CMH-17 Workshop: FAA Advances, Industry Standards & Integrated Product Development

- Innovation and IPD Repair Principles
- Transport airplane VALUE-101
  - Technology readiness for certification/production
- FAA advances that depend on standards
  - Composite Applications: Technical Standard Order
- Other SoBR Presentations at these meeting
**Innovation**

*FAA is aware of Industry’s desire to jointly pursue innovation early in a project’s life, such that future certification benefits from resulting knowledge transfer*

- FAA Certification Division reorganized directorates and processes to better meet industry needs, while staying close to technology advances (i.e., Policy and Innovation Division)
  - Webster Definition of “Innovation”: …*the introduction of something new*. Also … *the act or process of introducing new ideas, devices, or methods*.

- *Innovation* occurred regularly through the course of composite applications to airframes
  - Past success in *composite innovation* has been directly related to:
    1) use of Integrated Product Development principles,
    2) continuous technology readiness assessments throughout development,
    3) thorough understanding of technology strengths & weaknesses to establish design constraints, manage costs and
    4) related knowledge transfer, not only within a company, but also between suppliers, partners, customers and other technology users
Integrated Product Development

• Modern airplane product development requires integration of functional disciplines, all focusing on achieving product value goals
  – Product value diminishes with increased recurring costs (e.g., product fabrication), non-recurring costs (e.g., facilities, tooling, equipment, development, certification) and delivery delays
  – It is well-recognized that each functional discipline can affect other discipline’s costs and schedules
  – Size & product scaling efforts must advance in parallel to gain value

• Integrated Product Team (IPT) benefits
  – 70% of product cost is determined in the first 5% of design process\(^1\) (notional thought) illustrating the early importance of the IPT process
  – No other process would allow efficient solution to unknown problems
  – Specific goals established by discipline provide focus and successful implementation achieves a better product for all stakeholders

Integration of Composite Maintenance and Damage Tolerance

- Early development of maintenance procedures
- Efficient, low-cost NDI procedures to locate damage (that always find CDT)
- Reliable and simple NDE to quantify effects of damage
- Cost-effective repair with minimal down time when damage is found
- Design for Repair
- Well-defined ADL
- Damage tolerant design, including significant CDT

Some of the Presentation is taken from 2017 Elsevier Book Chapters Entitled
1. Certification & Compliance Considerations for Aircraft Products with Composite Materials, Ashforth & Ilcewicz
2. Scaling Crucial to Integrated Product Development of Composite Airframe Structures, Ilcewicz & Ashforth

- Composite references used for innovation and product value discussions applied throughout this seminar
- These chapters are as much from our industry lives as from work within the FAA
- We have had experiences where innovation has not worked and money was wasted
- We have also been involved in productive innovative work where the outcome was a successful product

Comprehensive Composite Materials II
Top-Level Checklist for Composite Product Value

- Total product costs, including nonrecurring development costs are known, leading to an acquisition cost that is marketable based on product performance metrics (e.g., range, payload, speed, fuel burn)
- Total direct operating costs for the product will help the customer make a profit (i.e., the product has real value)
- Knowledge transfer has been properly established such that all customers accept new technologies and the product will not increase maintenance or other product operational costs
- Product can be delivered on schedule, without acquisition cost increases (note: most new products in the transport airplane world have penalties that will help ensure they don’t absorb costs related to product development)
- Product continues to have a market value after it is released such that non-recurring costs can be quickly recovered, yielding a profit for investors
Composite technology is of interest in new aircraft products of all types because it can help decrease total direct operating costs (DOC) in 3 key areas (see example below from transport aircraft).

**Components of Ownership**
- Airframe: 51%
- Systems: 8%
- Engines: 19%
- Avionics: 11%
- Other: 2%
- Interiors: 9%
- Insurance: 1%
- Engine Maint.: 4%
- Airframe Maint.: 6%

**Typical Components of Total DOC**
- Ownership: 50%
- Fuel: 25%
- Flight Crew: 14%

**Potential for lower manufacturing costs**
- (1) Life-cycle cost related to structural weight savings
- (2) Proven weight savings reduce fuel costs
- (3) Potential for lower maintenance costs

Total DOC savings on the order of 5 to 8% appear possible with composites applied to both transport wing and fuselage.
Reduced Cycle Time to Market is Equally Important to Increased Product Value

Unless new composites technology becomes as accessible to the engineering community as metals, Total DOC benefits are lost.

Lack of composite standardization and engineering resource dilution pose serious safety & certification issues and limit aircraft product applications.
Different Types of Scaling to Support Applications

Six Stages of Concept Development and Application

1. Initial Concept
2. Concept Development
3. Large-Scale Development
4. Product Definition and Certification
5. Production
6. Field Support

Size Scaling
Efforts to apply information at one scale of study to predict the behavior at a larger, more complete level

Product Scaling
Efforts to verify a technology basis, which links design components, factory process cells, maintenance procedures, and cost evaluations
Sufficient Development to Ensure Product Value

- All costs reducing product value need to be considered from Stage 2 on and continuously updated.

- Each stage should have exit criteria to advance technology, meeting all challenges, and subsequently constraining the concept within a desired final definition cost space.

- *Large scale development* has sufficient size and product scaling to ensure accurate value assessments and exit criteria that directly supports *technology readiness*.
How to Measure Technology Readiness?

• Each functional area has evidence it is ready for final product definition
  - Design/stress manuals with criteria, objectives and any constraints relating to manufacturing, maintenance and plans for affordable structural substantiation data development
  - Manufacturing plans, including key quality control steps for part fabrication and assembly, effects of defects data/processes that minimize MRB, and plans for the scaling trials that establish facilities, tooling and equipment needs for final cost assessments
  - Maintenance procedures, final maintenance manual development plans and related knowledge transfer strategies

• Technical challenges addressed and affordable certification approaches identified

• Total product value assessments project positive market potential and launch customers identified
FAA Guidance Philosophy

• The FAA is moving toward performance-based standards, such as the new part 23

• Within the Policy and Innovation Division of Aircraft Certification, we are also moving away from prescriptive FAA guidance
  – Across all technical specialties in aircraft certification

• We will increasingly rely on industry documentation to provide means of compliance, which we can “accept”
FAA Guidance Philosophy

• FAA Guidance will be high-level only, and primarily designed to clarify requirements and points of emphasis for means of compliance (MOC), rather than describe the detailed MOC accepted by industry (moving to industry standards)
  – We are hearing that we will release nothing more specific than AC 20-107B, and possibly even that is too prescriptive

• This has a significant impact on the FAA’s Composite Plan as well as similar documents, such as the Additive Manufacturing Roadmap
FAA Guidance Philosophy Example

EXISTING SYSTEM:

- **Regulation:** 2x.603 says (in essence) “Suitability and durability of materials must meet approved specifications to ensure they have desired properties”

- **Guidance:** AC 23-20 titled “Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems”
  - Applicable to the material and process specifications, or other documents, used to ensure sufficient control of composite prepreg materials
  - Includes a description of sections and content to be included in the specification

- **Industry Standards:** Specific NCAMP and SAE material specifications that meet the guidelines in the AC
FAA Guidance Philosophy Example

• There are three types of documentation involved in the current scenario
  1. Regulation (FAA)
  2. Expectations to meet the regulation (FAA)
  3. Documentation that meets the expectations (Industry)
FAA Guidance Philosophy Example

FUTURE SYSTEM:

- **Regulation**: 2x.603 says (in essence) “Suitability and durability of materials must meet approved specifications to ensure they have desired properties”
- **Guidance**: Policy that describes when composites fall into the category of materials that must meet an approved specification
- **Industry Standard 1**: Description of sections and content to be included in the specification
- **Industry Standard 2**: Specific NCAMP and SAE material specifications that meet the guidelines in the AC or *non-standard proprietary information*

*Disclaimer: This is not yet official, but everything points to this approach*
Future FAA Process under study to facilitate innovation early in a project’s life, including certification benefits from joint efforts with measurable outcomes.

Innovation at the time of certification is met with rough seas without careful pre-development and measurable outcomes that demonstrate technology readiness.

Benefits

1. Knowledge Transfer
2. Technology Readiness
3. Safety Awareness
4. Value to Industry

Outcomes*

1. Rules, guidance and policy (FAA expectations/Industry MOC)
2. M&P Qualification thru prototyping
   a) Repeated trials at appropriate scales (results: coupon tests, manufacturing trials)
   b) Design tools under development (load path measurements, design manuals)
3. FAA Level II Applicant Training (approved by experienced industry)
4. Innovation sooner than later
CE H, Composite Applications TSO

Background:

• Develop a new TSO and associated guidelines for composite materials
  – Guidelines are essential in order to implement the TSO, since it is a new concept

• Allows companies to demonstrate technology readiness outside of a certification project

• Under the current system, we do not open certification projects for development of composite data, design tools or prototyping functional structures or airplane products
  – Some DAHs open projects to develop allowables and associated tools, then cancel the project. Resulting data, however, is FAA approved and can be applied to other projects, when shown to be applicable
  – Other parties have no avenue to develop data that is approved by the FAA
    • Some basic material data may be generated under NCAMP system accepted by the FAA

• There would be a significant advantage to the FAA to receive data packages with the TSO application that describe the limitations of the data – a learning tool and design guide
CE H, Composite Applications TSO

Scope → There could be three classes of data

1. Basic lamina-level M&P control data (NCAMP-style data)
2. Advanced laminate or detailed design data
3. Design tools that are tied to the data from class 1 and/or 2
4. Repetitive manufacturing trials or large-scale hardware demonstration test

Each class must have measurable outcomes that can be self-certified
CE H, Composite Applications TSO

• Deliverables

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<table>
<thead>
<tr>
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<tr>
<td>1. Hold workshop to gauge industry interest and identify a standards organization(s) to work with</td>
<td>Winter 2020</td>
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<td></td>
<td>Propose to fund through research plus-up</td>
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<td>2. Identify if any standards organization documentation is required, and scope working agreement(s)</td>
<td>Spring 2020</td>
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• Goal is to develop a TSO product so that applicants can develop data that would be approved by the FAA without a certification project

- The data would be restricted to a well-documented design space
- Certification activities are still required in order to use the material and data – it has to be shown to be applicable to the project; however, the tests used to develop the data would not have to be re-performed with project numbers, conformity, and witnessing (this is managed under the TSOA quality system)
- Brings parity to third parties so they can develop data in an economical method, the same as current DAHs (may be suitable to airline/MRO consortium)
Updates to Rev G of Chapter 14

• **Color Code:**
  - Sections completed and sent to Yellow Pages – Blue
  - Sections in work or some work performed on – Green
  - Sections in work with some sub-sections sent to yellow Pages – Green/Blue
  - Sections not yet worked on – Red
Updates to Rev G of Chapter 14

- Section 14.1 Introduction
- Section 14.2 Important Considerations
- Section 14.3 Service Experience
- Section 14.4 Inspection
- Section 14.5 Damage Assessment
- Section 14.6 Repair of Composite and Metalbond Structure
- Section 14.7 Repair Analysis
- Section 14.8 Composite Repair of Metallic Structure
- Section 14.9 Maintenance Documentation
- Section 14.10 Design for Supportability
- Section 14.11 Logistics Requirements
- Section 14.12 Bonded Repair Case Studies
Status of Section 14.6 as of May 30, 2019

- Section 14.6 Repair of Composite and Metalbond Structure
  - 14.6.1 Introduction
  - 14.6.2 Prerequisites for the repair of composite and metalbond structure
  - 14.6.3 Repair design and processing
    - 14.6.3.1 Design criteria
    - 14.6.3.2 Repair design and processing
      - 14.6.3.2.1 Introduction
      - 14.6.3.2.2 Damage removal and site preparation
      - 14.6.3.2.3 Bolted repair
      - 14.6.3.2.4 Bonded repair
        - 14.6.3.2.4.1 Repair concepts
        - 14.6.3.2.4.2 Repair materials
        - 14.6.3.2.4.3 Repair processing
        - 14.6.3.2.4.4 Repair examples
      - 14.6.3.2.5 Sandwich structure repair
  - 14.6.4 Composite and metalbond repair substantiation (see next chart)

Key: Complete, in work
Status of Section 14.6.4 Composite and metalbond structural repair substantiation

- 14.6.4.1 Introduction
- 14.6.4.2 Aircraft regulations and requirements
  - 14.6.4.2.1 Civil aircraft regulations
  - 14.6.4.2.2 Military aircraft requirements
- 14.6.4.3 Guidance and policy statements
  - 14.6.4.3.1 Structural criticality and other considerations
- 14.6.4.4 Structural substantiation approaches used for certification
  - 14.6.4.4.1 Prerequisite and design data needs
  - 14.6.4.4.2 Substantiation predominantly by test
  - 14.6.4.4.3 Substantiation by analysis supported by test
- 14.6.4.5 Building block planning considerations
  - 14.6.4.5.1 Introduction to the building block methodology
  - 14.6.4.5.2 Building block substantiation approach for a structure with multiple damages
  - 14.6.4.5.3 Substantiation approach for a structure with a single damage
- 14.6.4.6 Temporary or time-limited and interim repairs
- 14.6.4.7 Continued airworthiness
- 14.6.4.8 Interdependencies
  - 14.6.4.8.1 Bolted repairs
  - 14.6.4.8.2 Bonded repairs
Questions/Comments?
Backup Slides
### CACRC Main Meetings (Thursday, June 27)

<table>
<thead>
<tr>
<th>Time</th>
<th>Subject</th>
<th>Presenter</th>
<th>Organization</th>
<th>Content Description</th>
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<tbody>
<tr>
<td>10.30</td>
<td>CMH-17 Workshop: FAA Advances, Industry Standards &amp; Integrated Product Development</td>
<td>Larry Ilcewicz</td>
<td>FAA</td>
<td>Starts with IPT and product value, talks about industry standards that will work vs. turn-key approaches not available, why analyses don’t work without data, engineering solutions and things the FAA is proposing for the current SOA.</td>
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<tr>
<td>11.00</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Prerequisites for Bonded Repair</td>
<td>Mike Borgman</td>
<td>Spirit</td>
<td>Summarize Chapter 14.6.2, explaining why they may be the most difficult part of structural substantiation, including relationships with CACRC.</td>
</tr>
<tr>
<td>11.30</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Substantiation of Bonded Repair</td>
<td>Larry Ilcewicz</td>
<td>FAA</td>
<td>Summarize progress contained in all parts of 14.6.4 (except 14.6.4.5), outlining subsection goals, content and example clarifications so that repair substantiation is realized to be related to material and process prerequisites, as well as proof of structure.</td>
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<td>12.00</td>
<td>Lunch</td>
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<tr>
<td>1.00</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Substantiation of Bonded Repair, cont.</td>
<td>Larry Gintert</td>
<td>CMH-17</td>
<td>Summarize all parts of 14.6.4.5 (start + examples given in 14.6.4.5.1 and 14.6.4.5.2 to demonstrate certification by analysis supported by tests and certification primarily by tests, as related to efforts needs and related costs, incl. common tests needed for both). Review the updated Chap. 14 outlines for 14.7: Analysis for Composite and Metalbond Repairs (incl. bolted &amp; bonded repairs), note our relationship with V3, Chap. 10 &amp; 11 and highlight some of the unique analysis challenges for real repairs.</td>
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<td>1.30</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Other sections in work (e.g., analysis)</td>
<td>Mike Borgman</td>
<td>Spirit</td>
<td>Invited speaker, providing some emphasis on tests and analyses that cover BRSL expectations. The test and analysis correlations show how to eliminate conservative assumptions that generally underestimate the actual BRSL constraints.</td>
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<tr>
<td>2.00</td>
<td>FAA/Boeing R&amp;D: Bonded Repair Size Limits Analyses and Tests</td>
<td>John Lin</td>
<td>Boeing</td>
<td>Start with the Table of all Case Studies. Cover completed case Study #1 (Metalbond flap wedge) and progress to date with Case Study #2 and #3, including the options currently under TG consideration for last 15-20 minutes of your 45 Minute Segment.</td>
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<td>2.30</td>
<td>Break</td>
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<td>3.00</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Case Studies: Example A</td>
<td>Mike Borgman</td>
<td>Spirit</td>
<td>First 15 minutes go to Mike Borgman Last 15 Minutes go to Larry Gintert</td>
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<tr>
<td>3.30</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Case Studies: Example B</td>
<td>Mike Borgman/Larry Gintert</td>
<td>CMH-17</td>
<td>Choose at least two case studies for you 45 minute segment, conducting the last 15 to 20 minutes with Case Study 9 (GA Wing Spar/Skin repair).</td>
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<tr>
<td>4.00</td>
<td>CMH-17, Vol. 3/Chapter 14 Content Case Studies: Example C</td>
<td>Larry Gintert</td>
<td>CMH-17</td>
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</tbody>
</table>
14.1 Introduction
14.2 Important Considerations
14.4 Inspection
14.5 Damage Assessment
14.8 Composite Repair of Metallic Structure
14.9 Maintenance Documentation
14.12 Repair case studies
  14.12.1 Introduction
  14.12.2 Case study #1 – Substantiation of bond process changes

14.6 Repair of Composite and Metalbond Structure
  14.6.1 Introduction
  14.6.2 Prerequisites for the repair of composite and metalbond structure
    14.6.2.8 Equipment calibrations
    14.6.2.9 Technician/inspector/engineer qualifications and training
    14.6.2.10 Tooling and repair work station challenges to ensure proper form and fit
    14.6.2.11 Quality Control
  14.6.3 Repair design and processing
    14.6.3.1 Design criteria
    14.6.3.2 Repair design and processing
      1. Introduction
      2. 14.6.3.2.2 Damage removal and site preparation
      3. Bolted repair
        1. Repair concepts
        2. Repair materials
        3. Repair processing
    14.6.3.4 Bonded repair
      1. 14.6.3.4.1 Repair concepts
      2. 14.6.3.4.2 Repair materials
  14.6.4 Repair quality assurance
Back-up (Details)

Sections of Chapter 14 sent to Yellow Pages for Rev H after Wichita, 2017

14.6.2 Prerequisites for the repair of composite and metalbond structure
  14.6.2.1 Approved data
  14.6.2.2 Material and process specifications
  14.6.2.3 Purchase control
  14.6.2.4 Raw material storage and handling
  14.6.2.5 Qualified materials
  14.6.2.6 Facilities and work space control

Sections of Chapter 14 sent to Yellow Pages for Rev H after Charleston, 2018

14.6.2.7 Contact and non-contact materials
14.6.3.2.3.4 Example of a bolted repair

New outline for Section 14.6.4 Repair substantiation

Plan for Yellow Page Submittal after SLC, 2019

Section 14.6.4 Composite and metalbond repair substantiation

14.6.4.1 Introduction
14.6.4.2 Aircraft regulations and requirements
14.6.4.3 Guidance and policy Statements
  14.6.4.3.1 Structural criticality and other considerations
14.6.4.4 Substantiation approaches for structural repairs
  14.6.4.4.1 Prerequisites and design data needs
  14.6.4.4.2 Repair substantiation predominantly by test
  14.6.4.4.3 Repair substantiation by analysis supported by test
14.6.4.5 Building block analysis and test correlation
  14.6.4.5.1 Introduction to Building Block Methodology
14.6.4.6 Temporary or time-limited and interim repairs
14.6.4.7 Continued airworthiness