Composite Safety & Certification Initiatives

Presented at Boeing & NW DER Seminars in 2003

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Larry Ilcewicz
CS&TA, Composites

- Background and Timelines
- Technical Status
  - Material & process controls
  - Structural substantiation
  - Damage tolerance
  - Bonded joints
  - Repair
- Mil-Handbook-17, Revision F
- Summary

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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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Existing State-of-the-Art in Composite Aircraft Structures

Transport Aircraft
- Secondary structure
- Control Surfaces
- Empennage
- Wing & fuselage applications for new aircraft
- Some engine (e.g., fan blades)

Small Airplanes and Rotorcraft
- Most structures
  - Pressurized fuselage
  - Wing
- Dynamic components
  - Propellers & rotor blades
- Extensive bonding

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Technical Thrust Areas

Advancements depend on close integration between areas

Material Control, Standardization and Shared Databases

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

Damage Tolerance and Maintenance Practices
- Critical defects
- Bonded repair issues
- Fatigue & damage considerations
- Quantitative NDE
- Equivalent levels of safety

Bonded Joint Processing Issues

Advanced Material Forms and Processes

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

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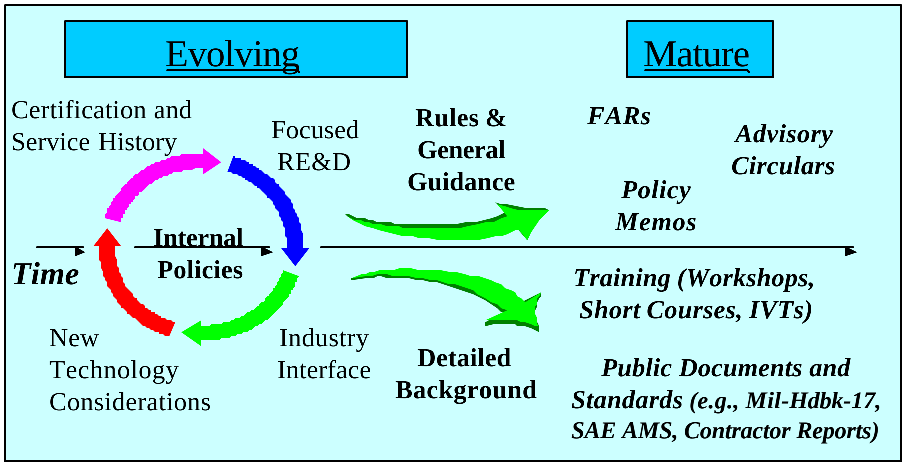
FAA Approach to Composite Safety and Certification Initiatives



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FAA Composite Team Members

Represented Group	Team Member Name	FAA Organization Number & Routing
FAA Tech. Center	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	Randy Blosser	ANM-100D (Denver ACO)
	Roger Caldwell	ANM-100D (Denver 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)
	David Swartz	ACE-115N (Anchorage ACO)
CSTA	Larry Ilcewicz	ANM-115N (CSTA, Composites)

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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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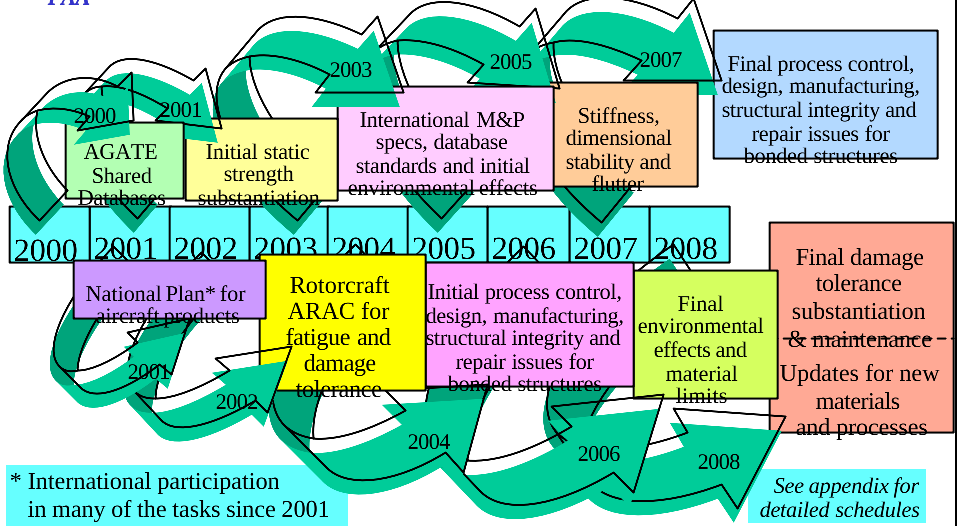
Milestones for Composite Safety and Certification Policy, Guidance and Training



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Background in Composite Material Control, Standardization and Shared Databases

- Mil-Handbook-17 has pursued standardization and shared databases for some time - first PMC data set approved in 1990
- NASA/FAA/Industry AGATE efforts accelerated the need for FAA policy on shared material qualification databases*
  1. Multi-batch material qualification to generate the database & set specs.
  2. Equivalency ("mini-qualification") sampling to show new users process the material to fall within the database population (also covers changes)
  3. Apply database to your product and continuously control the material

  * Updated and officially released by Small Airplane Directorate this year (contact Lester Cheng: 316-946-4111, lester.cheng@faa.gov)
- Mil-Handbook-17 DU WG initiatives and AGATE experiences led to a need for FAA guidance on M&P specs – AC in 2003
  – Linked with material control and shared databases

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Purpose of the Advisory Circular

To provide acceptance guidance on what should be included in material procurement and process specifications, or other documents, to ensure sufficient control of composite prepreg materials

- It helps *control and stabilize raw material,* which is needed for continued safe & reliable use of composites in aircraft products
  – Expanding applications, including the use of composites in other industries, is driving material supplier developments
- It promotes *consistent engineering practices,* which support requirements essential for base material control
- It prepares the FAA for *composite databases and specs shared throughout industry,* with the end result being the improved efficiency of suppliers, users and regulators

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FAA Advisory Circular 20-23

"Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems"

Engineering criteria & guidelines needed for:
a) control of stable composite materials and
b) reliable databases (company-specific or shared by industry)

- Qualification data should be used to set material requirements
- Documentation & databases should exist for <u>each</u> unique material
- Property drift (including upward shifts) should be minimized

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AC 23-20 Development Timeline

- Draft policy (Sep 2002)
- FAA internal process (Oct 2002)
- FAA meeting on desired conversion to AC (Jan 2003)
- Mil-17 Forum and Review (Feb/Mar 2003)
- Convert to AC (Mar/Apr 2003)
- Federal Registrar process and resolve comments (Apr-July 2003)
- Finalize AC for printing by FAA Headquarters (Sep 2003)

US Department of Transportation
Federal Aviation Administration

Advisory Circular

AC NO: 23-20
DATE:

ACCEPTANCE GUIDANCE ON MATERIAL PROCUREMENT AND PROCESS SPECIFICATIONS FOR POLYMER MATRIX COMPOSITE SYSTEMS

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Regulatory Guidance for the Material Procurement Specification

- Documentation and databases for material characteristics of each unique material
- Material supplier establishes a process control document (PCD) or equivalent to ensure repeatable raw material production
  - PCD lists all critical raw material ingredients and the associated suppliers
  - PCD defines "key characteristics (KC)" and "key process parameters (KPP)"
  - Property drift (including upward shifts) in KC & KPP, minimized by Statistical Process Control (SPC)
  - Reduced test sampling rates may be adopted if KC and KPP data indicate necessary levels of process control

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Regulatory Guidance for the Material Procurement Specification

- Material spec includes requirements that define specific raw constituents (resin and fiber)
  - One resin formulation
  - Single fiber class (i.e., specific fiber type, manufacturer)
- Requirements for uncured prepreg and cured prepreg are defined and identified in the material specification
- Qualification procedures and methods to initially characterize the material are documented in the material specification

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Regulatory Guidance for the Material Procurement Specification

- Use qualification data as a statistical basis for both equivalency (to evaluate new users or changes in material) and acceptance requirements (quality assurance)
- Outline methods to evaluate different levels of change in material and processes
- Document material packaging and shipping procedures needed to maintain material control through delivery
- Distributors in supply chain follow requirements of the material spec (and applicable portions of process spec)

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Regulatory Guidance for Process Info Needed for Material Control & Procurement

- Procedures to fabricate quality laminates are detailed in the process specification* to ensure consistent & stable processes
  - i.e., details for tool preparation, material handling, laminate layup, panel bagging, cure cycle, panel identification, inspection and machining
  - Qualified technicians for each major fabrication process step
- Document process parameters, material records, and tooling used to fabricate each specific panel

* The terminology "process specification" is used throughout the AC for instructions and controls used in test panel fabrication (as applied for material requirements).

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Regulatory Guidance for Process Info Needed for Material Control & Procurement

- Materials, equipment, facilities and tooling required for fabrication are specified and controlled
- Quality assurance procedures are needed to monitor fabrication processes, equipment, materials, facilities and tooling
- Recommendations are given to investigate corners of the process window and demonstrate scaled manufacturing trials at the time of M&P spec development to help define related material controls

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Data and Process Requirements for Each Unique Stable Composite Material

- Process control document, PCD, used for raw material production (usually proprietary to the supplier)
  - Specify ingredients, quality controls and change policies
- Process specification applicable to the material
  - Portions of a process specification crucial to material control
- Test reports for properties measured in qualification
- Quality control acceptance criteria
  - Benchmark key characteristics based on a representative population (i.e., multi-batch, qualification databases)
  - Incorporated into the material specification
- Storage and shipping limitations
- Material specification used for procurement

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Continuing FAA Efforts in Composite Material Control, Standardization and Shared Databases

- Three technical center reports to be released in 2003
  - Guidelines for material procurement specs (prepreg tape)
  - Guidelines for prepreg process specs as related to material control
  - Updated guidelines for material qualification and equivalency
- 2003 focused research efforts for other composite forms
  - M&P spec guidelines for prepreg fabric, dry fiber forms and liquid molding processes

    Chicago Workshop conducted on September 16-18 to review draft reports of recommended guidelines with the industry

    Draft reports and presentations at http://www.niar.twsu.edu/faa/
- FAA explored the feasibility of a composite TSO
  - SAE P-17 & Mil-17 efforts may supersede the need for a TSO

    FAA supports standardization in the industry at "building block" levels that are not product design & manufacturing specific

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Important Standards Organizations*

- Mil-Handbook-17 to define/approve database standards and provide overall coordination
  - http://www.mil17.org/
  - Data Utilization Working Group

Stephen Ward	Curtis R. Davies
505-758-4489	609-485-8758
shward@taosnet.com	curtis.davies@faa.gov

- SAE Committee P-17 to establish/approve material and process specifications
- ASTM D30 to establish/approve standard test methods

** Must continue to interface internationally to achieve optimum efficiency*

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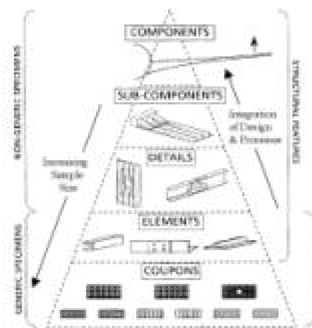
Structural Substantiation
Critical Issues for Composite Designs

- *Integration of structural design detail with repeatable manufacturing processes*
  - Material and process control
  - Traditional building block test & analysis approach is difficult for some new processes
- Design details, manufacturing flaws and service damage, which cause local stress concentration, drive static strength MS
  - Dependency on tests
  - Scaling issues (ongoing FAA research)
- Environmental effects
  - Temperature and moisture content
- Repeated load and damage tolerance considerations
- Maintenance inspection and repair



Building Block Tests & Analysis

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Initial Policy on Composite Static Strength Substantiation for Small Airplane Structure*

Purpose and Contents

- General guidance on the need for large-scale tests
- Reviews critical factors affecting composite strength
- Describes commonly accepted engineering practices, including the rationale for various means of compliance

Scope

- Developed for composite structures critical to safety of flight for small aircraft (Part 23)
  Some relevance to rotorcraft and transport aircraft
- Expands on guidance in AC 20-107A (1984)
- Based on composite experiences to date
- *Future plans to update policy with more certification experiences, service data, bonded joints research and new composite technology*

* Small Airplane Directorate #PS-ACE100-2001-006, December 2001
Contact Lester Cheng: 316-946-4111, lester.cheng@faa.gov

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Effects of Industry Trends on Structural Substantiation

- Industry is pursuing *"advanced analyses"* to reduce development and certification costs, i.e., less tests
  - FAA conducted a Composite Structural Development Workshop in Nov. 2000
    - *There is reason to be cautiously, optimistic in this area*
    - *However, there is also concern that advances are less than advertised (composite strength and fatigue analyses are generally bounded by limits of interpolation within a test database)*
- Industry pursuit of potential cost savings is expected to yield *new composite material forms and manufacturing processes*
  - More responsibility for manufacturing the material by the OEM
  - More difficult scaling efforts (i.e., processes applied for smaller test samples may not be representative of the real structure)

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Composite Damage Threats

- Non-detectable damage (e.g., barely visible impact damage) applied with the Ultimate load requirement
- Accidental service & environmental damage detected with selected maintenance inspection procedures
  - Ranging from detectable to clearly visible to obvious
  - Repeated loads (inspection intervals & Limit load requirement)
- Anomalous service incidents (e.g., severe overloads and service vehicle collisions) that should be reported
- Manufacturing flaws (e.g., weak bonds) that are not initially detected but become detectable in service
- Discrete source damage scenarios

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Key Composite Behavior for Fatigue and Damage Tolerance Assessment

- Relatively flat SN curves & large scatter leading to “no growth” fatigue demonstrations
  - Load enhancement factors needed to show reliability
  - Growth options have been applied conservatively
    - *To show high loads needed for growth*
    - *Past structure evaluated with a growth approach typically don’t have a residual strength issue*
- Sensitivity to impact and significant manufacturing defects drive damage tolerance assessments and maintenance inspection
  - Compression and shear are affected by damage
    - *Critical for many structures*
  - Similar tensile residual strength behavior to metals
    - *Sharp cracks and blunt notches yield similar results for composites*

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Composite Rotorcraft Fatigue & Damage Tolerance Rules and Advisory Circulars*

Rotorcraft ARAC efforts (FAR 27.573 and 29.573) ended in 2002

- Based on certification and service experiences for a wide range of composite applications (both dynamic components and airframe)
- Unique team of industry practitioners, regulatory officials and technical specialists, each with different composite experiences
- AC options for an acceptable means of compliance, included flaw tolerance/safe life and damage tolerance (with & without growth)
  - Some similarities with recent advisory circulars for composite propeller fatigue & damage tolerance (also based on past experiences)
- Working group believe that substantiation methods & maintenance practices will continue to evolve with service experiences
  - Re-consider the AC within 5 years

* Contact: Richard Monschke (817-222-5116, richard.monschke@faa.gov)

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Key Additions to Rotorcraft AC on Composite Fatigue & Damage Tolerance

- ***Threat assessments*** (based on service experiences and knowledge of critical damage events and anomalous manufacturing flaws for a particular structure) ***focus efforts to satisfy safety requirements and ensure maintenance relevance***

- Safe use of generally, quasi-brittle materials in rotorcraft structure is provided by ***static ultimate load capability and life for "likely, undetected damage types"*** *balanced with* ***repeated load tolerance and sufficient limit load capability for "rare damage types", managed by replacement times*** *and* ***inspection intervals***

- ***Damage tolerance options*** for "no-growth", arrested growth and slow growth

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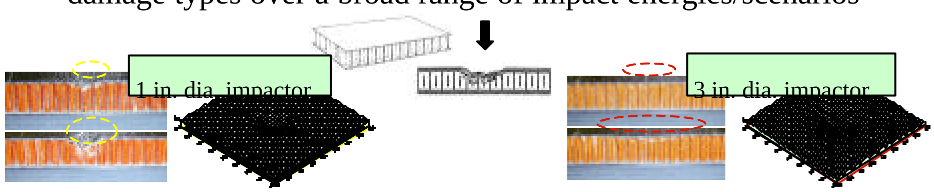
Key Additions to Rotorcraft AC on Composite Fatigue & Damage Tolerance

- ***Process quality control as a primary focus to ensure the long-term performance of bonded joints*** combined with added considerations for fail-safety and good service history

- ***Flaw tolerance/safe-life option*** for structure with damage threats and design details that allow fatigue tolerance without inspection until replacement time - ***ultimate load demonstration after fatigue***

- Use of an ***impact survey and service data*** to identify critical damage types over a broad range of impact energies/scenarios



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Composite Perspectives for Proposed Changes to FAR 25.571

- Structural damage capability (SDC)
  - Desirable for composites
  - Needed for anomalous accidental damage & mfg. mistakes
  - Large damage is needed in most composite structures before repeated loads can degrade strength to critical levels
  - "No growth" for a defined damage size or benign growth may be the only viable options for single load path structure
- Limit of validity (LOV)
  - No known WFD equivalent for typical composite structure strain levels taken beyond current design service goals
  - Relations with limits of the fatigue demonstration applied for certification *(some major issues related to the LEF applied to demonstrate composite life in practical test times)*

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Other Thoughts on Composite Fatigue and Damage Tolerance

- Safety by retirement (SBR) & safety by inspection (SBI)
  - Composite designs have used both (i.e., flaw tolerance/safe life combined with damage tolerance)
  - SBR & SBI can both be derived from data typically collected for composites (primary drivers become damage assumptions, i.e., not "normal or anomalous fatigue phenomena")
- Maintenance and operations groups should be aware of what has been done for fatigue and damage tolerance
  - Damage assumptions should be understood *(for metals also)*
  - Anomalous events must not go unreported - potential for most critical, least detectable damage *(e.g., high energy, blunt impact)*
  - Use of operations manuals/continued airworthiness instructions

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Recommendations on Future Composite Fatigue and Damage Tolerance Needs

- Study critical damage scenarios for control surfaces
  - Stiffness, aeroelastic stability and flutter
- Continue to collect service damage data with industry
  - Define design and maintenance criteria for structural details
- Validate analysis methods
- Develop test & analysis guidelines for impact damage
- NDE advances
  - Help define damage metrics
  - Methods to detect weak bonds & early stages of debonding
- Study fatigue and damage tolerance of new material forms and processes pursued by industry

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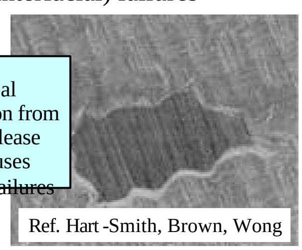
FAA Research at UCSB*: Bonding Surfaces Previously Subjected to Removable Layers

- Improper use of removable layers has led to AD
- Removable plies or layers that leave chemical contamination on bonding surfaces include release fabrics and release films
  - Surface abrasion (grit blasting) will not guarantee the elimination of contaminates and potential, undesirable adhesive (interfacial) failures
  - Ongoing efforts to establish standard terminology for removable plies and update product labels & technical literature to warn of potential bonding problems
- The term “peel ply” will be used only for those removable plies that contain no chemical treatment to aid release
  - More research is needed to establish guidance for peel ply use in bonding

Chemical contamination from a nylon release fabric causes interfacial failures


Ref. Hart -Smith, Brown, Wong

* University of California at Santa Barbara (Bardis and Kedward)

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Terminology for Removable Plies

- Peel Ply: a cloth cured against a laminate. It has no chemical release agent treatment. It is intended to attach to the part during cure and be difficult to peel off, fracturing the part's surface matrix and leaving an impression in it. May undergo treatment (e.g., mechanical calendering), but not with release chemicals. Examples: NAT & VLP
- Release Fabric: a cloth cured against a laminate. It has been treated with chemical release agents. It is intended to peel easily from a part, leaving an unfractured surface impression that has chemical residue. Example: SRB
- Release Film: a sheet of film cured against a laminate. It is generally a derivative of Teflon. It is intended to be easily removed from a part and leave a smooth surface finish, though it transfers chemicals to the part in the process. Example: FEP

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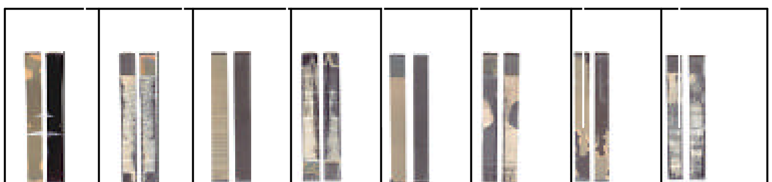
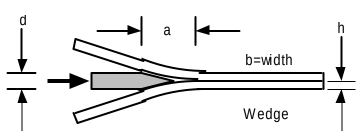
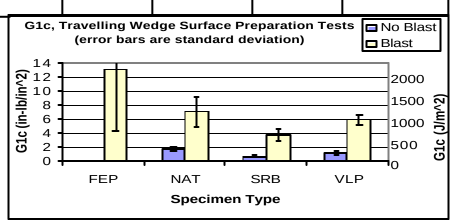
UCSB Traveling Wedge Test Results

crack travel ??



Bond	FEP, no blast	FEP, blast	NAT, no blast	NAT, blast	SRB, no blast	SRB, blast	VLP, no blast	VLP, blast
Failure	interfacial	cohesive/ interlaminar	interfacial/ interlaminar	cohesive/ interlaminar	interfacial	interfacial/ interlaminar	interfacial	cohesive/ interlaminar





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Preliminary Recommendations to Industry

- Results show that peel plies and release fabrics are entirely different materials that are not interchangeable
- Any surface to be secondarily bonded should not be exposed to a release fabric
- Pre-bond abrasion of adherends is recommended but may be omitted for bonding materials & processes with adequate qualification testing and controls
  - Dependent on specific combinations of materials (adhesive, composite substrate and peel ply) and process steps
  - Sufficient qualification of a bonding process should always include considerations of long-term environmental durability
  - Process and material control must be strict
  - Shear tests are not reliable indications of bond problems
  - Peel testing & surface checks for interfacial failure modes are best

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Objectives of FAA Research on Bonded Repair of Composite Sandwich Panels

- Investigate bonded repair variables and characterize strength of repairs using different experiments to determine the effectiveness of the repair
- Compare Original Equipment Manufacturer (OEM) repairs against air carrier's repair stations
  - Commercial Aircraft Composite Repair Committee (CACRC) repair procedures will be used by the repair stations as documented in SAE
- Evaluate bonded sandwich repair design and load variables
  - Scarf ratio, core size and 1D versus 2D repairs
  - Tension, compression and shear
  - Scarfed-out damage (with and without bonded repair)
- Use experiments to validate available analytical techniques and make recommendations

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Research Team for Bonded Repair of Composite Sandwich Panels

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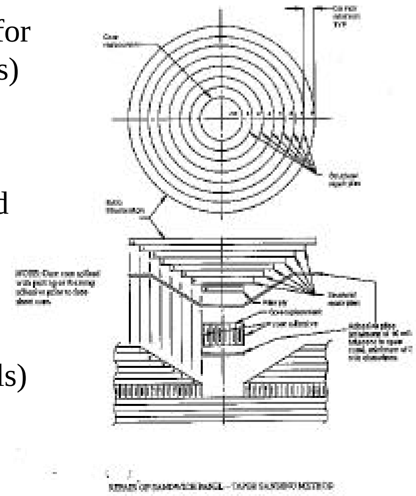
- Boeing – manufactured all coupons for the program (material and man hours)
- Delta Airlines, United Airlines (Indianapolis and San Francisco), US Airways, and Lufthansa provided field repairs of OEM panels using CACRC techniques
- CACRC analytical task group (numerous companies and individuals)
- Wichita State overall management, testing and analysis (John Tomblin)



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Test Results for Bonded Repair of Composite Sandwich Panels

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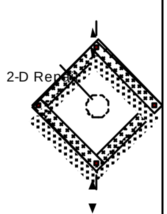
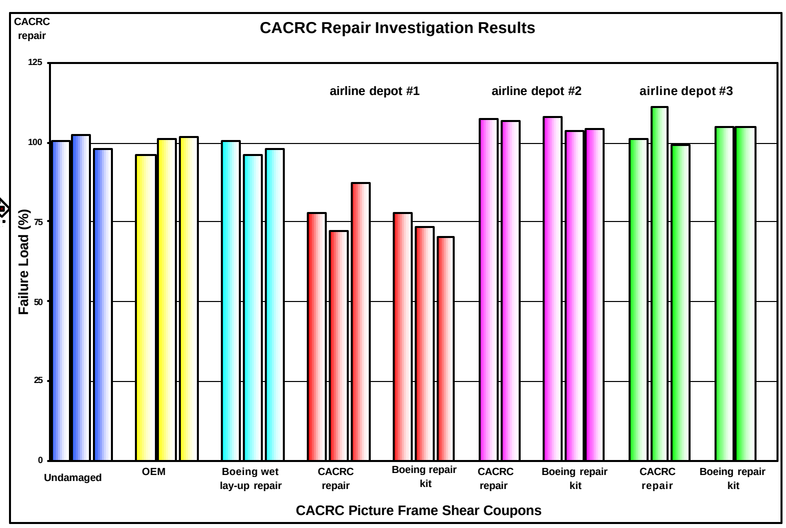


Shear



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Benchmark Bonded Structures
Primary Deliverables

- Development of a FAA Technical Center Report on “best engineering practices” for bonded structure (technical issues to consider)
- Bonded Structure Workshop in 2004 to review the draft FAA Technical Center Document
  - To be coordinated with joint meetings of Mil-17 and CACRC (May or early June)
- FAA policy covering the different engineering aspects of bonded structure

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Benchmark Bonded Structures
Technical Scope

- Commercial general aviation, rotorcraft and transport aircraft (coordinated with military groups)
- Secondary bonding in structural applications
  - 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 (stiffened and sandwich structure)
  - Product development and structural substantiation

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Approach Used to Benchmark Bonded Structures

Timeline

2a) Focussed research to draft "best engineering practices"

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

2b) Workshop & industry review to release detailed documentation on "best engineering practices"

3) Rules, policy and/or guidance as necessary

4) Training for industry and government workforce

» Initial research and industry review *(light yellow boxes)*, used to generalize industry experiences and identify longer-term research needs

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Progress for Bonded Structures *FAA and NASA Research*

- 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)

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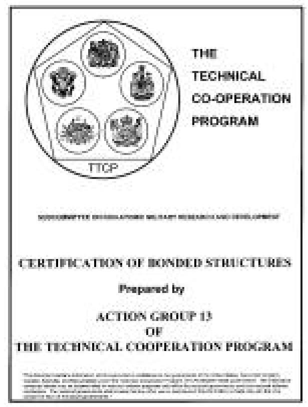
Progress for Bonded Structures

Action Groups for Detailed Documentation

- Some guidance for bonded structures, which comes from military and commercial aircraft experiences, are documented in a TTCP report
  - 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

CERTIFICATION OF BONDED STRUCTURES

Prepared by

ACTION GROUP 13
OF
THE TECHNICAL COOPERATION PROGRAM

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Mil-Handbook-17 History

http://www.mil17.org/

2002 MIL-HDBK-17B Vol. 1F, 2F, 3F, 4A, 5

1999 MIL-HDBK-17B Vol. 2E,Vol 4

1997 MIL-HDBK-17B Vol. 1E,3E

1996 First CMC Coordination Meeting

1993 First MMC Coordination Meeting

1990 First PMC Data Set Approved

1988 MIL-HDBK-17B Vol. 1

1986 Secretariat Added

1978 Coordination Group Formed

1971 MIL-HDBK-17A Plastics for Aerospace Vehicles

1959 MIL-HDBK-17 Plastics for Air Vehicles

1943 ANC Bulletin 17 Plastics for Aircraft

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Structure of the Mil-Handbook-17

- **Vol. 1** Polymer Matrix Composites: *Guidelines for Characterization of Structural Materials*
- **Vol. 2** Polymer Matrix Composites: *Material Properties*
- **Vol. 3** Polymer Matrix Composites: *Materials Usage, Design and Analysis*
- **Vol. 4** Metal Matrix Composites, MMC
- **Vol. 5** Ceramic Matrix Composites, CMC (New with 2002 Release)
- **Vol. 6** Structural Sandwich Composites (Planned)

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Overview of Long-Term Plan to Develop Composite Engineering Handbooks

Synopsis

- 3 major revisions (**2002**, 2006, 2010) of the official "released document"
- Regular electronic updates to current draft versions available to *members**
- Pursue commercial ventures to offset costs of the Mil-17 Organization
- User review input will be used to guide handbook developments
- Ongoing thrusts: increase data utilization, release sandwich volume, update Volume 3 and incorporate results from safety and certification initiatives

Major milestones for the 2002 release (Rev. F) include:

- New guidelines sections for building block and damage tolerance
- Many additions to supportability, test methods, statistics and M&P sections
- Road maps to enhance handbook utilization
- New sections for "spacecraft applications"
- Initial release of CMC volume

* Contact the Secretariat at http://www.mil17.org/

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Long-term Plans for Composite Safety and Certification Initiatives

A multi-year plan has been developed and implemented

- Initially based on recent general aviation applications
- Input for rotorcraft and transport aircraft over last 3 years
- Will be continuously reviewed and updated in public forum (e.g., Mil-Handbook-17, national conferences, “town meetings” and FAA seminars & workshops – ***your input is requested***)
- Continuously integrated with FAA strategic & business plans
- Continued support by NASA, other government agencies, and industry are critical to future efforts
- Focus for 2004 on bonded structure

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Progress in Composite Safety and Certification Initiatives

Milestones achieved to date

- FAA policy/training for base material qualification and equivalency testing for shared databases (initial 2000, update 2003)*
- Policy/training for static strength substantiation based on small airplane certification experiences (2001)
- New rule and AC for damage tolerance and fatigue evaluation of composite rotorcraft structure have been drafted (2002)
- New AC on acceptance guidance for material procurement & process specifications (2003)*
- Revision F to Mil-Handbook-17 was released (2002)
- Research in structural substantiation, bonded joints, damage tolerance and repair support future policy, guidance & training*

* FAA Technical Center reports exist for detailed background on engineering practices

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Appendix

The remaining charts contain additional details:

a) Schedules for the composite safety & certification initiatives

b) References for supporting FAA Technical Center Reports

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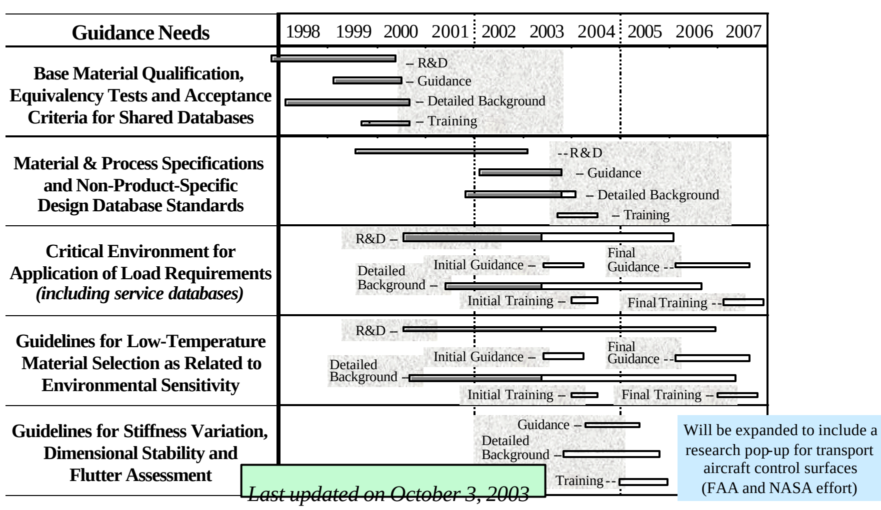
Plan for Composite Safety & Certification Initiatives: Databases, M&P Specs, Environmental Effects & Stiffness Assessment



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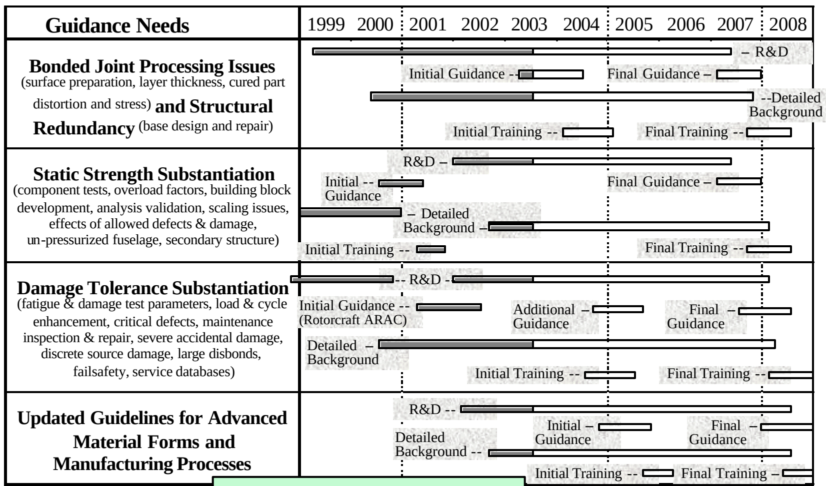
Plan for Composite Safety & Certification Initiatives: Static Strength, Damage Tolerance, Bonded Joints and Advanced Material Forms & Manufacturing Processes



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Detailed Background: FAA Technical Center Reports

Material Standardization and Shared Databases

- "Material Qualification and Equivalency for Polymer Matrix Composite Material Systems," DOT/FAA/AR-00/47, April 2001, "Update Procedure," DOT/FAA/AR-03/19, September 2003.
- "Verification of the Wyoming Combined Load Compression (CLC) Test," DOT/FAA/AR-00/26, August 2000
- "Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Unidirectional Prepregs," DOT/FAA/AR-02/109, March 2002.
- "Guidelines for the Development of Process Specifications, Instructions and Controls for the Fabrication of Fiber Reinforced Polymer Composites, DOT/FAA/AR-02/110, March 2002.
- "Tabbing Guide for Composite Test Specimens," DOT/FAA/AR-02/106, October 2002.

Structural Substantiation

- "Stress Analysis of In-Plane Shear Loaded Adhesively bonded Composite Joints and Assemb lies," DOT/FAA/AR-01/7, April 2001.
- "Investigation of Thick Bondline Adhesive Joints," DOT/FAA/AR-01/33, June 2001.
- "Investigation of Adhesive Behavior in Aircraft Applications," DOT/FAA/AR-01/57, September 2001.
- "Determination of Temperature /Moisture Sensitive Composite Properties", DOT/FAA/AR-01/40, September 2001.
- "Shear Stress-Strain Data for Structural Adhesives," DOT/FAA/AR-02/97, October, 2002.
- "Analytical Modeling of ASTM Lap Shear Adhesive Specimens," DOT/FAA/AR-02/130, February 2003.

Bonded Joint Processing Issues

- "Effects of Surface Preparation on Long –Term Durability of Bonded Composite Joints," DOT/FAA/AR-01/8, April 2001 and DOT/FAA/AR-03/53, July 2003.

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Detailed Background: FAA Technical Center Reports, *cont.*

Damage Tolerance and Maintenance Practices (Sandwich)

- "Review of Damage Tolerance for Composite Sandwich Airframe Structures," DOT/FAA/AR-99/49, August 1999.
- "Imaging Flaws in Composite Honeycomb Aircraft Structures Using Instrumented Tap Test," SPIE Proceedings on Nondestructive Evaluation of Aging Materials and Composites, Vol. 3585, 1999. pp. 236-245.
- "Damage Tolerance of Composite Sandwich Structures," DOT/FAA/AR-99/91, January 2000.
- "Impact Damage Characterization and Damage Tolerance of Composite Sandwich Airframe Structures," DOT/FAA/AR-00/44, January 2001.
- "Damage Resistance Characterization of Sandwich Composites Using Response Surfaces", DOT/FAA/AR-01/71, March 2002.
- "Impact Damage Characterization and Damage Tolerance of Composite Sandwich Airframe Structures – Phase II," Final Report, DOT/FAA/AR-02/80, September 2002.
- "Damage Tolerance Characterization of Sandwich Composites Using Response Surfaces", DOT/FAA/AR-02/101, October 2002.
- "Damage Tolerance Characterization of Sandwich Composites Using Response Surfaces", DOT/FAA/AR-02/101, October 2002.
- "Guidelines for Analysis, Testing, and Nondestructive Inspection of Impact Damaged Composite Sandwich Structures," DOT/FAA/AR-02/121, March 2003.

Advanced Material Forms and Processes

- "Design, Manufacturing, and Performance of Stitched and Unstitched Panels with and without Impact Damage," DOT/FAA/AR-02/111, Oct. 2002.