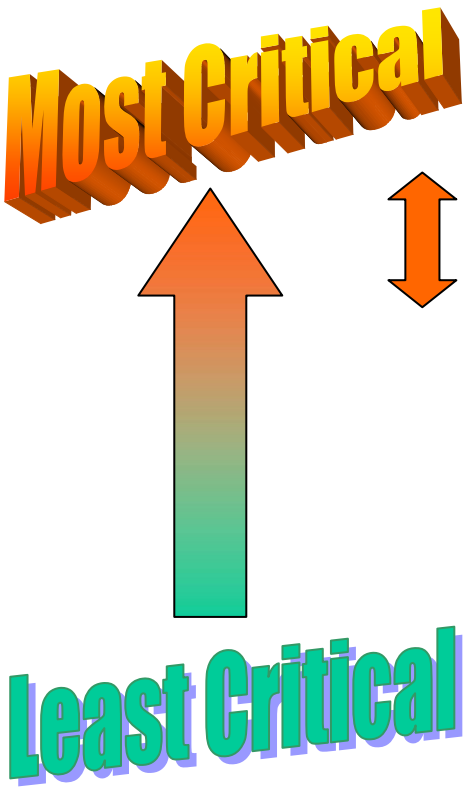
- Bonded attachments (stringers, sandwich panels) for composites, but major joints remain bolted
- Bonded fiberglass/aluminum (GLARE) laminate fuselage crown panels are planned for the A380



Bonded repair is common for all product types, e.g., sandwich panels

Levels of Application Criticality

FAA



	Flight Safety	Loads	Environment	Service Experience	Other Factors
	Primary Single load path	High shear Moderate peel	High temp, moisture and fluids	Bad service records	?
	Complex?	Inaccurate?	Unknown?	No service records?	?
	Primary Multi-load path	Moderate shear Some peel	Standard temp, moisture and fluids	Limited good service records	?
	Secondary structure	Low shear No peel	Benign environment	Good service records	?

2004 Bonded Structures Initiative
Justification and Purpose

FAA

- Bonding applications for the manufacture & repair of aircraft structures exist throughout the industry
  - New applications are expanding faster than the qualified workforce, making documentation and training a priority
- Technical issues are complex and cross-functional, requiring extensive teamwork for successful applications
  - Known production and service bonding problems highlight a need to properly document the associated technical issues

Collectively, the industry and regulatory agencies should be able to combine our bonding experiences and technical insights to the mutual benefits of improved safety and efficiency in development & certification

2004 Bonded Structures Initiative
Primary Deliverables

FAA

- Survey industry to benchmark critical technical issues and engineering practices for existing applications
- Bonded Structure Workshops in 2004 to review the survey and gather more insights from experts
  - Coordinated with Mil-17 meetings (June 16-18/Seattle WA)
  - Follow-on workshop in Europe (Oct. 26-27/Gatwick UK)
- Develop FAA Technical Center Report(s) on critical technical issues and existing engineering practices
- Late 2004 FAA policy covering safety issues and certification considerations for bonded structure

2004 Bonded Structure Initiative

Objectives for 6/04 Workshop & Follow-on Report(s)

FAA

Primary objective

Collect & document technical details that need to be addressed for bonded structures, including critical safety issues and certification considerations

Secondary objectives

1) *Give examples of proven engineering practices*
2) *Identify needs for engineering guidelines, shared databases and standard tests & specs*
3) *Provide directions for research and development*

Background: The primary objective relates to a FAA goal for outlining ***what*** needs to be considered for aircraft safety and certification. Secondary objectives are intended to help industry develop guidelines, standards and training in addressing the critical issues.

Approach Used for Initial Bonded Structures Efforts

FAA

Timeline: 2004 - 2005

2a) Focussed research to survey industry on the critical technical issues and benchmark engineering practices

1) Start with input from certification, production and service experiences, plus research performed to date

2b) Workshops to collect more inputs & draft reports for industry review

3) Draft policy on critical safety issues & certification considerations

4) Training for industry and government workforce

» Initial research and industry review *(light yellow boxes)*, used to gain agreement on critical issues, generalize industry experiences and identify needs (standards and longer-term research)

Progress and Plans in the Bonded Structures Initiative through 2004

FAA

Oct. to Dec. 2004 — Draft FAA policy for Bonded Structures, FAA workshop in Europe, update reports

July to Sept. 2004 — Draft FAA TC Bonded Structures Report(s) and plan follow-on activities

June 2004 — FAA workshop to review survey and collect insights from bonding experts at Mil-17 mtg.

Apr. to May 2004 — Develop workshop agenda & invite speakers

Feb. to Mar., 2004 — Select team, setup AACE grant & survey industry

Oct. 2003 to Jan. 2004 — Meet with industry and military groups to develop detailed plans and ID experts to support work

July to Sept. 2003 — Introduce plans to industry and collect initial technical inputs at composite M&P control workshop (Chicago)

May 2003 — Developed strategy & resource requests for near term work

Feb. 2001 — TTCP document on “Certification of Bonded Structures”

2000 to 2003 — FAA research per the ***“Don Oplinger Plan”***

Progress for Bonded Structures
FAA and NASA Research

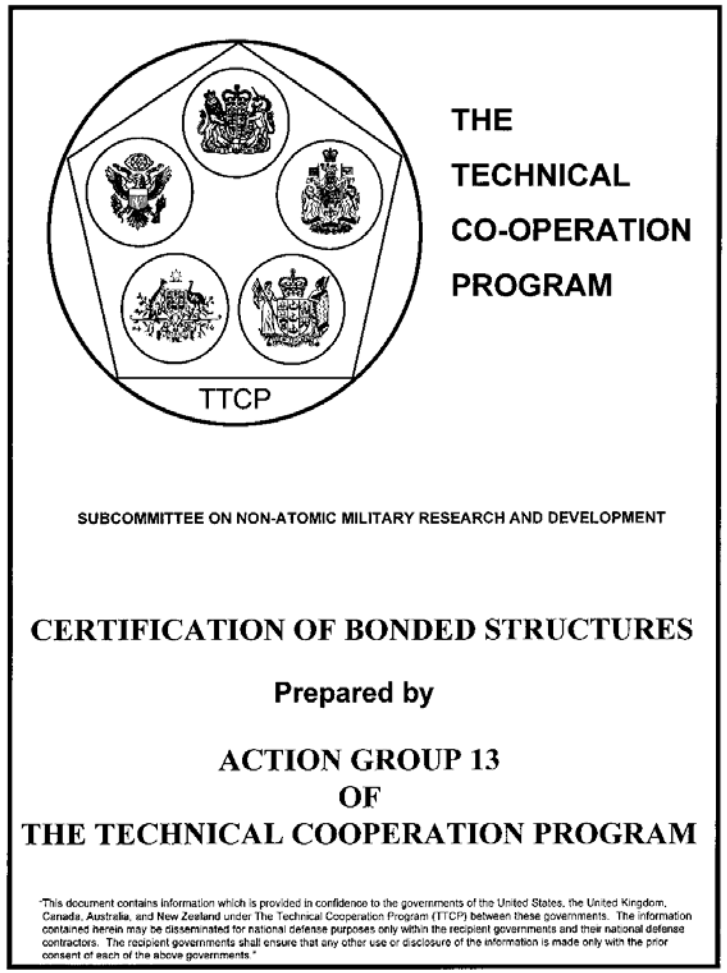
FAA

- Surface prep studies on removable plies and abrasion
  - Clarify terminology for peel plies and release fabrics
  - In-process control testing
- Advances in test methods for adhesive joint shear and peel
- Characterization of environmental effects, fatigue and creep for a wide range of adhesives used by industry
  - Consideration of temperature guidelines used for material selection
- Evaluation of structural analysis methods for strength and damage tolerance
  - Development & test validation of methods suitable for design
  - Evaluation of realistic structural detail (e.g., thick and variable bondlines, joggles) and load cases (e.g., shear flow)

Progress for Bonded Structures
Action Groups for Detailed Documentation

FAA

- Some guidance for bonded structures, which comes from military and commercial aircraft experiences, are documented in a TTCP report
  - Chairman: Jack Lincoln, WPAFB
  - Composite and metal bonding
  - Starting point for current effort
- Mil-17 Debond & Delamination Task Group since 2000
  - T.K. O'Brien, K. Kedward and Hyonny Kim are Co-chairman



THE TECHNICAL CO-OPERATION PROGRAM

TTCP

SUBCOMMITTEE ON NON-ATOMIC MILITARY RESEARCH AND DEVELOPMENT

CERTIFICATION OF BONDED STRUCTURES

Prepared by

ACTION GROUP 13
OF
THE TECHNICAL COOPERATION PROGRAM

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Synopsis of Progress to Date

FAA

- Structural bonding has been used in fabrication and repair of many types of commercial and military aircraft components
  - Safety issues & certification considerations are application dependent
- FAA Bonded Structures Initiatives in 2004 are being used to benchmark the industry
  - Document critical safety issues and certification considerations
  - Document examples of proven engineering practices
  - Identify needs (databases, standards, focused research)
- FAA will continue to pursue the identified needs with other government agencies, industry and standards organizations
- Our long-term goal is to establish guidance, detailed documentation and training, which is useful for the certification and continued airworthiness of bonded structures

Technical Scope of the Bonded Structures Workshop

FAA

Material & Process Qualification and Control

Bonding applications where at least one side of the joint is metal or pre-cured composite

Manufacturing Implementation and Experience

Regulatory Considerations

- Proof of structure: static strength
- Fatigue and damage tolerance
- Design and construction
- Materials and workmanship
- Durability
- Material strength properties & design values
- Production quality control
- Instructions for continued airworthiness
- Maintenance and repair

General aviation, rotorcraft and transport aircraft

Design Development and Structural Substantiation

Commercial and military applications were reviewed

Repair Implementation and Experience

Critical Bonding Issues

Material & Process Qualification and Control

FAA

- Material selection and process definition
  - *Bonding processes lead to a complex material system (substrate, adhesive and an interface region that is more complex than either)*
- Qualification testing
- Material control

FAR 23/25/27/29.603 Materials
FAR 33.15 & 35.17 Materials
FAR 33/35.19 Durability

FAR 25.603 (Paraphrased): Suitability & durability of materials used for critical parts must

(a) be established by experience or tests.
(b) conform to approved specifications that assure strength and other design properties
(c) account for service environmental conditions

Critical Bonding Issues

Material & Process Qualification and Control

FAA

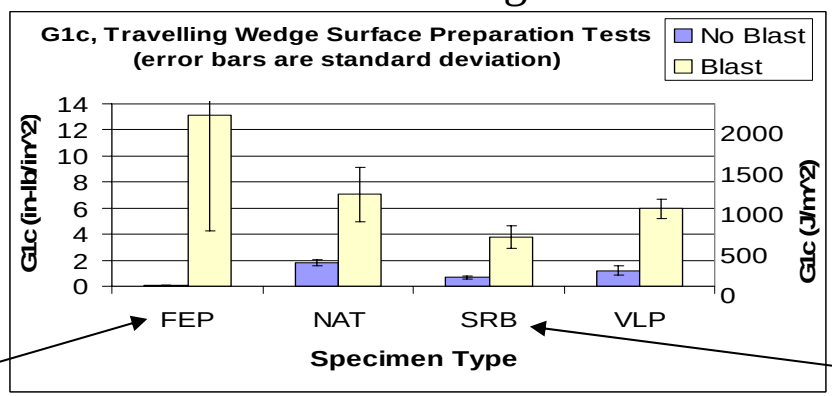
- Process control
- Major changes to materials or processes

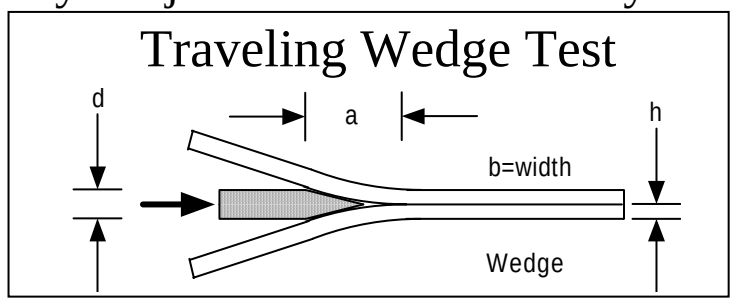
FAR 23/25/27/29.605 Fabrication methods

FAR 25.605: "(a) Fabrication methods must produce consistently sound structure. If a fabrication process (such as gluing, …) requires close control to reach this objective, the process must be performed under an approved process spec

(b) Each new aircraft fabrication method must be substantiated by a test program"

FAA Research at UCSB: Bonding Surfaces Previously Subjected to Removable Layers





Release Film

Peel plies: NAT and VLP

Release Fabric

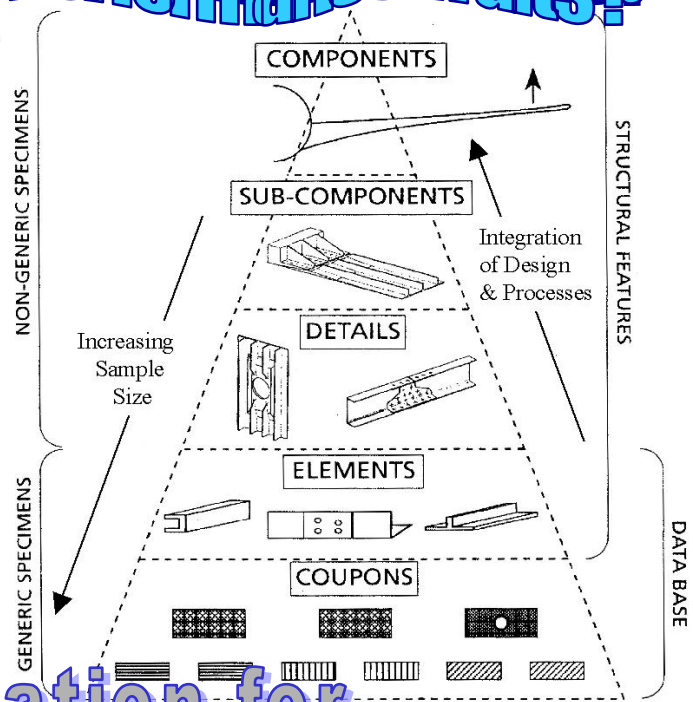
Critical Bonding Issues

Design Development and Structural Substantiation

FAA

- Design and construction
  - Criteria and guidelines
  - Structural detail and redundancy
  - Manufacturing/tooling constraints
  - Design for maintenance
  - Systems interface
- Design data and allowables
  - Defect and damage considerations
  - Environmental effects
- Analysis methods
- Proof of structure
  - Analysis validation
  - Static strength & deformation
  - Damage tolerance & fatigue
  - Long-term durability
- Service experience

Manufacturing-Induced Performance Traits?



Complex Interal Load Paths ?

Validation for Real-Time Exposure

Critical Bonding Issues

Design Development and Structural Substantiation

FAA

Subpart B: Design and Construction

FAR 23/25/27/29.601 General

FAR 35.15 Design features

FAR 25.601: "The airplane may not have design features or details that experience has shown to be hazardous or unreliable. The suitability of each design detail or part must be established by tests."

FAR 23.573 Damage tolerance and fatigue evaluation of structure

paragraph (a) Composite airframe structure

FAR 23.573 (a)(5): "For any bonded joint, the failure of which would result in catastrophic loss of the airplane, the limit load capacity must be substantiated by one of the following methods –" (each paraphrased)

(i) Structural redundancy *(ii) Proof loading* *(iii) NDI*

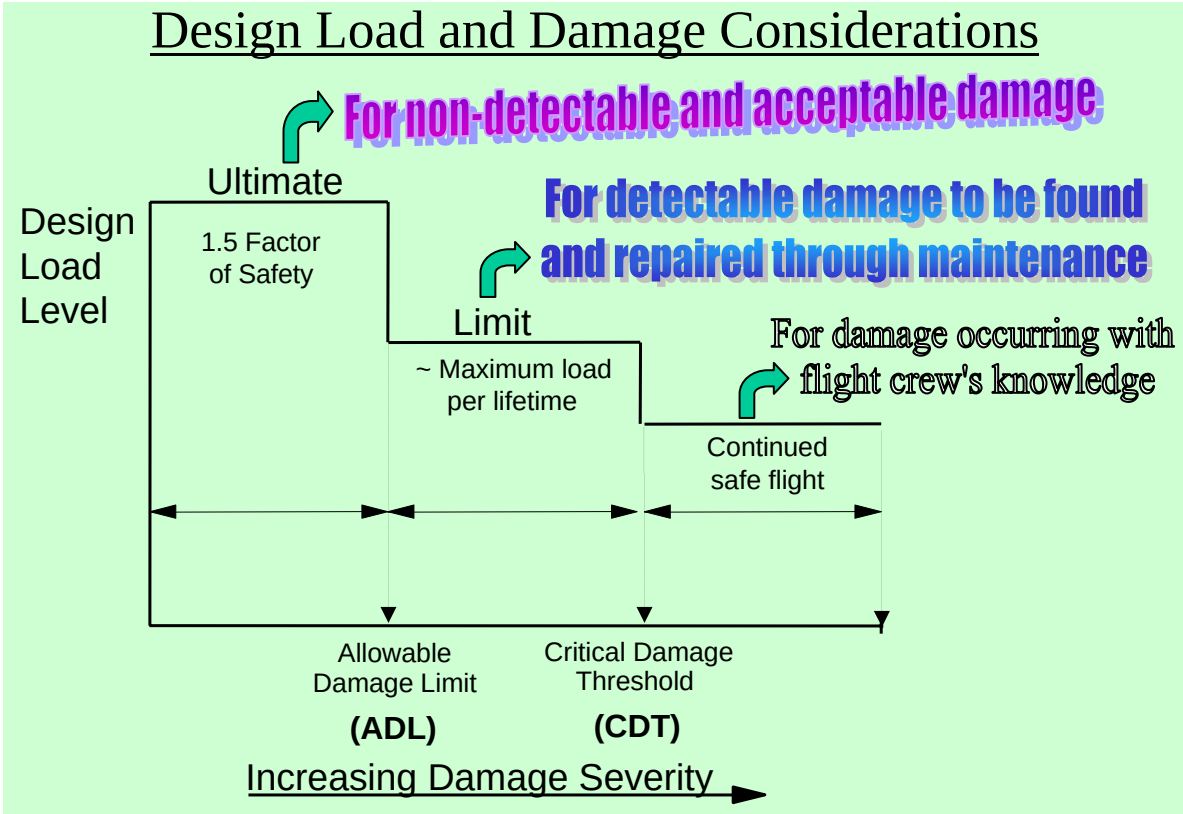
Critical Bonding Issues

Design Development and Structural Substantiation

FAA

- All damage tolerance and fatigue rules* imply catastrophic failure due to fatigue, environmental effects or accidental damage will be avoided during the aircraft operational life

- *Lost Ultimate load capability should be rare* with safety covered by damage tolerance & practical maintenance procedures



** 23.573, 25.571, 27/29.573*

Critical Bonding Issues

Design Development and Structural Substantiation

FAA

- A well-qualified structural bonding process and strict material & process controls are paramount

  Fatigue and damage tolerance methods can not cover for an "unacceptable bonding process"

  Reason 1: the degradation of "weak bonds" is generally not predictable or repeatable in mechanical tests

  Reason 2: bad chemistry, real time and environmental effects dominate the degradation process

  Reason 3: large area debonding is unacceptable for a large number of structural details (i.e., degradation is not "rare")

- Fatigue and damage tolerance methods are useful for structure using a qualified bonding process that is under control

  Reason 1: to cover *rare*, *local debonding*, which occur for good processes

  Reason 2: to provide sufficient fail-safety & coverage for accidental damage

Critical Bonding Issues

Manufacturing Implementation and Experience

FAA

- Scaling of process details found to yield reliable adhesive bonds
  (e.g, time limits, cure temp./contact pressure, bondline thickness control)
- Factory environmental cleanliness controls
- Tooling and equipment
- Quality control
- Nondestructive inspection
- Manufacturing defects
  (bonded structure discrepancies)
- Skills and training of production workforce
- Process documents and records

Part 21, Subpart G:
Production Certificates
FAR 21.139 Quality Control
(Paraphrased)

In order to get a production certificate, applicants must establish and maintain a quality control system so that each product meets the design provisions of the pertinent type certificate.

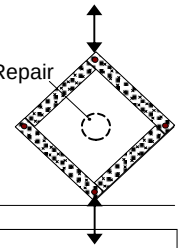
Critical Bonding Issues

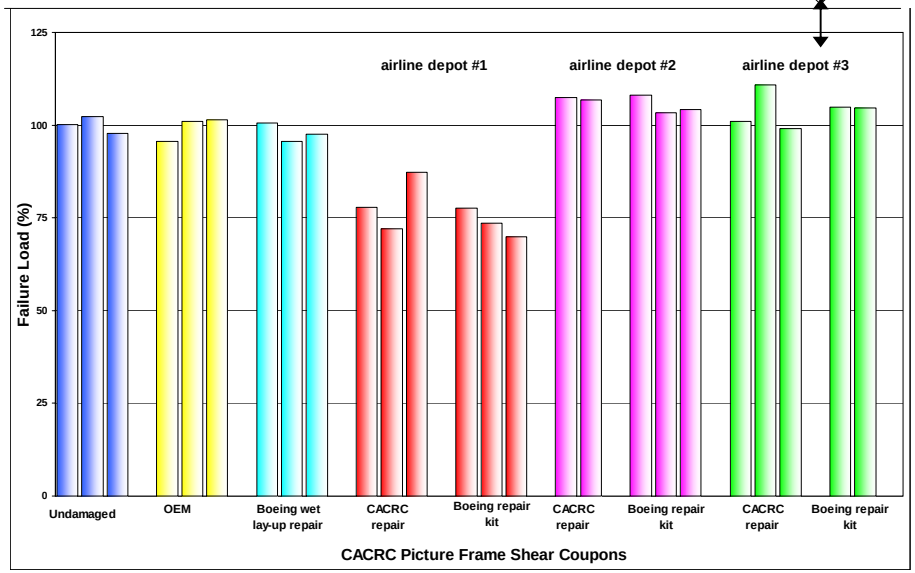
Repair Implementation and Experience

FAA

- Accessibility for maintenance inspection and repair
- Field implementation of bonded repair process details
  - Shop tooling and equipment
  - Environment & cleanliness control
  - Material acceptance & control
  - Cure temp./contact pressure for variable structural detail
  - Quality control
  - Repair defect disposition
- Nondestructive inspection
- Service damage disposition (allowable damage and repair limits)
- Skills & training of workforce
- Maintenance documents and records

FAA Research at WSU:
CACRC Repair Investigation





FAR Part 43 Maintenance, Preventive Maintenance, Rebuilding and Alteration

Support During & After the Workshop

FAA

- Rules of engagement during the workshop
  - Please pose major points during your presentation
  - All speakers will respect the time of others
  - Some priority for questions and comments will be given to those who haven't spoken yet
  - Let your voice be heard but if time doesn't allow it, consider communicating with us after the workshop
- Communications following the workshop
  - Public website will post workshop presentations www.niar.wichita.edu/faa
  - Please send your thoughts and notes to WSU kristin.strole@wichita.edu
  - All inputs will be considered in drafting FAA Report(s), which will be written and reviewed by selected experts

Future Plans for Bonded Structures Initiatives

FAA

- Draft FAA Technical Center Reports (2004 & 2005)
  - Primary content: information collected on bonding issues critical to safety & certification (before/during/after workshop)
  - Secondary content: Give examples of proven engineering practice, future R&D directions and standards support needs
  - Following a rigorous review process, publicly release reports for purposes of training, coordination and standardization
- Draft FAA policy to summarize critical bonding issues
  - Released per FAA internal and public processes
- Continue to work on composite safety and certification initiatives related to bonded structures

Summary

- Composite safety & certification initiatives (CS&CI) are progressing with international help
  - Bonded structure work integrates all technical thrust areas
  - 2004 initiatives will benchmark critical bonding issues
    TTCP document and FAA R&D provides a starting point
    Survey and workshop leading to technical center report(s)
- Safety management of bonded structures includes:
  - Adequate qualification/control of materials and processes
  - Coordinated design development and substantiation
  - Robust manufacturing and maintenance implementation
  - Continuous updates based on service experience

Thank-you for your help