2011 FAA Interface with Industry & Other Regulatory Org. to Support Active Composite Educational and Guidance Initiatives

Federal Aviation Administration

Larry Ilcewicz
Federal Aviation Administration

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- *2011 Composite Industry Interface*
  - *Background & Expanding Applications*
  - *Workshops & Working Group Meetings*
  - *Ongoing Initiatives to support expanded policy, guidance and training (FAA R&D, CMH-17, CACRC)*
- *FAA Educational Initiatives*
  - *Background and timelines*
  - *Composite Structural Engineering Course*
- *AC 20-107B Content of Relevance*
- *Future Regulatory Needs (e.g., crashworthiness rulemaking)*

Background

- Composites aircraft structures are non-standard technology
- **Composite Safety and Certification Initiatives (CS&CI)** proactively pursue composite needs based on field support to certification and safety-related issues
  - Structured to meet FAA Flight Plan & AVS "Processes"
  - Utilizes the "FAA Composite Team" (field offices & each directorate)
  - CS&CI approach expands the safety/regulatory workforce through the use of industry and other country regulatory technical experts

    Important to the most challenging safety-related issues (i.e., limited FAA resources with required composite experience)
- CS&CI have a successful track record since 1999
  - Industry acceptance has been inherent through this approach
  - Inter-directorate/field office integration through the composite team
  - Global harmonization with participation of EASA/TCCA
  - Training has become a current priority with expanding applications

Rationale for Re-starting Industry Composite Transport WG and Conducting 2011 Workshop

- Many new transport products are considering significant use of composite airframe structure
- Insufficient resources with composite experience, driving a need for more policy, guidance, training and (in some cases, regulation)
- Several issues have arisen in current projects that could lead to an "un-level playing field" for composite certification, with significant potential for safety and economic impact

• Proposed Solution

- Need for more composite technical benchmarking of "best practices" (engineering, manufacturing and maintenance), e.g.,
  - Charter *ad hoc* WG to define workshops & more formal regulatory initiatives
  - Document best practices in international standards (CMH-17, SAE CACRC) and other forum, which support the development of related training
- Work with key members of the industry to gain near-consensus for more definitive policy and guidance based on the benchmarks

New Content for 2011 Update to Airbus/Boeing/EASA/FAA WG Charter

1) Review outline, teaching objectives and course content for Fatigue & Damage Tolerance and Maintenance Awareness Modules of Level II Composite Structural Engineering Safety Awareness Course
2) Discuss fatigue, damage tolerance & maintenance subjects of topical interest and ID any need for joint policy, guidance or standards development to update the corresponding detailed charter item
    a) Composite LEF factors and other issues important to the test and analysis protocol for certification of hybrid composite/metal airframe structures
    b) Engineering, maintenance and operations interface protocol to ensure the safety of composite aircraft structure subjected to high energy, wide area, blunt impact (HEWABI): Transition between Damage Categories 2, 3 and 5
    c) Understand current rulemaking activities for engine, tire and runway debris impact threats
    d) Engineering protocol for the use of probabilistic methods to support composite damage tolerance design, substantiation and maintenance inspection practices
    e) Engineering design protocol for bonded repair size limits as a function of structure criticality and other factors such as field repair conditions & technician skill levels

Red text used to derive current Workshop Objectives

New Content for 2011 Update to Airbus/Boeing/EASA/FAA WG Charter, cont.

3) Identify the fatigue & damage tolerance and maintenance issues from 2) that require near-term attention by a larger WG that includes other responsible OEM, major supplier, airline and MRO support
   (to be started in FAA 2011 Composite Workshop)
4) Discuss the existing policy for shared composite databases/specifications and the use of international standards organizations (NCAMP, CMH-17, CACRC) to self-regulate the process
5) Review outline, teaching objectives and course content for Crashworthiness Module of Level II Composite Structural Engineering Safety Awareness Course
6) Discuss analysis and test protocol used to meet recent special conditions for composite fuselage structural crashworthiness anticipating that detailed design differences will likely exist in the current generation of new aircraft developments and ID any need for joint policy, guidance or standards development to update the corresponding detailed charter item
7) Identify the crashworthiness issues from 6) that require near-term attention by a larger WG that includes other responsible OEM and major suppliers
   (to be started in FAA 2011 Composite Workshop)

Red text used to derive current Workshop Objectives

CMH-17 Rev. H: Safety Management Initiatives

- Field support for safety management initiatives is not readily available at CMH-17 Mtgs.
- FAA/Safety Management WG will continue to interface with industry groups inside/outside CMH-17 Meetings
  - Ad Hoc Industry/Regulatory WG, SAE CACRC Meetings, and other activities where the required expertise is present
  - Periodic CMH-17 updates (e.g., WG Mtgs., PMC Forum)
  - Strategy: initial CMH-17 (Rev. G) content in this area was general
  - Current Initiatives:
    1) Extensive repairs that fail in field (CACRC)
    2) High energy blunt impact (Damage Tolerance TG)
    3) Disbond min. gage/low density sandwich (D&D TG)
- FAA support to composite initiatives
  - Larry Ilcewicz, Rusty Jones, Cindy Ashforth, Curt Davies, Mark Freisthler, Dale Hawkins, Angie Kostopoulos, Lynn Pham, Allen Rauschendorfer, Melanie Violette, Nathan Weigand, and David Westlund

Structural Safety TG Actions for *Extensive Repairs that Fail in the Field*

- Continue to interface with CACRC Airworthiness & Training TG on *"extensive repairs to composite structure that fail in service"*
  - Active CACRC initiative on a process guidance document for best practices in extensive repair of metal bonded sandwich construction
  - Some FAA actions for DER designations and field enforcement
- Key focal:
  - Allen Rauschendorfer (FAA), Interface with FAA AEG/FSDO
  - Dale Hawkins (FAA), Interface with airlines
  - Charlie Seaton (WSU/Heatcon), Document case studies of failed repairs for training (e.g., FAA Composite Structural Engineering Technology course development) & new CMH-17 content (see Rev. G Vol. 3, Ch. 17 content)
- Current Airbus/Boeing/EASA/FAA WG Meeting subject
- Continued review with Commercial Aircraft Safety Team (CAST)
- To be addressed in current FAA Composite Workshop

Damage Tolerance TG Actions
High Energy Blunt Impact

- Problem: High energy, wide area, blunt impact to composite structures (e.g., service vehicle collisions)
  - Potential Category 5 damage that poses significant safety threat if not immediately reported/properly inspected
  - Action: Continued interaction with the Commercial Aircraft Safety Team (CAST) and European equivalent (ECAST)
  - Action: Progress in FAA R&D efforts by UCSD (Hyonny Kim) and Airbus/Boeing/EASA/FAA WG
  - Action: Periodic updates & new Rev. H content as appropriate
- Note summary pitch in 3/1/11 PMC Forum (Hyonny Kim)
- Current Airbus/Boeing/EASA/FAA WG Meeting subject
- To be addressed in current FAA Composite Workshop

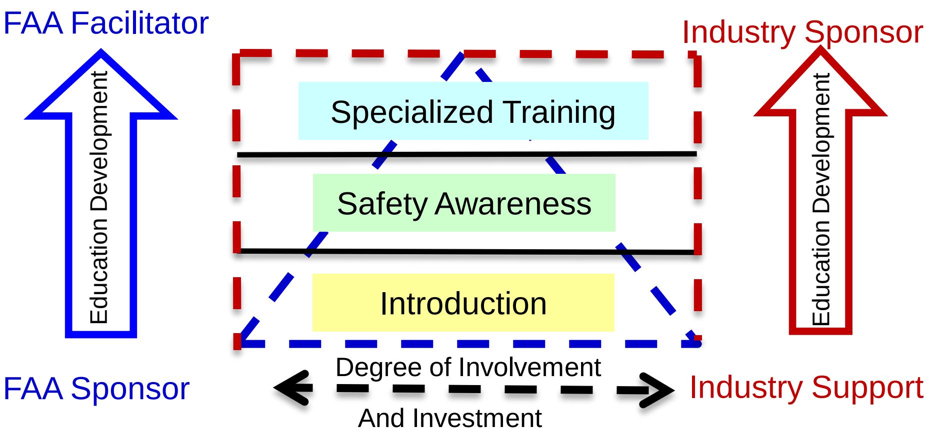
Debond & Delamination TG Actions
Disbond Growth in Sandwich

- Problem: Sandwich Damage Growth Scenarios for minimum gage, low density honeycomb sandwich panel construction
  - Relatively small defects (debonds from mfg., repair, impact) may grow under ground-air-ground cycles leading to lost residual strength or stiffness and potential flutter (synergistic fluid ingression effect also possible)
  - Action: Work with Airbus engineers and develop engineering tools (analysis, test methods) and guidelines added as Rev. H content to properly manage the problem for existing and future sandwich construction
  - Action: Continued interaction with the Commercial Aircraft Safety Team (CAST) and European equivalent (ECAST)
  - Action: Related JAMS R&D projects (e.g., Adams, Univ. of Utah)
- CMH-17 Disbond & Delamination TG Meeting (3/2/11) and working meeting with Airbus (Roland Thevenin and Ralf Hilgers) held in Virginia (March 23 and 24, 2011)
  - Note summary pitch in 3/1/11 PMC Forum (Ronald Krueger)
- Current Airbus/Boeing/EASA/FAA WG Meeting subject
- To be addressed in current FAA Composite Workshop

Composite Educational Initiatives

FAA AVS Composite Training

- FAA composite training strategy using existing courses, FAA COE & industry support **[Sept., 2009]**
  - Courses to support airframe engineering, manufacturing and maintenance functional disciplines
- Incl. three levels of competency:



I) Introduction (common to all functional disciplines)

Self-study intro content for composite basics/terminology

CMH-17 Tutorial for composite certification & compliance [since Aug, 2008]

II) Safety Awareness (courses for each functional discipline)

Skills needed for FAA workforce supporting composite applications

FAA development status summarized on the next chart

III) Specific Skills Building (most courses developed by the industry)

Specialized skills needed in the industry & some FAA experts

Safety Awareness Course Timelines

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013

▲ Start Composite Maintenance Tech. (CMT) Course Development
▲ Brainstorm CMT course content needs
▲ Focus on critical CMT safety issues (ID Terminal Course Objectives, TCO)
▲ Establish initial course content (narrative modules) & review with industry
▲ Draft teaching points that give a level of course detail below TCO
▲ Perform beta online course and lab (+ created "instructor's guide")
▲ Draft International Standard (SAE AIR 5719)
▲ Start work to convert course to AFS FAA Reqmt.
▲ Start to offer CMT to FAA ASI

Start Composite Struc. Eng. Tech. (CSET) Course Develop. ▲
Develop detailed CSET course outline ▲
Conduct M&P Control Workshop & develop related course content ▲
Contract Subject Matter Experts (SME) to create CSET content ▲
Finalize TCO and deliver course content to AIR-520 ▲

Start Composite Manufacturing Tech. (CMfgT) Course Develop. ▲
Contract Major contractor to develop detailed CMfgT course outline/TCO ▲
Update major contractor SOW to create CMfgT content ▲
Conduct CMfgT Workshop to beta check course content with SME ▲
Update course and deliver content to AIR-520 ▲

Composite Educational Initiatives

Composite Level II Course Development Status

- Composite Safety Awareness for Maintenance/Repair [CACRC AIR5719]
  - FAA-led course development completed [Sept., 2008]
  - AFS-500 class-room version available to FAA [since 2009]
    ~ 400 AFS ASI trained to date through FAA contract with ABARIS
  - On-line version is also available to the industry thru WSU NIAR
- Composite Safety Awareness for Structural Engineering – *In work*
  - Development sponsored by FAA R&D COE & AIR-520
  - Detailed outline and Material & Process Control module [Sept., 2010]
  - Course content 75% completed [Sept., 2011] and available in 2012
- Composite Safety Awareness for Manufacturing – *In work*
  - Development sponsored by FAA R&D COE & AIR-520
  - Detailed outline and key contractors [Sept., 2011]
  - Course content completed [Sept., 2012] and available in 2013
- Industry experts support course development and delivery

Composite Structural Engineering Technology Level II Safety Awareness Course Development

- Composite Structural Engineering Technology (CSET) course development started in 2010 for *"safety awareness"*
  - *80 Hour* classroom/lab equivalent (3 days of hands-on lab)
  - More hours in self-study when taught online
- Draft top-level outline following AC 20-107B
  - Difficulties faced in composite applications (2 hours)
  - Design, material and fabrication development (~4 days)
  - Proof of structure – general, static and fatigue & damage tolerance (~4 days)
  - Manufacturing interface issues (3/4 day)
  - Maintenance interface issues (3/4 day)
  - Other: flutter, crashworthiness, fire safety & lightning strike protection (3/4 day)
- 2010 FAA Workshop conducted at Wichita State Univ. to "beta test" module on composite material & process control
  (part of design, material & fabrication development)
  - Material & process qualification (test matrices, statistics)
  - Material & process specifications (material rqmts., process details, quality control)
  - Shared databases (NCAMP/CMH-17/SAE P-17 initiatives, equivalency sampling)
  - "Material allowables" versus design values – Statistical methods

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Composite Structural Engineering Technology Level II Safety Awareness Course Development

- **FAA Composite Team (led by L. Ilcewicz, C. Seaton & L. Cheng)**
  - Structures Specialists, Dave Walen (Lightning Protection CSTA), Cabin Safety Experts (Joseph Pellettiere, Crash Dynamics CSTA, Dick Hill & Alan Abramowitz, FAA Technical Center, Jeff Gardlin, Transport Directorate Standards)
- **Key subject matter experts (SME)**
  - Keith Kedward, UCSB (incl. composite design/analysis textbook)
  - Steve Ward (M&P control, design/analysis and proof of structure)
  - NSE Composites (Tom Walker and D.M. Hoyt, fatigue & damage tolerance)
  - Wichita State University (Ng, Senevertine, Clarkson, lab development)
  - Delft University (Christos Kassapoglou)
  - Other SME (contractors and volunteers)

    Michael Niu (composite design)
    Max Davis (metal-bonding)
    Michael Borgman (repair substantiation)
    Peter Smith (retired Boeing)
    John Halpin (retired Air Force)
    Will McCarvill (retired Hexcel)
    John Adelmann (retired Sikorsky)
    Dan Ruffner (Boeing, Mesa)
    FAA JAMS (Paolo Feraboli, Hyonny Kim, Tim Kennedy, Dan Adams, others)
    Workshop participants: presentations, discussions, testimonials
    (M&P control, fatigue & damage tolerance, crashworthiness)

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Composite Structural Engineering Technology Selected Course Outline Details

1. Prerequisite self-study module to ensure common level of basic understanding and terminology
2. Practical appreciation for the challenges of composite applications (high non-recurring costs, limited advantages from shared data, industry trends to keep developing "advanced technology", while not striving for standardization)
3. Design, Material and Fabrication Development Module
   - 3.1 Integrated product team needs (emphasis on composite specialists)
   - 3.2 Material & Process Control Section (roughly 1/3 of this section)
   - 3.3 Composite Structural Design (roughly ½ of this section)
   - 3.4 Manufacturing Interface Section (as related to the integration of design and manufacturing)
   - 3.5 Maintenance Interface Section (as related to the integration of design and maintenance)
4. Proof of Structure Module [integrated for static strength, fatigue & damage tolerance]
   - 4.1 to 4.9 General (incl. rules/guidance, key concepts, compliance approaches, damage & defects and related design considerations)
   - 4.10 Damage Threat Assessment
   - 4.11 to 4.13 Structural substantiation (building block approach, reliability and full scale tests)
   - 4.14 Inspection Program Definition and Substantiation

Composite Structural Engineering Technology Selected Course Outline Details, *cont.*

5. Quality Control of Composite Manufacturing Processes
   - 5.1 Quality Control methods and Examples
   - 5.2 Critical Items to Consider
   - 5.3 Conformity Issues Unique to Composites
   - 5.4 Production Defect Disposition
6. Maintenance Interface issues
   - 6.1 Repair Design and Process Substantiation
   - 6.2 Need for Teamwork and Skilled Disposition
   - 6.3 Composite Damage Characterization (Detection, Inspection)
   - 6.4 Bonded and Bolted repair Methods
   - 6.5 Dependence on Source Documentation in Meeting Regulations
7. Additional Considerations
   - 7.1 Proof of Structure - Flutter
   - 7.2 Crashworthiness
   - 7.3 Fire Safety and Fuel tank Issues
   - 7.4 Lightning Protection
   - 7.5 Maintenance of Structural Coatings and Paint

AC 20-107B Outline (released in 9/09)

AC 20-107A 11 pages
AC 20-107B 37 pages
Harmonized AMC 20-29

(Selected content of relevance to current workshop highlighted by blue text)

1. Purpose
2. To Whom This AC Applies
3. Cancellation
4. Regulations Affected
5. General
6. Material and Fabrication Development
7. Proof of Structure – Static
8. Proof of Structure – Fatigue and Damage Tolerance
9. Proof of Structure – Flutter
10. Continued Airworthiness
11. Additional Considerations

Appendix 1
Applicable Regulations & Guidance

Appendix 2
Definitions

Appendix 3
Change of Material & Process

8a Damage Tolerance Evaluation

1) Damage threat assessment
2) Structural tests for damage growth
3) Extent of initially detectable damage
4) Extent of damage/residual strength
5) Repeated load testing
6) Inspection program
7) Discrete source damage
8) Environmental effects

8b Fatigue Evaluation

8c Combined Damage Tolerance and Fatigue Evaluation

Proposed Key Areas for 5/17 & 5/18 (Session 1) Composite & Metal Interface Discussions

- ***Best industry practice*** **of large-scale test & analysis protocol for the certification of hybrid composite/metal airframe structure**
  - Under what circumstances can large-scale static, fatigue and damage tolerance tests have meaning to both metal & composite components?
  - What are expected considerations for treatment of thermal fatigue stresses?
- ***Best recommended engineering practice*** **for generating LEF factors for a given design**
  - Default values justified by limited test sampling
  - Reduced values justified by extensive testing
  - Value of shared LEF databases and mixed load/life validation
- **Further study to determine critical parameters of a hybrid design that requires coverage in certification**
  - Wide spread fatigue demonstration for appropriate parts (metal-yes and composites?/how)
  - Life limits linked to test evidence, service experience & other considerations

AC 20-107B Para. 8: Proof of Structure – Fatigue & DT

- Initial bullet summaries
  - *Final static strength, fatigue, and damage tolerance substantiation may be gained in testing a single component test article* if sufficient building block test … ensure that the selected sequence of repeated and static loading yield results representative of service or provide a conservative evaluation.
  - Peak repeated loads are needed to practically demonstrate the fatigue and damage tolerance of composite aircraft structure in a limited number of component tests. *As a result, metal structures present in the test article generally require additional consideration and testing*…
- Paragraph 8.a.(2)
  - Structure details, elements, and subcomponents of critical structural areas should be tested under repeated loads to define the sensitivity of the structure to damage growth. … The environment used should be appropriate to the expected service usage. *Residual stresses will develop at the interfaces between composite and metal structural elements in a design due to differences in thermal expansion. This component of stress will depend on the service temperature during repeated load cycling and is considered in the damage tolerance evaluation*…
- Paragraph 8.a.(5)
  - The repeated load spectrum developed for fatigue testing and analysis purposes should be representative of the anticipated service usage. Low amplitude load levels that can be shown not to contribute to damage growth may be omitted (truncated). Reducing maximum load levels (clipping) is generally not accepted. *Variability in repeated load behavior … covered by appropriate load enhancement or life scatter factors and … take into account the number of specimens tested. The use of such factors … should be consistent with the fatigue and damage tolerance behavior characterized for the materials, processes and other design details of the structure in building block tests*
- Paragraph 8.c
  - Generally, it is appropriate for a given structure to establish both an inspection program and demonstrate a service life to cover all detectable and non-detectable damage... *Extensions in service life should include evidence from component repeated load testing, fleet leader programs (including NDI and destructive tear-down inspections), and appropriate statistical assessments of accidental damage and environmental service data considerations.*

Proposed Key Areas for 5/17 & 5/18 (Session 2) High Energy Wide Area Blunt Impact Discussions

- Engineering, maintenance and operations interface protocol to ensure the safety of composite aircraft structure subjected to high energy, wide area, blunt impact (HEWABI). Primary engineering problem is: *Transition Between Damage Categories 2, 3 and 5*
- Continue to document the problem and practical means of solution (following in the theme of 2008 FAA White Paper for safety awareness)
  - Develop guidelines for recommended Category 2 and 3 damage states
  - Safety awareness training for operations *(to ensure proper reporting)* and line maintenance *(to ensure safe reaction)*
  - Establish an industry-wide awareness campaign through Aircraft Maintenance Manuals and communications with customers
- Recommendations for further study (+ research) to determine critical parameters of the impact event, design and current ramp maintenance practices to mitigate safety risks for Category 5 damage
  - Practical tests that have representative boundary conditions
  - Accurate analyses to extrapolate from limited full-scale testing
  - Simple analyses/guidelines to support event disposition for specific structure

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AC 20-107B, Paragraph 8 and 10

- Paragraph 8.a.(1)(c)(v)
  - **Category 5:** Severe damage created by anomalous ground or flight events, which is not covered by design criteria or structural substantiation procedures. This damage is in the current guidance to ensure the engineers responsible for composite aircraft structure design and the FAA work with maintenance organizations in making operations personnel aware of possible damage from Category 5 events and the essential need for immediate reporting ... *It is also the responsibility of structural engineers to design-in sufficient damage resistance such that Category 5 events are self-evident to the operations personnel involved. An interface is needed with engineering to properly define a suitable conditional inspection based on available information from the anomalous event.* Such action will facilitate the damage characterization needed prior to repair…
- Paragraph 8.a.(6)(b)
  - … By definition, Category 5 damages do not have associated damage tolerance design criteria or related structural substantiation tasks. *Category 5 damage will require suitable inspections based on engineering assessment of the anomalous service event, and appropriate structural repair and/or part replacement, prior to the aircraft re-entering service.*
- Paragraph 10.d.(2)
  - *Pilots, ramp maintenance, and other operations personnel that service aircraft should be trained to immediately report anomalous ramp incidents and flight events that may potentially cause serious damage to composite aircraft structures. In particular, immediate reporting is needed for those service events that are outside the scope of the damage tolerance substantiation and standard maintenance practices for a given structure.* The immediate detection of Category 4 and 5 damages are dependent on the proper reaction of personnel that operate and service the aircraft. Please refer to regulations in parts 21, 121, and 135 for reporting requirements.

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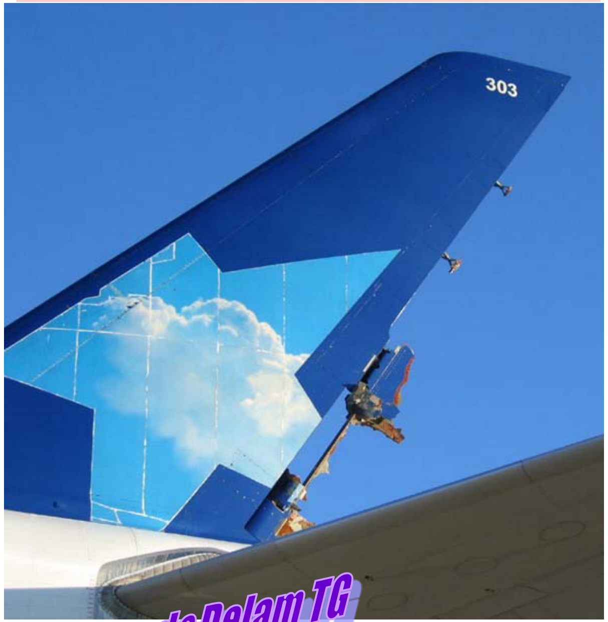
Proposed Key Areas for 5/17 & 5/18 (Session 3) Damage in Sandwich Construction Discussions

- Why does sandwich construction generally have a poor service history?
- Problematic sandwich design and process details that historically lead to undesirable damage growth mechanisms (difficult to simulate in lab testing)
  - Studies on undesirable damage growth mechanisms as a function of structural design detail, damage type and environmental exposure
- Fail safe design features
  - Panel breakers to avoid large damage growth per core tearing, core to face sheet disbonding or face sheet delamination
  - Natural solid laminate transitions for internal structure attachments, hoist points, areas of penetrations for exterior attachments
- Analysis methods for sandwich damage tolerance
  - Critical flaw sizes for different damage types and structural configurations
  - Practical damage growth simulations
  - Accelerated fluid ingression tests proven to accurately represent field conditions, including the effects of representative design details and arrestment structures

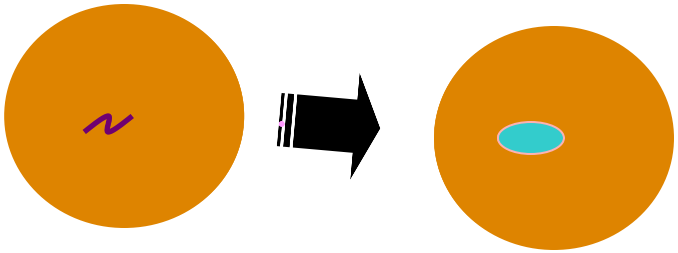
Potential Flutter Problems with Minimum Gage Control Surfaces or other "Critical Structures"

- **Highlights of Airbus presentations from 2009 FAA Workshop in Tokyo, Japan**
  1. Airbus shared essential safety data on a rare composite growth phenomena (root cause and engineering solution) not previously available
  2. minimum-gage sandwich disbond growth under GAG cycles [Growth rates = f (disbond size)]
  3. Potential bonded repair problem covered in breakout sessions (see below)

Air Transat Flight 961



Blunt Impact of Sandwich Part With Sharp Penetration Near Center



Followed by Poorly Bonded Repair Patch to Penetration Zone Only

- *CMH-17 Disbond&Delam TG*
- *Initiative to study sandwich*
- *damage growth mechanisms*

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AC 20-107B, Paragraph 8

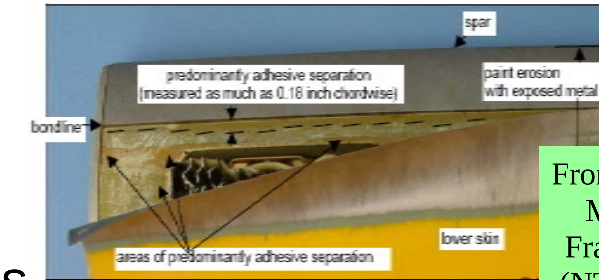
- Paragraph 8.a.(2)
  - *Structure details, elements, and subcomponents of critical structural areas should be tested under repeated loads to define the sensitivity of the structure to damage growth.* This testing can form the basis for validating a no-growth approach to the damage tolerance requirements. *The testing should assess the effect of the environment on the flaw and damage growth characteristics and the no-growth validation.* The environment used should be appropriate to the expected service usage… *Inspection intervals should be established, considering both the likelihood of a particular damage and the residual strength capability associated with this damage. The intent of this is to assure that the structure is not exposed to an excessive period of time with residual strength less than ultimate, providing a lower safety level than in the typical slow growth situation*…
  - Para. 8.a.(2).(a) covers *"slow growth"* – Para. 8.a.(2).(b) covers *"arrested growth"*
- Paragraph 8.a.(3)
  - *The extent of initially detectable damage should be consistent with the inspection techniques employed during manufacture and in service. This information will naturally establish the transition between Category 1 and 2 damage types (i.e., inspection methods used by trained inspectors in scheduled maintenance)*… Flaw/damage growth data should be applied to validate both growth and no-growth concepts should be statistically significant, and may be determined by load and/or life considerations and a function of damage size. *The growth or no growth evaluation should be performed by analysis supported by test evidence or by tests at the coupon, element, or subcomponent level.*
- Paragraph 8.a.(4)
  - *The extent of damage for residual strength assessments should be established, including considerations for the probability of detection using selected field inspection procedures.* The first four categories of damage should be considered based on the damage tolerance threat assessment… The evaluation *should demonstrate that the residual strength of the structure will reliably be equal to or greater than the strength required for the specified loads (considered as ultimate), including environmental effects. The statistical significance of reliable subcomponent and detail residual strength assessments may include conservative methods and engineering judgment. It should be shown that stiffness properties have not changed beyond acceptable levels.*
- Paragraph 8.a.(5) → *Inspection content covered in Chart 19*

Proposed Key Areas for 5/17 & 5/18 (Session 4) for Discussions on Bonded Repair Size Limits

- Understand industry experience supporting bonded repair size limits any possible confusion related to major composite applications and field practice
- Engineering design protocol for bonded repair size limits as a function of structure criticality and other factors, such as field repair conditions & technician skill levels
- Consistent practices for adequate structural substantiation for given design and process detail defined for damage outside the SRM
- Discuss whether additional regulatory guidance is needed to ensure safe bonded repair practices in the field
- Further study (+ research) to document detailed background to support more definitive guidance for bonded repair

Bonding Field Difficulties

- **Helicopter main rotor blade metal bonding problems**
  - 2008 NTSB Safety Recommendations
  - Possible metal bond processing problems



From Air Force MP3 Mtg. Frank Zankar (NTSB, 2008)

- **Rudder debonding**
  - NDI to control current field problems
  - OEM shared technical solutions & design concerns with industry in FAA 2009 Tokyo Workshop (standards to be adopted by CMH-17)

In-flight Rudder Failure
(Large damage causing flutter)
Air Transat Flight 961 [3/6/05]

- **Extensive repair deficiencies**
  - DER-approved *repair design and processes* without supporting data
  - Inappropriate material substitutions, poor workmanship & inadequate tooling
  - Discovered when rigging on aircraft

AC 20-107B, Paragraph 6 and 10

- Paragraph 6.c.(3)
  - 14 CFR § 23.573(a) sets forth requirements for substantiating the primary composite airframe structures, including considerations for damage tolerance, fatigue, and bonded joints. *Although this is a small airplane rule, the same performance standards are normally expected with transport and rotorcraft category aircraft (via special conditions and issue papers).*

  (a) For any bonded joint, § 23.573(a)(5) states in part: *3 options (fail safety, proof testing, advanced NDI)*

  (b) *These options do not supersede the need for a qualified bonding process and rigorous quality controls for bonded structures.* For example, fail safety implied by the first option is not intended to provide adequate safety for the systematic problem of a bad bonding process applied to a fleet of aircraft structures. Instead, it gives fail safety against bonding problems that may occasionally occur over local areas (e.g., insufficient local bond contact pressure or contamination)....

- Paragraph 6.c.(4)
  - Adhesion failures found in production require immediate action to identify the specific cause and isolate all affected parts and assemblies for disposition. *Adhesion failures discovered in service require immediate action to determine the cause, to isolate the affected aircraft, and to conduct directed inspection and repair.* Depending on the suspected severity of the bonding problem, immediate action may be required to restore the affected aircraft to an airworthy condition.

- Paragraph 10.b.(2)
  - Certain processing defects cannot be reliably detected at completion of the repair (e.g., weak bonds). *In such cases, the damage threat assessment, repair design features, and limits should ensure sufficient damage tolerance.*

- Paragraph 10.c.(1)
  - …*Bonded repair is subjected to the same structural bonding considerations as the base design (refer to paragraph 6.c).*

Proposed Key Areas for 5/19 Sessions for Discussion on Crashworthiness Cert. Protocol

- Discuss analysis and test protocol used to meet recent special conditions for composite fuselage structural crashworthiness anticipating that detailed design differences will likely exist in the current generation of new aircraft developments
- Understand industry perspectives on important crash analysis and test considerations for substantiation
- Discuss the levels of analysis assumptions, calibration and verification needed to cover all critical failure modes in meeting four criteria in the special conditions
- Further study (+ research) to document detailed background to support industry "best engineering practice" in meeting four criteria in the special conditions (and/or new and evolving regulations)
- Discuss whether additional rules and regulatory guidance are needed to support compliance with 4 criteria in special conditions
  - June 2009 Federal Notice outlined FAA future rulemaking initiative

AC 20-107B: Paragraph 11

- **Para. 11: Additional Considerations (recognizing product differences)**

  11a. Crashworthiness

  Equivalent levels of safety to metal wing & fuselage

  General test and analysis considerations

Content increased from 1.25 to 5 pages

- Paragraph 11.a.(1)
  - Fleet experience has not demonstrated a need to have an aircraft level crashworthiness standard. As a result, the regulations reflect the capabilities of traditional aluminum aircraft structure under survivable crash conditions. This approach was satisfactory as aircraft have continued to be designed using traditional construction methods. *With the advent of composite fuselage structure and/or the use of novel design, this historical approach may no longer be sufficient to substantiate the same level of protection for the passengers as provided by similar metallic designs.*
- Paragraph 11.a.(2)
  - …*A composite design should account for unique behavior and structural characteristics, including major repairs or alterations, as compared with conventional metal airframe designs.* Structural evaluation may be done by test or analysis supported by test evidence. …
- Paragraph 11.a.(4)
  - *Special conditions are anticipated for transport category airplanes with composite fuselage structure to address crashworthiness survivability. The impact response of a composite transport fuselage structure must be evaluated to ensure the survivability is not significantly different from that of a similar-sized aircraft fabricated from metallic materials.* Impact loads and resultant structural deformation of the supporting airframe and floor structures must be evaluated. *Four main criteria areas should be considered in making such an evaluation.*

    (a) Occupants must be protected during the impact event from release of items of mass (e.g., overhead bins).

    (b) The emergency egress paths must remain following a survivable crash.

    (c) The acceleration & loads experienced by occupants during a survivable crash must not exceed critical thresholds.

    (d) A survivable volume of occupant space must be retained following the impact event.

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- Paragraph 11.a.(5)
  - The criticality of each of these four criteria will depend on the particular crash conditions. For example, the loads and accelerations experienced by passengers may be higher at lower impact velocities where structural failures have not started to occur. *As a result, validated analyses may be needed to practically cover all the crashworthiness criteria for transport fuselage*.
- Paragraph 11.a.(7)
  - …The local strength, energy absorbing characteristics, and multiple, competing failure modes need to be addressed for composite structure subjected to a survivable crash. This is not simply achieved for airframe structures made from anisotropic, quasi-brittle, composite materials. *As a result, the accelerations and load histories experienced by passengers and equipment on a composite aircraft may differ significantly from that seen on a similar metallic aircraft unless specific considerations are designed into the composite structure.* …
- Paragraph 11.a.(8)
  - … *Depending on aircraft loading (requiring investigation of various aircraft passenger and cargo configurations), structural dynamic considerations, and progressive failures, local strain rates and loading conditions may differ throughout the structure. Sensitivity of the structural behavior to reasonable impact orientation should also be considered for transport airplane and rotorcraft applications. This can be addressed by analysis supported by test evidence*.