Key Characteristics for Composite Material Control
Presented at 8/6/02 FAA/NASA Workshop (Chicago, IL)

• Introduction
  – Importance of stabilizing composite materials
  – Events leading to current efforts & future plans

• Composite safety & certification initiatives
  – Expanding applications
  – Background, approach and status
  – Shared databases and M&P controls

• Material data and process requirements
  – Material procurement specification
  – Process specification
  – Important standards organizations
    (SAE, Mil-Handbook-17, CACRC, ASTM)

• Summary
Importance of Stabilizing Composite Materials for Safety and Efficiency

• Stable source of raw material is needed for continued safe and reliable use of composites in aircraft products

• Consistent engineering practices are needed to support requirements essential for base material control
  – Qualification database should be the statistical basis for equivalency (for new users and changes) and QC acceptance requirements
  – Documentation and databases should exist for each unique material
  – Property drift (including upward shifts) should be minimized

• Composite databases and specs shared throughout industry will improve the efficiency of suppliers, users and regulators
Who Pays the Cost for a Lack of Standardization and Shared Databases?

“Company Specifications: One of the major problems of aircraft repair today is that most airframe and engine manufacturers tend to write their own specifications, especially for adhesives, pre-pregs, potting compounds, and sealants. These are found in the various manuals as …, and others -- almost infinitum. This leads to a vast amount of duplicated testing by suppliers, who may have to test the same batch of material to three or more slightly different requirements and using slightly different test methods.” Page 257 of Care and Repair of Advanced Composite Materials, by Keith B. Armstrong and Richard T. Barrett, SAE International, 1998.
What Should/Can Be Shared Within the Composite Industry?

Databases and specifications for material control

Databases and specifications for maintenance (repair)

Non-product-specific design databases

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Events Leading to Current Efforts

- **2002** Industry review (August 6-8, Chicago, IL)
- **2002** McCarvill, Bogucki and Ward draft M&P spec recommendations
- **2002** Bogucki and Fields selected to co-chair SAE M&P spec efforts
- **2002** WSU (Tomblin) research with industry experts
- **2002** MIL-HDBK-17B Vol. 1F, 2F, 3F, 4A, 5
- **2001** Davies joins the FAA // SAE agrees to co-develop specs with Mil-17
- **2001** NASA feasibility study (Davies, Raine and Ward)
- **2000** Mil-17 coordination meetings with CACRC & SAMPE
- **2000** Swartz/Ilcewicz (FAA) meet with Boeing & maintenance groups
- **2000** Davies/Ward/Ilcewicz planning (teleconferences)
- **2000** WSU Report (Tomblin & Ng), FAA policy & training for shared databases
- **1999** Acceptance criteria for material equivalency (Vangel)
- **1999** Data pooling to stabilize AGATE method (Shyrykevich)
- **1998** Chartered Mil-Handbook-17 Data Utilization WG
- **1997** AGATE material initiative (Tomblin)
- **1993** General Aviation Task Force Report to NASA
- **1990** First Mil-Handbook-17 PMC Data Set Approved
- **1971** MIL-HDBK-17A Plastics for Aerospace Vehicles
- **1943** ANC Bulletin 17 Plastics for Aircraft

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Near Term Plans for Detailed Background
Recommending Engineering Practice

Industry review of *detailed background* documented in two FAA Technical Center Documents (8/02 workshop + those unable to attend)

1. Recommendations and guidelines for the development of pre-impregnated composite material specifications
2. Recommendations and guidelines for the development of an associated process specification

- Update the documents per industry review
- Release the documents as "recommendations" to industry
  - Each program will have freedom to pursue:
    i) release of databases and specs shared by industry *or*
    ii) traditional proprietary databases and specs *or*
    iii) some combination (e.g., business arrangement between funding partners)
  - Scope of associated database will self-limit the benefit to applications
- Consider the contents of documents for updates to Mil-Hdbk-17
Future Plans

- Draft FAA policy for composite M&P specs
  - Higher level document, which contains a synopsis of essential needs
  - Consider any criteria needed for material control as a basis for policy and guidance (info from 2 FAA Tech. Center Reports and workshop discussions)
  - To be initially released through Small Airplane Directorate in Fall, 2002

- The FAA policy will be released after a public review process, which includes posting in the Federal Registrar for final updates
  - To be considered in updating AC 21.26 Quality Control for the Manufacture of Composite Structures (6/26/89, AIR 200)

- Work with SAE and Mil-Handbook-17 to develop approval processes for shared composite data and associated M&P specs

- Determine whether a TSO is needed to acknowledge FAA involvement in approving the control of composite raw materials
Existing State-of-the-Art in Composite Aircraft Structures

Transport Aircraft
- Secondary structure
- Control Surfaces
- Empennage
- Some new wing & fuselage (Europe is leading)
- Some new 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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Future Trends and Barriers to Expanded Application

Transport Aircraft

- Manufacturing cost
- Non-recurring development costs
- Maintenance technology
- Limited resources with sufficient training (engineers & technicians)
- Lack of standardization

Small Airplanes and Rotorcraft

- Manufacturing cost
- Need to reach high production rates
- Maintenance technology
- Limited resources with sufficient training (engineers & technicians)
- Lack of stable material supplier base
- Lack of standardization

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List of Recent Certification Programs with Significant Composite Structure

- Cirrus Design Corp., SR20 and SR22 (Part 23, Chicago, IL ACO)
- Pacific Aviation, Lancair LC40-550FG (Part 23, Seattle, WA ACO)
- Euro-ENAER, Eaglet (Part 23, Dutch/Chile aircraft, KC Small Airplane Directorate)
- Flight Dynamics, Seawind (Part 23, New York, NY ACO/Transport Canada)
- Morrow, Boomerang (Part 23, Seattle, WA ACO)
- Diamond, DA-40 (Part 23, Austrian aircraft, KC Small Airplane Directorate)
- CAP Aviation, 222 (Part 23, French aircraft, KC Small Airplane Directorate)
- Robin Aviation, DR400/500 (Part 23, French aircraft, KC Small Airplane Directorate)
- STW Composites, Liberty XL-2 (Part 23, Denver, CO ACO)
- Adam Aircraft, A500 (Part 23, Denver, CO ACO)
- Raytheon, Premier I, Model 390 (Part 23, Wichita, KS ACO)
- AASI, Jetcruzer 500 (Part 23, Los Angeles, CA ACO)

Initial development of a national plan for composites (per Bobby Sexton’s vision) was dominated by input from small airplane programs.

List updated on 7/16/02
List of Recent Certification Programs with Significant Composite Structure

- Raytheon, Horizon (Part 25, Wichita, KS  ACO)
- Bell, BA609 Tilt Rotorcraft (Part 29, Fort Worth RCO)
- Sikorsky, S92 Rotorcraft (Part 29, Boston ACO)
- Carson Services Inc., Main Rotor Blades (Part 29, NY ACO)
- 737 Business Jet and 747, Winglets (Part 25 STC, Seattle, WA  ACO)
- Airbus, A340 -500/-600 (Part 25, Seattle Transport Airplane Directorate)
- Airbus, A380 (Part 25, Seattle Transport Airplane Directorate)
- General Electric, GE90-115B fan blades (Part 33, Boston, MA ACO)

Additional input for the national plan for composites was collected from industry in workshops, DER seminars and Mil-Handbook-17 Forum.
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

* Formal planning efforts started in 1999 to address issues associated with increasing composite applications
# FAA Composite Team Members

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<tr>
<th>Represented Group</th>
<th>Team Member Name</th>
<th>FAA Organization Number &amp; Routing</th>
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<tr>
<td><strong>FAA</strong></td>
<td><strong>Curtis Davies</strong></td>
<td>AAR-450 (FAA Tech. Center)</td>
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<td>Tech. Center</td>
<td><strong>Peter Shyprykevich</strong></td>
<td>AAR-450 (FAA Tech. Center)</td>
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<tr>
<td>Headquarters</td>
<td>John Masters</td>
<td>AIR-110 (Cert. Procedures Branch)</td>
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<td>Directorates</td>
<td><strong>Lester Cheng</strong></td>
<td>ACE-111 (Small Airplane Dir.)</td>
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<td><strong>Richard Monschke</strong></td>
<td>ASW-111 (Rotorcraft Dir.)</td>
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<td>Richard Yarges</td>
<td>ANM-115 (Transport Airplane Dir.)</td>
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<td>Hank Offermann</td>
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<td>Jay Turnberg</td>
<td>ANE-110 (Engine &amp; Propeller Dir.)</td>
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<tr>
<td>Flight Standards</td>
<td>William Henry</td>
<td>AFS 350 (Aircraft Maintenance Div.)</td>
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<td>ACOs &amp; MIDOs</td>
<td>Roger Caldwell</td>
<td>ANM-100D (Denver ACO)</td>
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<td><strong>Angie Kostopoulou</strong></td>
<td>ACE-116C (Chicago ACO)</td>
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<td><strong>David Ostrodka</strong></td>
<td>ACE-118W (Wichita ACO)</td>
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<td>Richard Noll</td>
<td>ANE-150 (Boston ACO)</td>
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<td><strong>David Swartz</strong></td>
<td>ANM-108S (Seattle MIDO)</td>
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<tr>
<td>NRS</td>
<td><strong>Larry Ilcewicz</strong></td>
<td>ANM-115N (NRS, Composites)</td>
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*Names in italics are present at the 8/6 to 8/8/02 FAA/NASA, Chicago Workshop*
FAA Approach to Composite Safety and Certification Initiatives

Evolving
- Certification Projects
- Focused RE&D
- New Technology Considerations

Internal Policies
- Industry Interface

Rules & General Guidance
- Detailed Background

Mature
- FARs
- Advisory Circulars
- Policy Memos
- Training (Short Courses, IVTs)
- Public Documents (e.g., Mil-Hdbk-17, Contractor Reports)

Time

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Technical Thrust Areas

Advancements depend on close integration between areas

Material 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

Advanced Material Forms and Processes

Bonded Joint Processing Issues

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

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Milestones for Composite Safety and Certification Policy, Guidance and Training

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<tr>
<td>AGATE</td>
<td>Initial static strength substantiation</td>
<td>National M&amp;P specs, database standards and initial effects of environment</td>
<td>Stiffness, dimensional stability and flutter</td>
<td>Final static strength and bonded structural substantiation</td>
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- **Initial damage tolerance, process control and repair issues for bonded composite structures**
- **Final environmental effects and material limits**
- **Final damage tolerance substantiation & maintenance**
- **Updates for new material forms & processes**

* International participation in many of the tasks

*Presented by L. Ilcewicz at 8/6/02 FAA/NASA Workshop for Composite Material Control*
Progress to Date in Composite Safety and Certification Initiatives

An 8-year plan has been developed and implemented
  – Initially based on recent general aviation applications
  – Input for rotorcraft and transport aircraft applications over the last 2 years
  – Will be continuously reviewed and updated in public forum
    (e.g., Mil-17, national conferences, “town meetings”, and FAA seminars and workshops - input requested)
  – Continued support by NASA, other government agencies, and industry is critical to future efforts

Milestones achieved to date
  – Base material standardization and FAA policy/training for shared databases
  – Policy/training for static strength substantiation based on GA experiences
  – New rule and AC for rotorcraft fatigue and damage tolerance evaluation
  – Guidelines for material & process specs are nearly complete
  – Research in bonded joints & sandwich panel damage tolerance
Composite Material Qualification, Equivalency Testing, and Shared Databases

• The AGATE Program led to a need for FAA policy on those composite databases that can be shared by OEM & product users
  – Initial step towards standardized material control, with the associated base material properties and M&P specifications
  – Levels of “building block” testing that are not product design and manufacturing specific

• Three-step approach
  1 Multi-batch material qualification to generate the database & set specs.
  2 Equivalency (“mini-qualification”) to sample and show you process the material to fall within the database population and, if desired, update specs. per your specific use of material as allowed within guidelines
  3 Apply database to your product and continuously control the material
FAA Policy and Detailed Background

Shared Base Material Databases

Detailed Documentation
Updated for FAA Release in 2001

- Industry, NASA, FAA and NIST worked together to establish engineering protocol in qualification, equivalency testing, and acceptance criteria for shared databases of polymer matrix composite systems
- Detailed description of engineering procedures
- Available in PDF format at: http://AAR400.TC.FAA.GOV/AAR-430/reports/AAR.HTM (or contact Peter Shyprykevich, 609-485-4967)

FAA Draft Policy & Training in 2000

- Process for multiple users to share a multi-batch, material database
- Small Airplane Directorate (Lester Cheng, 316-946-4111)
- Workshop at WSU (September, 2000)
Static Strength Substantiation

**Critical Issues for Composite Designs**

- Integration of structural design detail with repeatable manufacturing processes
  - *Material & process control are essential prerequisites to current efforts for advanced analyses and more efficient building block testing*

- Design details, manufacturing flaws and service damage, which cause local stress concentration, drive static strength margins
  - Dependency on tests
  - Scaling issues

- Environmental effects
  - Temperature
  - Moisture content

- Maintenance inspection and repair

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This workshop was intended to provide a forum where industry and government can discuss the most efficient ways to achieve composite material control.

We hope to reach general agreement on what is important to safety.

We expect some confusion/disagreement, which relates to specific engineering details and the scope of shared information being sought.

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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
Composite Material Procurement Specification

Guidelines for development of material controls

- Primary goals to help ensure consistent and stable materials
- Specs and associated databases for each unique material
- Allow industry freedom to pursue shared specs & databases for improved engineering efficiency and reduced costs

Material requirements

- Material supplier process control document (PCD)
  - Control of prepreg ingredients & processes for producing the material
  - Defines key material process parameters
  - Statistical process control (SPC)
- Fiber & resin properties to control the quality and ensure a consistent supply of constituents
- Uncured prepreg properties, defects, storage, handling and out-life
- Baseline cure cycle and cured laminate physical & mechanical properties
  - Minimum requirements and options to expand the database for enhanced utility
Composite Material Procurement Specification, cont.

- **Material characterization**
  - Material qualification to collect data representative of the population and set initial requirements in the spec
    
    *Minimum of three batches for fiber and resin dominated properties*
  - Periodic property testing to expand the database and update the spec
    
    *Increased database, which is more representative of the population*

- **Process for dealing with changes to qualified materials**
  - Equivalency sampling for five levels of change ranging from minor to major (highest level requiring a new qualification, database and specs)

- **Quality assurance**
  - Supplier site qualification and SPC implementation
    
    *Demonstrate compliance with PCD and training*
  - QC test panel fabrication per an associated process spec
  - QC test methods and acceptance criteria per material procurement spec

- **Packaging and shipping requirements**
  - Identify materials and maintain control through delivery

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Composite Process Specification

Composite process specification is an important part of material control because properties advance in part fabrication.

• Guidelines for development of process specification
  – Primary goals to: 1) define repeatable composite fabrication processes and 2) support the control of consistent and stable materials
  – Composite process spec for each unique material
  – Allow industry freedom to pursue shared process specs

• Develop stable & consistent processes before material qualification
  – Crucial to repeatable test panel fabrication
  – Manufacturing scaling issues and the effects of design detail for real parts indicate a need to demonstrate producibility as part of process development

- **Process requirements**
  - Personnel training and mentoring programs
  - All materials, equipment, facilities and tooling must be identified and controlled
  - Detailed processing procedures are needed
    
    Tool preparation, material preparation, lay-up procedures, cure cycle, panel identification, inspection and machining
  

- **Quality assurance**
  - Inspection
    
    Monitoring procedures for materials, equipment, facilities & tooling
    Cured part tolerances and NDI
  - Process records of detailed steps, in-process controls and post-fabrication inspection
Update on FAA Consideration of a Technical Standard Order (TSO)

• Updated the working draft TSO for composite prepreg
  – Considerations for minor to major changes
  – Initial shared database efforts following the AGATE protocol have benchmarked possible issues within the industry

• Coordination with FAA AIR-120 suggest a TSO is feasible
  – A TSO for composites would have more controls and requirements, i.e., different than how current TSO are viewed in the industry and FAA
  – Use of SAE, Mil-17 and ASTM as organizations to help define the required specs and database standards were considered essential

    Use of these organizations for pre-requisite approval of the data and associated specs is also under consideration

  – Policy, guidance and training will be needed to implement the TSO

• More discussion within the FAA is needed to gain acceptance
NASA/FAA/Industry Teams for Composite Standardization

Several research programs involving NASA, FAA and industry teams have worked together to accelerate standardization:

- Advanced General Aviation Transport Experiments
  NASA Langley Research Center

- Rotorcraft Industry Technology Association
  National Rotorcraft Technology Center at NASA Ames Research Center

- Standards organizations (Mil-Hdbk-17, SAE Committee P, ASTM D30) should benefit from the advances achieved in above efforts

- Desirable to have the DOD work with the FAA and standards organizations in future efforts
Important U.S. Standards Organizations*

- Mil-Handbook-17 to define/approve database standards and provide overall coordination
  - Data Utilization Working Group
    - Stephen Ward 505-758-4489  shward@taosnet.com
    - Curtis R. Davies 609-485-8758 curtis.davies@tc.faa.gov

- SAE Committee P to establish/approve material and process specifications

- ASTM D30 to establish/approve standard test methods

*Must interface with international standards groups to achieve optimum efficiency*

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Summary

• Consistent and stable materials are crucial to the safe use of composites for expanding applications with aircraft structure
  – Associated databases and M&P specs may be shared within the industry
  – Significant progress to date in related safety and certification initiatives
  – Pre-requisite to industry initiatives for more efficient composite structural development

• Draft recommendations and guidelines have been developed for composite material procurement and process specifications
  – Engineering details will be reviewed and discussed in this workshop
  – Data and process requirements for stable composite materials will be posed as general requirements in FAA policy to be drafted this year

• Future efforts by standards organizations can help facilitate the approval of shared databases and M&P specs