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# Composite Safety & Certification Initiatives Progress and Plans for Bonded Structure

Larry Ilcewicz, FAA

# Workshop Dedications

*for Contributions to Bonded Structures Initiatives*

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**Mr. Don Oplinger**  
**December 2, 1928**  
**June 12, 2000**



**Dr. Jack Lincoln**  
**March 22, 1928**  
**February 10, 2002**



**Dr. Jim Starnes**  
**March 2, 1939**  
**October 27, 2003**

# Composite Safety & Certification Initiatives

## Progress and Plans for Bonded Structure

*Presented at 6/16/04 FAA Bonded Structures Workshop*



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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 & speaker instructions
  - Synopsis of progress to date
- Critical bonding issues
  - Certification and continued airworthiness
  - Material & process qualification and control
  - Design development and structural substantiation
  - Manufacturing implementation and experience
  - Repair implementation and experience
- Support during & after the workshop



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# Ongoing Composite Safety & Certification Initiatives\*

## 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*



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

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

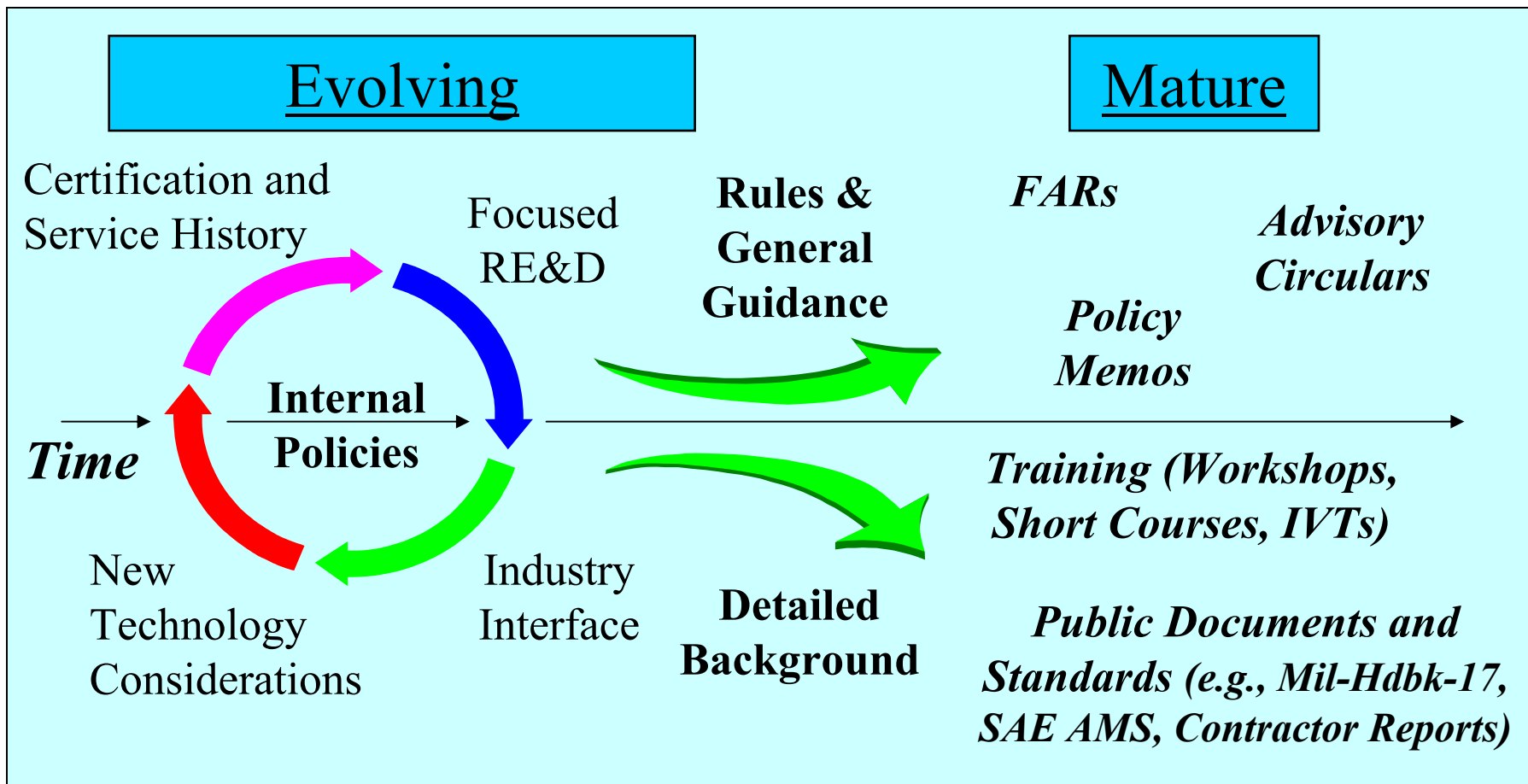
*Support from cabin safety research groups*

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



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# FAA Approach to Composite Safety and Certification Initiatives





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# FAA Composite Team Members

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

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

*Present at this workshop*



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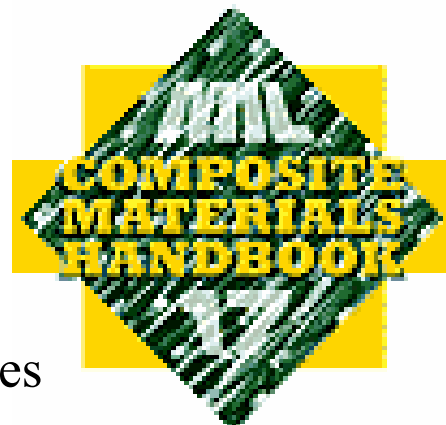
# Importance of NASA, Industry Standards Groups and Other Support Organizations

~~NASA~~

- NASA has been a leader for composite applications
  - Significant research funding to composite safety & certification initiatives
  - Closely involved in the AA587, A300-600 accident investigation
  - Both aeronautics and space activities will be integrated in long-term plans
- Partnerships with industry are essential, e.g., Mil-Handbook-17, CACRC, SAE, ASTM, SAMPE, AGATE, SATS, RITA, SAS/IAB/AACE



Training  
Standardization  
Shared databases  
Engineering guidelines



- Continued support of other organizations will be sought (e.g., DOD, DARPA, JAA and other foreign research/standardization links)





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# FAA Strategic Plan: Safety Continuum

Each function within the continuum is an integral part of Safety Management



Information and experience derived from each phase is systemically applied to subsequent phases throughout the continuum

The success of the entire continuum is dependent on effective Safety Management in each and every phase

*Safety management system linking certification standards, maintenance and operations*



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# Accident Investigations

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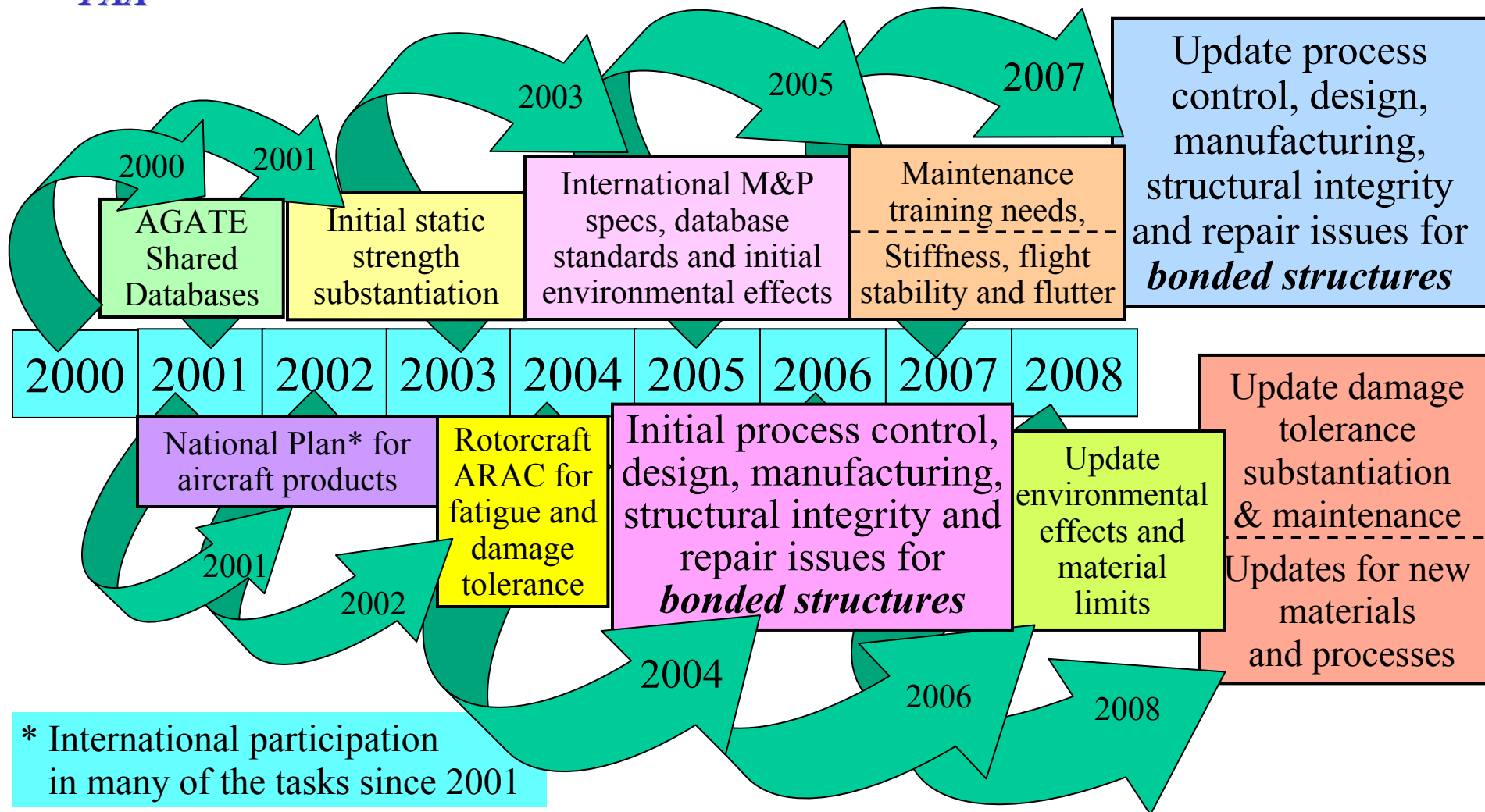
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- Detailed studies indicate there are generally many factors that combine to contribute to an accident
  - Precursors are often evident but are usually not obvious because they must combine with other factors
- Safety management must combine the skills 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



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





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# Use of Bonding for Structural Joining & Attachments in Commercial Aircraft

## 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*

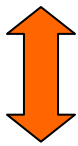
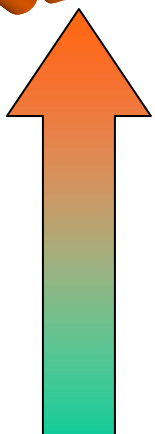


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# Levels of Application Criticality

	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	?	

**Most Critical**



**Least Critical**



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# 2004 Bonded Structures Initiative

## *Justification and Purpose*

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- 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**



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# 2004 Bonded Structures Initiative

## *Primary Deliverables*

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- 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
  - To be coordinated with June Mil-17 meetings
  - Follow-on workshop in Europe (TBD)
- 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





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# 2004 Bonded Structure Initiative

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

### 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.





# 2004 FAA Adhesive Bonding Workshop

## *Speaker Instructions*

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- Items to include at the start of your presentation
  - Briefly describe your background and experiences with adhesively bonded structure
  - Provide a synopsis of the bonded structural applications to be covered by examples in your presentation
  - Identify the critical safety issue(s) and/or certification consideration(s) you plan to address
    - To provide linkage with the primary workshop objective*
- The remainder of your presentation may contain
  - Additional details on your experiences and applications
  - Advice on best engineering practices and other items related to bonded structures (*see secondary objectives*)



# 2004 FAA Adhesive Bonding Workshop

## *Technical Scope*

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- General aviation, rotorcraft and transport aircraft  
*(coordinated with military groups)*
- Structural applications of bonding *(manufacturing and/or repair when at least one side of the joint is pre-cured or metal)*
  - Composite to composite
  - Metal to metal
  - Composite to metal
- Functional areas to be covered
  - Control of raw materials & process (raw material manufacturing)
  - Bonding process controls
  - Manufacturing
  - Design
  - Analysis and failure prediction
  - Product development and structural substantiation
  - Repair
  - Maintenance



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# Approach Used for Initial Bonded Structures Efforts

## Timeline

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) Workshop to collect more inputs & draft reports for industry review

3) Draft policy on critical safety issues & certification considerations

» 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)

4) Training for industry and government workforce



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# Progress and Plans in the Bonded Structures Initiative through 2004

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*

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- 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)

SAE  
INTERNATIONAL



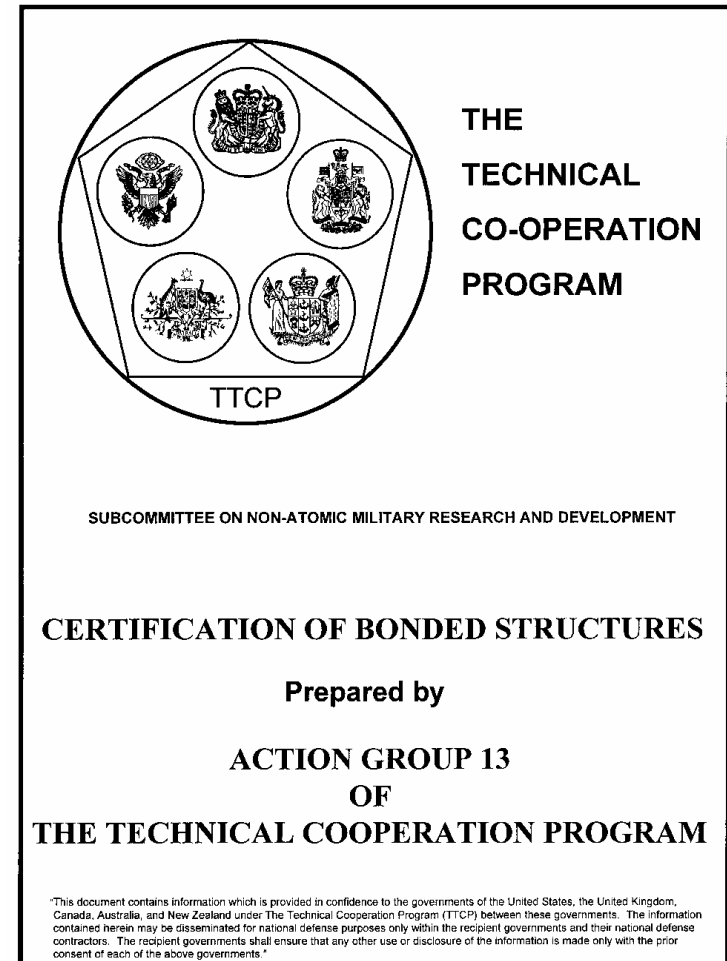


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# Progress for Bonded Structures

## *Action Groups for Detailed Documentation*

- 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





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# Synopsis of Progress to Date

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- 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



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# Certification and Continued Airworthiness

- Certification

- Step 1: components of a product's design are qualified, conformed, and substantiated to get a *Type Certificate* (extensive FAA oversight)
- Step 2: approval of the quality control system that ensures every product produced conforms to its type design leads to a *Production Certificate*
- During aircraft production and beyond, special design and production approvals are sought for changes, modifications, repairs, or improvements
- Step 3: each aircraft must also have an *Airworthiness Certificate*, which certifies it conforms to type design and is in safe operating condition

- Service problems are addressed with industry during the aircraft's life

Data, analysis & procedures defining the aircraft product and demonstrating it meets Federal Regulations

Repeatable production of certified aircraft products

Additional info may be needed for changes occurring during production or the product life cycle





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# Technical Subjects Covered in the Bonded Structures Workshop

Material &  
Process  
Qualification  
and Control

## 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

Design  
Development  
and Structural  
Substantiation

Manufacturing  
Implementation  
and Experience

Repair  
Implementation  
and Experience



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# Critical Bonding Issues

## *Material & Process Qualification and Control*

- 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

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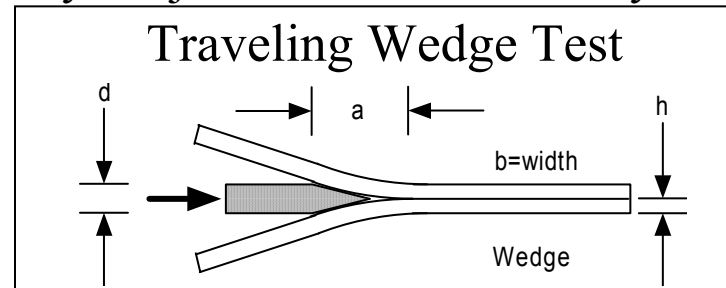
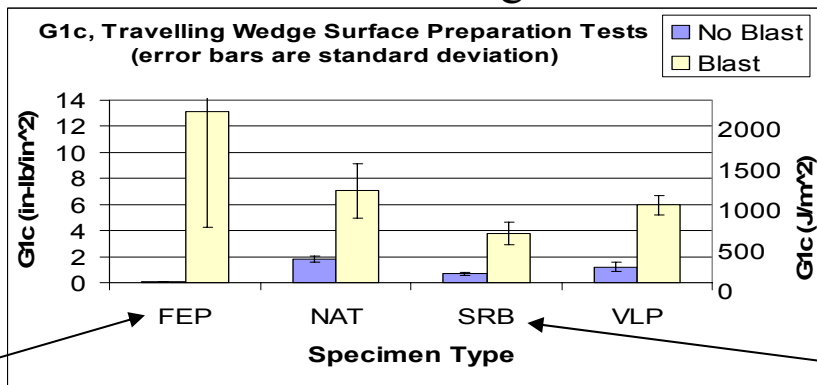
- Process control
- Major changes to materials or processes

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



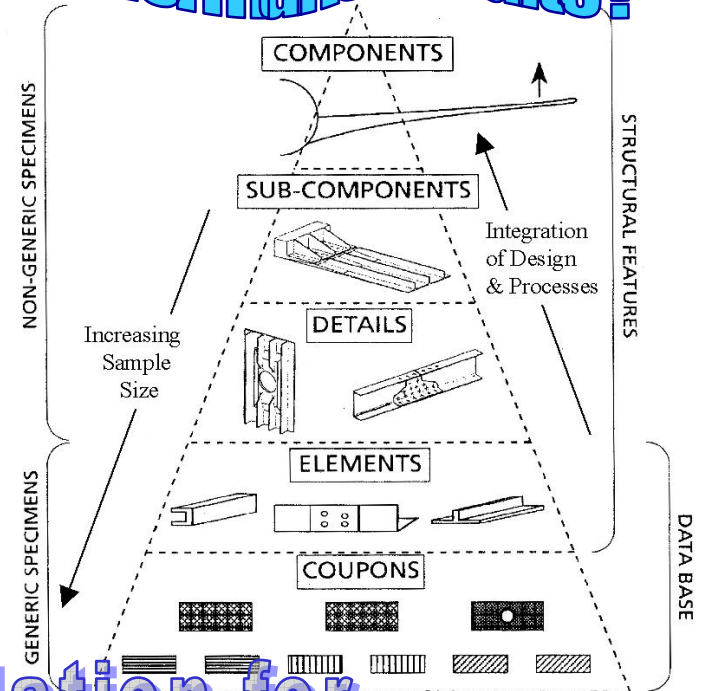
# Critical Bonding Issues

## *Design Development and Structural Substantiation*

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- 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 Internal Load Paths?**

**Validation for Real-Time Exposure**



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# Critical Bonding Issues

## *Design Development and Structural Substantiation*

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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*



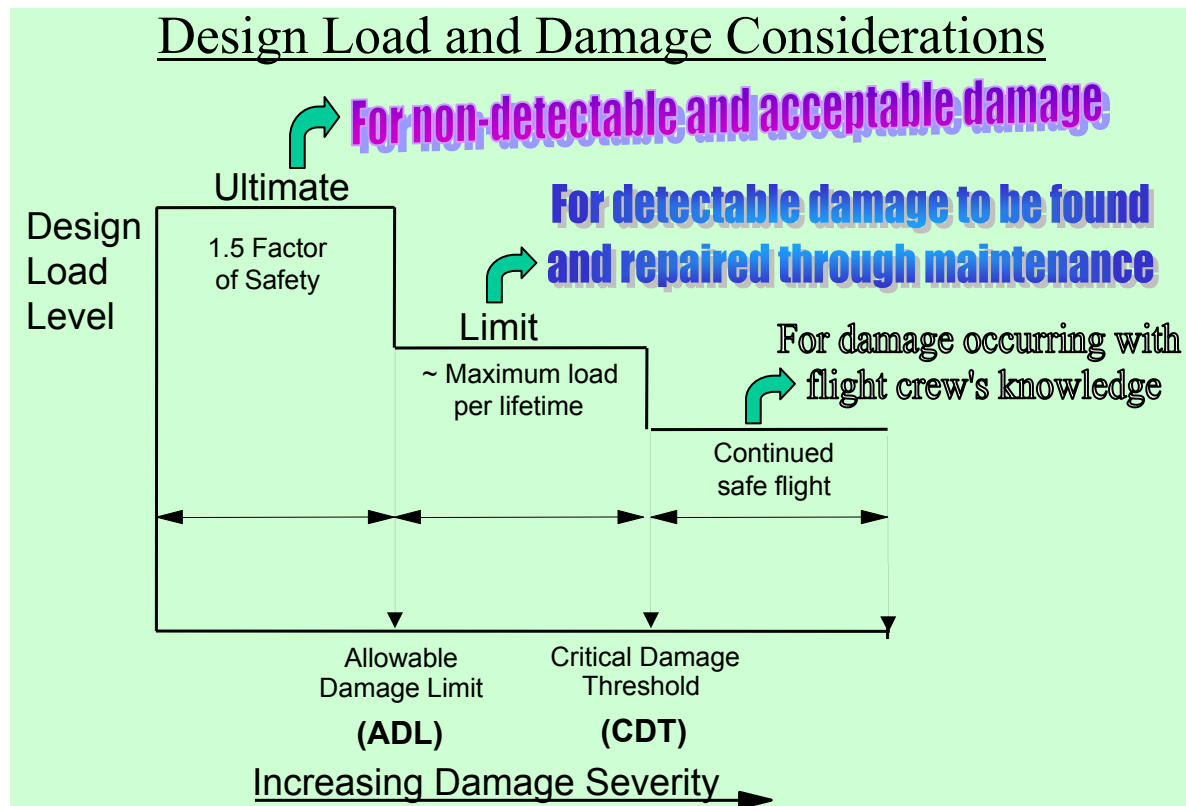
# Critical Bonding Issues

## Design Development and Structural Substantiation

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- 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*

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- 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



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# Critical Bonding Issues

## *Manufacturing Implementation and Experience*

- 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.*





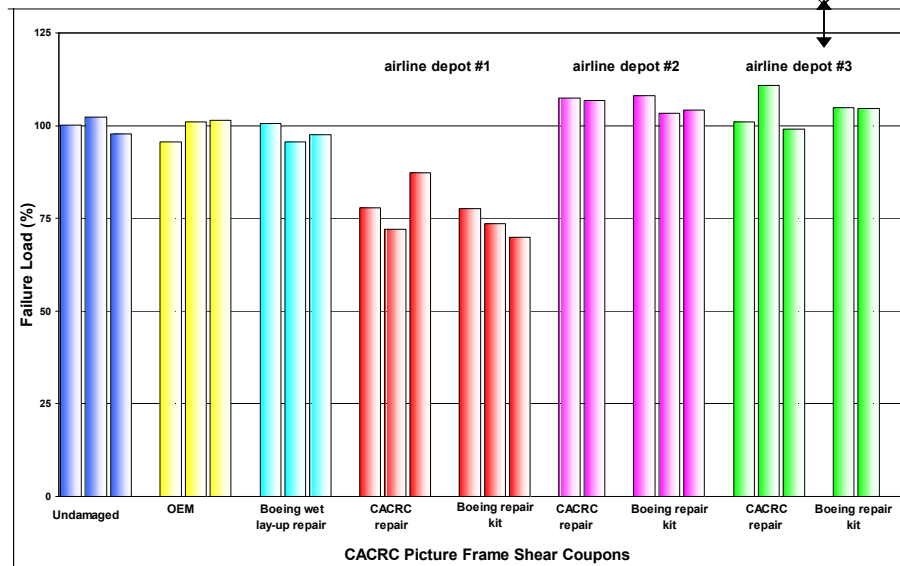
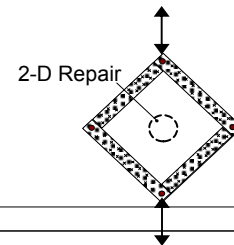
# Critical Bonding Issues

## *Repair Implementation and Experience*

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- 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



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# Support During & After the Workshop

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- Rules of engagement during the workshop
  - Please pose major points during your presentation or in your first chances at questions or comments
  - 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](http://www.niar.wichita.edu/faa)
  - Please send your thoughts and notes to WSU
  - All inputs will be considered in drafting FAA Report(s), which will be written and reviewed by selected experts



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# Future Plans

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- **Draft FAA Technical Center Reports**
  - 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**



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# Summary

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- 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