FAA Perspectives on Future R&D Requirements for Structural Integrity - Composites

Presented to: AMTAS Industry Meeting

By: Larry Ilcewicz

Date: March 16, 2010

Outline

- **Composite Safety & Certification Initiatives**
  - Background
  - Selection process for R&D projects
  - FAA Teammates and industry interface
- **Progress and plans linking to research**
  - 2005 to present
  - Future plans (incl. FY12 composite research requirements)
    - ➢ Damage tolerance of composite structures
    - ➢ Structural integrity of adhesive joints
    - ➢ Composite maintenance practices
    - ➢ Environmental & aging effects for composite structures
  - Open discussion

Ongoing FAA Composite Safety & Certification Initiatives

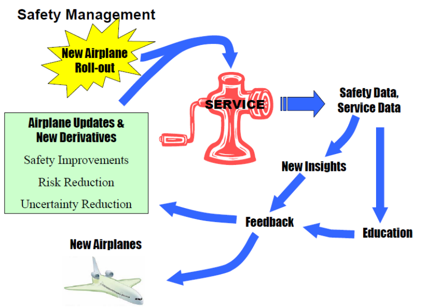
- **Actively working with industry since 1999**

•Approach Following
•Principles of
•Safety Management

Objectives

1) Work with industry, other government agencies, and academia to ensure safe and efficient deployment of composite technologies used in existing and future aircraft

2) Update policies, advisory circulars, training, and detailed background used to support standardized composite practices



- **Safety management (airworthiness) Task Groups initiated within composite standards organizations**
- **Significant efforts underway to educate FAA personnel**

Challenges for Composite Applications

- **Lack of qualified resources for expanding applications**
- **Lack of practical standards and educational materials of relevance to industry applications**
- **Pressure to apply composites to new applications due to potential cost and weight savings**
- **Relatively high development costs not shared within the industry, putting pressures on some segments**

A combination of the above issues pose safety risks that must be mitigated through pro-active efforts

- **Recent FAA focus areas have been in areas of damage tolerance, maintenance and structural bonding**

How Can FAA Reduce Composite Concerns?

- **Promote standardization**
- **Develop guidance that recognizes safety concerns with industry push to minimize costs**

- **Establish safety awareness education for FAA Workforce (FSDO, ACO, MIDO, industry designees)**
- **Continue to benchmark the industry groups and members showing leadership for safe composite applications**
  - Standards organizations (CMH-17, CACRC, ASTM)
  - Applicants that portray leadership as "Model Citizens"
  - FAA/EASA/Industry Workshops

Presentations, recaps and breakout session summaries at:
http://www.niar.wichita.edu/niarworkshops/

Composite Technical Thrust Areas

Advancements depend on close integration between areas

Material Control, Standardization and Shared Databases

Structural Substantiation

- Advances in analysis & test building blocks
- Statistical significance
- Environmental effects
- Manufacturing integration

Progress to Date

- AC 20-107B (9/09)
- 2 other Advisory Circulars
- 6 Policy Memos
- 11 Workshops
- 3 Training Initiatives
- 2 Technical Documents
- CMH-17 Updates
- SAE CACRC Standard
- ~60 FAA R&D Reports

Damage Tolerance and Maintenance Practices

- Critical defects (impact & mfg.)
- Bonded structure & repair issues
- Fatigue & damage considerations
- Life assessment (tests & analyses)
- Accelerated testing
- Structural tear-down aging studies
- NDI damage metrics
- Equivalent levels of safety
- Training standards

Crashworthiness & Flammability

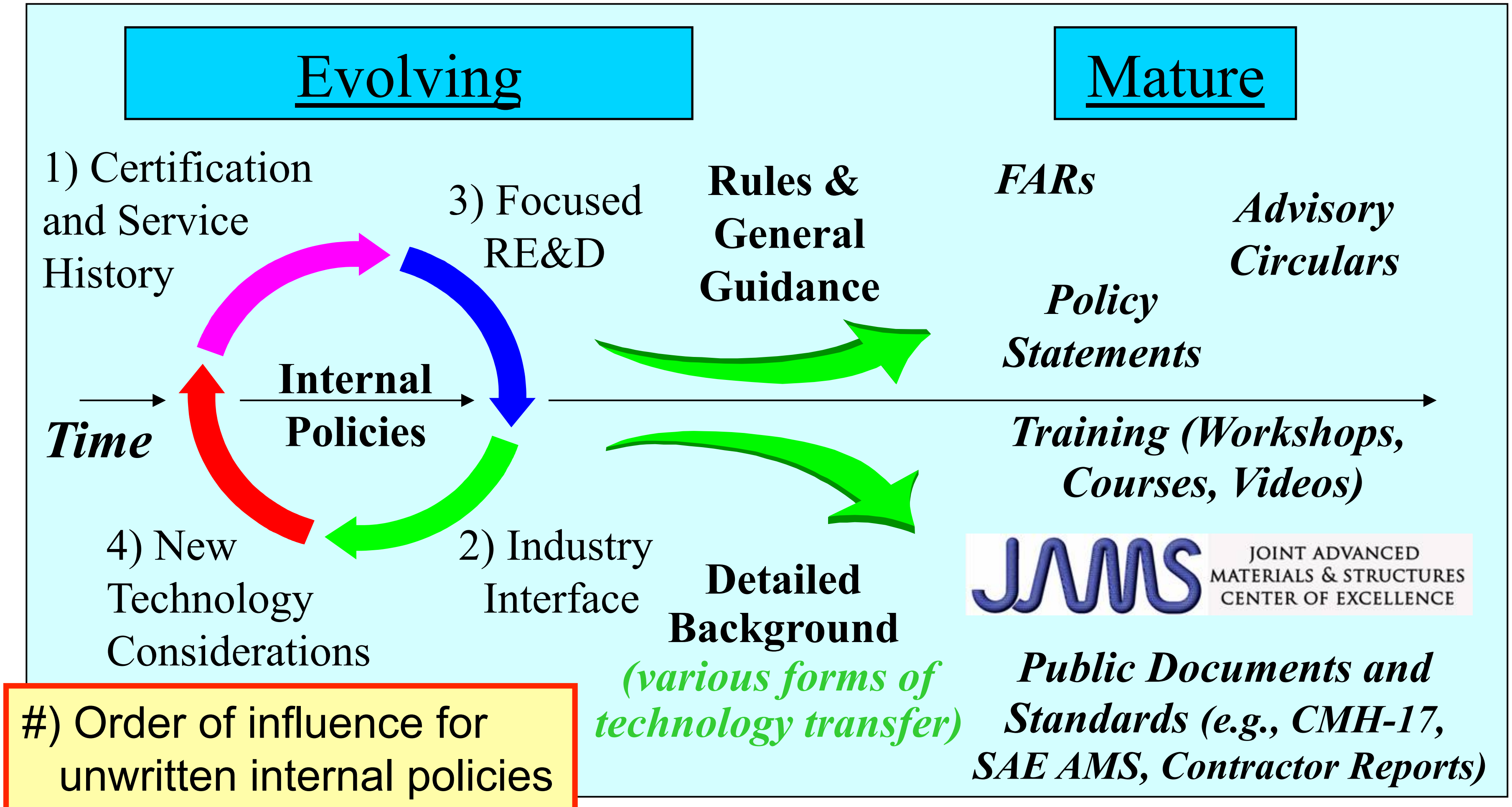
Support to cabin safety research groups

Bonded Joint Processing Issues

Advanced Material Forms and Processes

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

FAA Approach to Composite Safety and Certification Initiatives



Outside (Ref: M. Rassaian, Boeing) View of Selection Process for Composite Research Projects

FAA needs and requirements for the next funding cycle focus in composite research areas

Is there one for AMTAS?

New Technology Considerations

Just received one from JAMS?

AMTAS
Composite technology development….

JAMS
Composite Technology development …

When?

Timing?

Budget?

Alignment with Industry Technology Needs

Identify PI and budget

Evolving

Peer review

Mature

Time

- *Tech Transfer*
- *Advisory Circulars*
- *Training*

FAA Update of Outside View of Selection Process for Composite Research Projects

1) Certification and Service History

3) FAA needs and requirements for the next funding cycle focus in composite research areas

2) Industry Interface

Is there one for AMTAS?

4) New Technology Considerations

Just received one from JAMS?

AMTAS

Composite technology evaluation/ development….

JAMS

Composite Technology evaluation/ development …

When?

Timing?

Budget?

Alignment with Industry Technology Needs/Support

Identify PI and budget

Evolving

Peer review

Mature

Time

- *Tech Transfer*
- *Advisory Circulars*
- *Training*

Answers to Questions and the Complexities of FAA R&D

- **Key FAA Focal (research sponsors and providers)**
  - Larry Ilcewicz (Chief Scientific & Technical Advisor, Composites), lead directorates & field offices to define research requirements (i.e., as related to field problems and certification challenges) and combine the research *outputs* with other factors affecting safety and certification to develop *outcomes* (rules, guidance and training)
  - Curt Davies (Advanced Materials Research Program Manager), lead the FAA advanced materials research to meet *sponsor* requirements and deliver *outputs* to support the sponsor *outcomes*
- **AMTAS & JAMS have the same research requirements**
- **Much of our research has focus on safety concerns from field problems and certification issues**
  - Rarely linked with technology development
  - More likely linked to the evaluation of technology having interest to industry (as related with application to actual parts on aircraft)

Answers to Questions and the Complexities of FAA R&D, cont.

- **Alignment with industry technology needs and support currently comes through an ad-hoc interactive process**
  - Industry cost-share partners have a strong influence
  - Earmarks to specific university groups will ID some research providers
  - Base FAA research budget allows freedom in selecting other research providers per government grant & contract allocation processes
- **Scheduling issues**
  - Three year budget cycle (i.e., new research requests are linked to a congressional cycle that is three years in the future)
  - Budgets in any given year are subject to change during the allocation process --- *This can be a problem but it can also give some freedom to move research projects to an earlier date through "pop-ups", earmarks, or updated plans*
- **Significant FAA efforts needed to *"integrate research"***
  - Attempts to parse out "different pieces of requirements" to different research providers requires considerable FAA efforts

FAA Composite Team Members

Represented Group	Team Member Name	FAA Organization Number & Routing
FAA Technical Center	*Curtis Davies*	*AAR-450 (FAA Technical Center)*
	Michael Shiao	*AAR-450 (FAA Technical Center)*
	Lynn Pham	AAR-450 (FAA Technical Center)
	David Westlund	AAR-450 (FAA Technical Center)
Directorates	*Lester Cheng*	*ACE-111 (Small Airplane Directorate)*
	Bob Stegeman	ACE-111 (Small Airplane Directorate)
	Sharon Miles	ASW-110 (Rotorcraft Directorate)
	Mark Freisthler	*ANM-115 (Transport Airplane Directorate)*
	Allen Rauschendorfer	*ANM-115 (Transport Airplane Directorate)*
	Jay Turnberg	ANE-110 (Engine & Propeller Directorate)
DC Certification	*Dale Hawkins*	*AIR-120 (Aircraft Standards Division)*
Flight Standards	*Otto Hill (& Rusty Jones)*	*AFS-320 (Aircraft Maintenance Division)*
	Gary Goodwin	ANM-200 (Seattle AEG)
ACOs, and MIDOs,	Roger Caldwell	ANM-100D (Denver ACO)
	Hassan Amini	ACE-117A (Atlanta ACO)
	Fred Guerin	ANM-120L (Los Angeles ACO)
	Ken Paoletti	*ANM-120S (Seattle ACO)*
	Angie Kostopoulos	*ACE-116C (Chicago ACO)*
	Richard Noll	ANE-150 (Boston ACO)
	John Harding	ANM-108B (Seattle CMO)
	David Swartz	*ACE-115N (Anchorage ACO)*
CS&TA	*Larry Ilcewicz*	*ANM-115N (CS&TA, Composites)*

Those shown in Blue Italics are most active in CS&CI.
(Many names in black joined for educational purposes. Training has been a priority since recent meeting with AVS management and CAST.)

CSTA Advisors:
Al Broz, Robert Eastin, Terry Khaled, Dave Walen, Chip Queitzsch

Important Teammates

- Partnerships with industry have been essential, **e.g., CMH-17, SAE P-17, CACRC, ASTM, SAMPE, AGATE, SATS, RITA, SAS/IAB/AACE**

Training
Databases
Standardization
Engineering guidelines

- NASA research and other support
  - Significant research support since 1970/1980s
  - AA587, A300-600 accident investigation
- DOD and DARPA research
  - NCAMP support to material standardization
- EASA and other foreign research/standardization

Progress in Composite Safety and Certification Initiatives

Milestones achieved to date

- **FAA policy/training for base material qualification & equivalency testing for shared databases** (update 2003)*
- **Policy/training for static strength substantiation** (2001)
- **New rule & AC for damage tolerance & fatigue evaluation of composite rotorcraft structure** (2002, 2005 & 2009 releases)
- **AC for material procurement & process specs** (2003)*
- **Tech. document on composite certification roadmap** (2003)
- **Policy on substantiation of secondary structures** (2005)
- **Policy for bonded joints & structures was released** (2005)*
- **Tech. document on composite maintenance & repair** (2006)
- **Composite maintenance & repair awareness training** (2008)*
- **AC 20-107B (Composite Aircraft Structure) updates** (2009)*
- **Revision G to CMH-17 in work** (2010)

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

Recent Milestones for Composite Damage Tolerance and Maintenance Initiatives

FAA/NRC Workshop (5/04) Composite Maintenance Overview

FAA Seattle Workshop (11/04) Initiate Composite Maintenance Training (CMT)

JAMS CMT Develop. (11/04-7/05) Draft Course Objectives/Modules

FAA/Industry CMT Workshop (9/05) Detailed CMT Review

Airbus/Boeing FAA/EASA Composite Damage Tolerance and Maintenance WG

Toulouse (9/05) Seattle (3/06)

Workshop presentations, recaps and breakout session summaries at: http://www.niar.wichita.edu/niarworkshops/

JAMS CMT Develop. (7/06-10/09)
SAE CACRC Course Standard

FAA/EASA/Industry Damage Tolerance and Maintenance Workshops

Chicago (7/06) Amsterdam (5/07) Tokyo (6/09)

White Paper on High-Energy, Blunt Impact (9/08)

FAA/EASA/TCCA WG Draft CMH-17 Certification and Compliance Chapter, V3C3 (9/07)

New content in AC 20-107B (9/09)

Ongoing CMH-17 Revision G Developments (2005-2009)

2004	2005	2006	2007	2008	2009

FAA Composite Damage Tolerance & Maintenance Workshops

Chicago, IL, USA July 19-21, 2006

	Wednesday, July 19	Thursday, July 20	Friday, July 21
1st Hour	CMH-17 COMPOSITE MATERIALS HANDBOOK	**Session 2*** Substantiation of Structural Damage Tolerance	**Session 6** Technical Breakout Sessions (*Separate *working meetings covering technical subjects from Sessions 2 - 5)*
2nd Hour			
Break (15 min.)			
3rd Hour		**Session 3*** Structural Test Protocol	**Session 7** Breakout Team Summary Recap/Actions/Closure/Adjourn
4th Hour			
Lunch (1 Hour)			
5th Hour	FAA Initiatives Safety Management Airbus/Boeing/EASA/FAA WG Maintenance Training Update	**Session 4*** Substantiation of Maintenance Inspection & Repair Methods	
6th Hour			
Break (15 min.)			
7th Hour	**Session 1** Applications & Service Experiences	**Session 5*** Damage/Defect Types and Inspection Technology	
8th Hour			

~150 Participants

Amsterdam, Netherlands May 9-11, 2007

	Wednesday, May 9	Thursday, May 10	Friday, May 11
1st Hour	**SAE Commercial Aircraft Composite Repair Committee** Overview of Progess & Plans	**Session 1** **Applications & Field Experiences** *(continued)* Service History of Composite Structure Service Damage & Reliability of Repairs	**Session 5*** **Field Inspection and Repair QC** Test Standards & Inspector Qualifications Reliable NDI Technology Advances Material & Process Controls
2nd Hour			
Break (15 min.)			
3rd Hour	**Airbus and Boeing** Perspectives on Safe Industry Practices	**Session 2*** **Damage Tolerance** Design Criteria & Objectives Structural Test Protocol	**Session 6** **Technical Breakout Sessions** (*Separate *working meetings covering technical subjects from Sessions 2 - 5)*
4th Hour	**Airbus & Boeing (continued)** **SAE CACRC** Active Task Group Reports		
Lunch (1 Hour)			
5th Hour	**SAE CACRC** Active Task Group Reports	**Session 3*** **Damage in Sandwich Construction** Fluid Ingression Growth Mechanisms Analysis & Accelerated Tests	**Session 7** **Breakout Team Summary Recap/Actions/Closure/Adjourn**
6th Hour	**FAA & EASA Initiatives**		
Break (15 min.)			
7th Hour	**FAA & EASA Initiatives** *(cont.)* Recent Progress/Safety Management	**Session 4*** **Repair Design and Processes** Repair Limits Design Criteria & Process Guidelines Structural Substantiation	
8th Hour	**Session 1** **Applications & Field Experiences**		

~110 Participants

Tokyo, Japan June 4 & 5, 2009

	Thursday, June 4	Friday, June 5
1st Hour	**FAA Initiatives** Recent Progress/Safety Management	**Session 4*** **Damage Tolerance & Maintenance Guidance** Near- and Long-term Needs Design and Process Guidance Structural Substantiation = f(application criticality)
2nd Hour	**EASA Initiatives** **Session 1: Applications & Field Experiences**	
Break (15 min.)		
3rd Hour	**Session 1: Applications & Field Experiences** *(continued)* Service History of Critical Composite Structure Service Damage & Reliability of Repairs (all applications) Anticipated issues for expanding applications	**Session 5*** **CACRC Advances for the Future** Near and Long-term Initiatives Shared Databases and Methods Design & Process Guidelines = f(application criticality)
4th Hour		
Lunch (1 Hour)		
5th Hour	**Session 2*** **Damage Threats & Inspection Strategies** Data for Damage Threat Assessments Test Standards & Inspector Qualifications Reliable Technology Advances for Inspection	**Session 6** **Technical Breakout Sessions** (*Separate *working meetings covering technical subjects from Sessions 2 - 5)*
6th Hour		
Break (15 min.)		
7th Hour	**Session 3*** **Damage Tolerance & Repair Substantiation** Design Criteria & Objectives Building Block Approaches (benefits & est. costs) Structural Test & Analysis Protocol	**Session 7** **Breakout Team Summary Recap/Actions/Closure/Adjourn**
8th Hour		

•~120 Participants

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

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

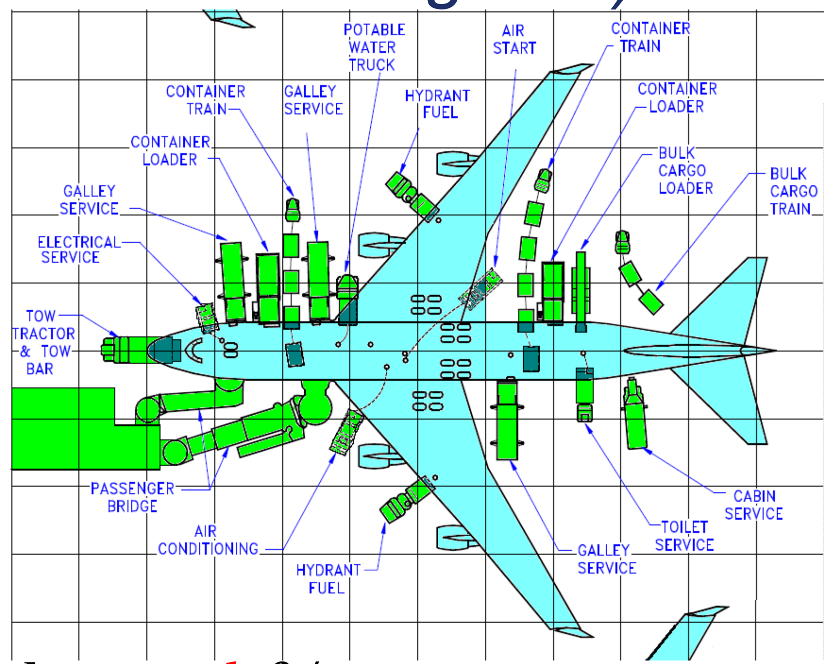
Appendix 2

Appendix 3 (updates to EASA CS 25.603, AMC No. 1, Para. 9 and No. 2: *Change of Material & Process*)

AC 20-107A 11 pages
AC 20-107B 37 pages
Harmonized AMC 20-29
(new sections highlighted by blue)

FAA Technical Paper on Awareness & Reporting of Significant Impact Incidents Involving Composite Airframe Structures
(effort initiated by FAA/EASA/Airbus/Boeing WG)

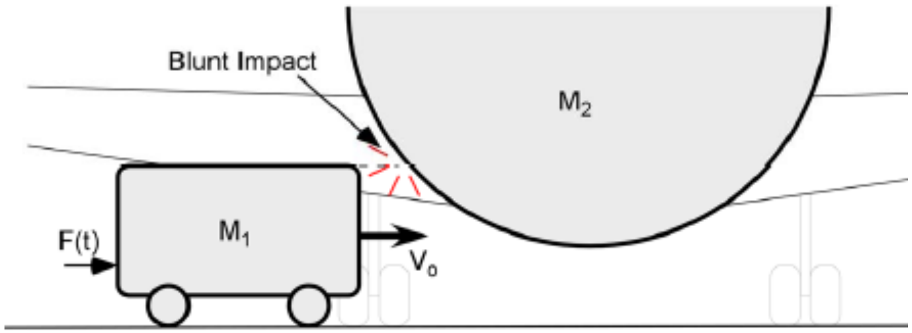
Not all damaging events (e.g., severe vehicle collisions) can be covered in design & scheduled maintenance

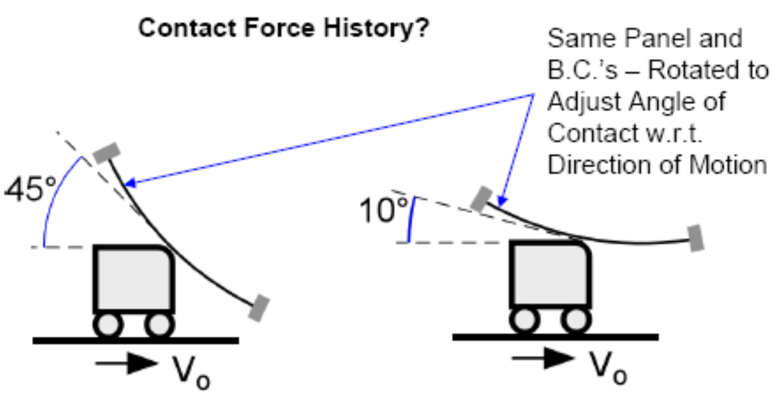


- **Safety must be protected for severe accidental damage outside the scope of design (defined as Category 5 damage) by operations reporting**
- **Awareness and a "No-Blame" reporting mentality is needed**
- **Category 5 damage requirements:**
  a) damage is *obvious* (e.g., clearly visual) and *reported* &/or
  b) damage is *readily detectable* by required pre-flight checks &/or
  c) the *event* causing the damage is otherwise *self-evident* and *reported*
  e.g., obvious, severe impact force felt in a vehicle collision

FAA/Industry Research at University of California, San Diego (UCSD)

- **New R&D started to help bound important variables and worst case scenarios (i.e., most severe internal damage with least exterior visually detectable indications)**
- **Both analysis and test evaluations are planned**
  - Vehicle collision characteristics (e.g., speed, angle of incident, impactor geometry/material and structural location) important to:
    a) damage severity,
    b) details worth reporting,
    c) possible visual evidence and
    d) identification of inspection needs (coordinated with M&I TCRG)



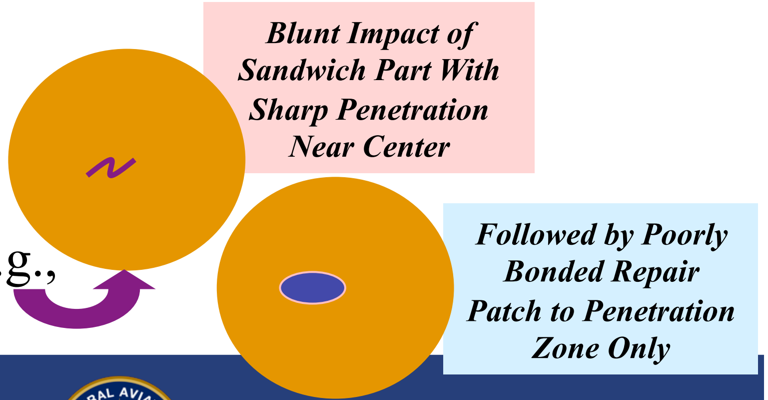


Dr. Hyonny Kim, UCSD

Aero-elastic Stability and Flutter of Damaged Control Surface Structure

- **Transport rudder lost during 2005 flight** (flutter event) **led to service bulletins and associated airworthiness directives**
  - Evidence from the investigation indicated large damage (e.g., extensive sandwich face-sheet disbonding) was needed to cause rudder flutter
  - Airbus presentations at FAA workshops shared key safety findings (e.g., sandwich design details susceptible to disbond growth in ground-air-ground cycling and supporting tests & analyses)
- **Active FAA research to study:**
  - Effects of composite damage on flutter
  - Characterize sandwich damage growth mechanisms & document bad design details
  - Scenarios for damage initiation & growth, e.g.,
  - Standard test & analysis methods

Air Transat Flight 961



Metal Bond Durability Test Standard and Related Guidance

- **Focus on bond durability problems occurring in service**
  - NTSB Safety Recommendations A08-25 to -29 for metal bond failures of helicopter rotor blades
  - Bond process qualification issues (e.g., surface preparation that doesn't provide sufficient long-term durability)
  - Issues of void development and hydration, leading to adhesion failures
- **Research needs**
  - Detailed background for guidance/training on technical issues & proven industry practice
  - Level II safety awareness course development
  - Evaluation of real-time vs. accelerated test degradation mechanisms
  - Standard tests for qualification of long-term environmental durability

Taken from Fiji Accident Reports

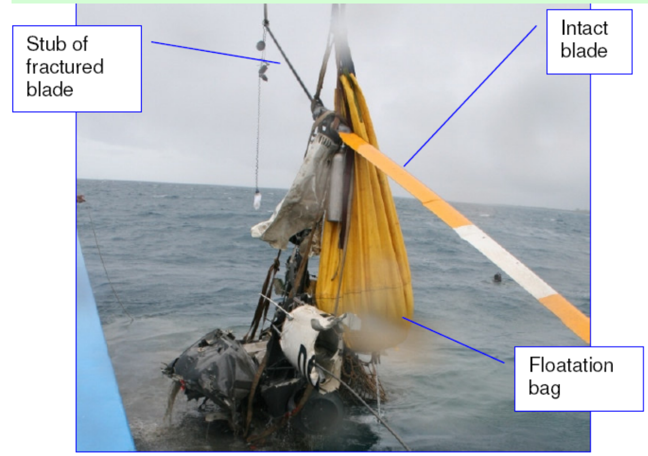


Fig A2 Lifting the main wreckage out of the water

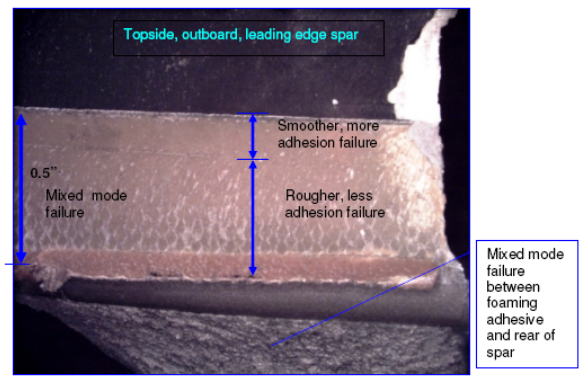


Fig A17 NTSB blade failure analysis

Service Problems With Extensive Repair of Metal-Bond & Composite Aircraft Structure

- **Airline members of the CACRC have been sharing case studies of improper composite repair found in the field**
  - Numerous cases of extensive bonded repairs that have some indication of a problem before destructive tear-down inspection reveals the likely root cause
  - Evidence of the the industry challenges of insufficiently trained resources and economic pressures

Example Case Study: Repaired TE Flap delivered to airline for installation

Improper fit and considerable warp suggested a repair problem

- **Research needs**
  - Detailed background for regulatory guidance and training on the technical issues and proven industry practice
  - International safety standards on expectations for “approved repairs”
  - Level II safety awareness course updates

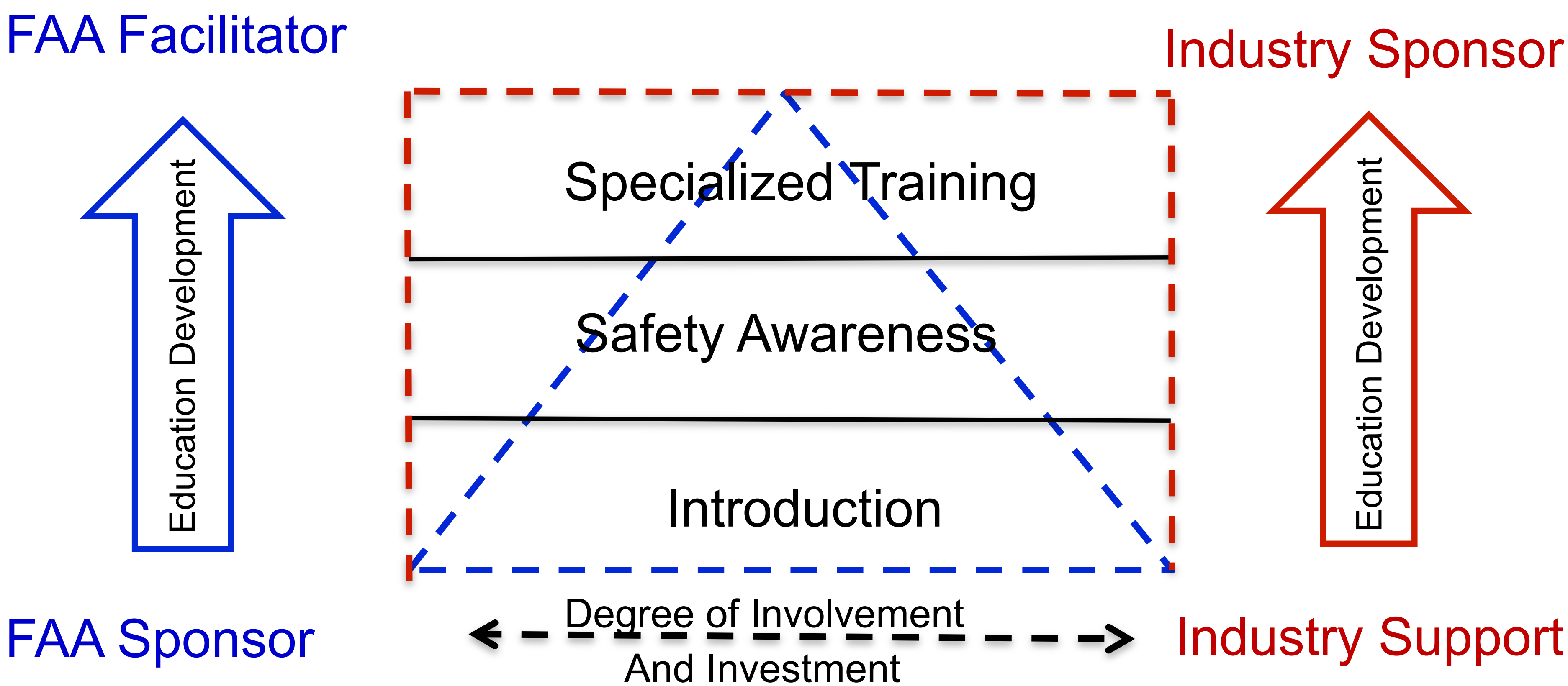
Composite Education Initiatives
Proposed education progression through three levels

Increasing Specialization

Specialized Training (Level III)	→	1. Skill building in specific areas for existing & emerging applications 2. Training for practitioners using experts with real-world experience 3. Industry leadership needed
Safety Awareness (Level II)	→	**1. Composite safety focus, including hands-on laboratory** **2. More details of regulatory guidance and industry practice** **3. Joint FAA/industry leadership**
Introduction to Composites (Level I)	→	1. Basics of composite technology 2. Intro to job roles & responsibilities 3. Certification basics

Some additional focus for functional disciplines (e.g., structural engineering, manufacturing and maintenance) for levels II and III.

Composites Education Initiatives
Joint FAA and Industry Development



Recent/Future Milestones for Composite Safety & Certification Guidance & Training

Release CMH-17 Revision G

- *Advances in statistics, test methods and data reduction protocol*
- *Major Volume 3 re-organization*
- *New Volume 6 (Sandwich)*
- *New certification & compliance chapter* → •6 Hour Tutorial •developed in 2008
- *New crashworthiness chapter*
- *New safety management chapter*
- *Updates to damage tolerance & maintenance* → •FAA/EASA/Airbus/Boeing WG •Inputs - Primary Deliverables

Implement Composite Maintenance Awareness Course

High Energy Blunt Impact Awareness

Release AC 20-107B (Composite Aircraft Structure)

NCAMP shared databases and specifications (CMH-17, SAE AMS)

Composite maintenance guidance/policy for extensive repair

FAA/Industry composite education initiatives

Metal bond durability standards & guidance

Composite damage tolerance guidance

Crashworthiness guidance

2009	2010	2011	2012	2013

- Remaining Charts Include
- FY12 Requirements Sent in
- 3/24/10 from C. Davies and
- the 4 Priorities "Funded" by
- Current FAA Base Budget Process

- **Open Discussion**

Priority 1: Damage Tolerance of Composite Structures

- Study critical defects (e.g., disbonding and other defects) and service damage threats (e.g., impact damage, fluid ingression) to understand the damage tolerance of airframe structures (e.g., sandwich and laminated)
- Support large-scale structural substantiation by establishing structural test protocol, load enhancement factors to cover reliability, analysis limits and test/analysis methods to simulate damage
- Address safety concerns from expanding composite applications such as transport wing and fuselage structure
- Understand damage threats (damage detectability, residual strength, and growth potential) from high energy blunt impact
- Determine the probability of critical damage threats (e.g. in-flight hail, bird strike) and realistic analysis & test simulations along with deterministic engineering assessment to create practical design criteria
- Identify laminated skin design parameters that affect large notch/ penetration residual strength
- Develop a fatigue and damage tolerance module for the structural safety awareness course

Damage Tolerance of Composites, SIC-12-01

Drivers/Rationale

- Study the effects of critical defects and service damage on representative composite airframe structure
  - Potential sources of impact damage, disbonding, fluid ingression, and heat-induced damage
- Damage tolerance design principles and related maintenance practices used by the industry have not been standardized for many damage threats
  - Evaluate industry design criteria and certification test & analysis protocol for critical damage threats
- Identification of emerging risks (see 2/5/09 CAST review of severe blunt impact, e.g., service vehicle collisions)
- Enabling insertion of new composite technologies

Outcome

- Research helps study critical composite damage threats, evaluate industry practices & standardize as appropriate
- Key outcomes include regulatory guidance, industry standards, workshops and related course content
- New composite damage tolerance standards & guidance
  - Shared databases on reliability factors (2012)
  - Severe blunt impact policy (2012)
  - Advance beyond the general AC 20-107B guidance that was just released (2014)
- Composite detailed standards document updates (e.g., CMH-17), training materials & workshops, including SIC research areas (2011, 2014)
- Structural Eng. Safety Awareness Course Module (2012)

Outputs

- Damage tolerance evaluations for composite structure currently in service and near-term applications
  - Identify critical damage and evaluate analysis & test protocol for sandwich & skin-stiffened designs
- Bound threats/risks associated with severe blunt impact, including key parameters affecting damage severity
- Sandwich panel degradation mechanisms due to disbond growth, fluid ingression and freeze/thaw failures
  - Quantify growth rates and the effects on residual strength, stiffness and flutter
- Effect of fasteners in arresting delamination & debonds
- Related safety awareness course developments

Funding

Priority 2: Structural Integrity of Adhesive Joints

- Evaluate the effects of adhesive joint design, process and tooling issues on the integrity of bonded structure (e.g., static strength, fatigue, environmental resistance, aging, and damage tolerance)
- Ensure reliable bonded structure by documenting engineering guidelines and process acceptance criteria; establishing environmental durability testing of metal-bonded aircraft structures and composite bonded joints
- Study bonded stiffening attachments to ensure sufficient process control, certification test and analysis protocol
- Consider combined load conditions, environmental and aviation fluid resistance, long-term aging and damage to support structural joint substantiation protocol
- Develop a bonding module for structural safety awareness course

Structural Integrity of Adhesive Joints, SIC-12-02

Drivers/Rationale

- Evaluate the effects of adhesive joint design, process & tooling issues on the integrity of bonded aircraft structure
- Bonding practices used by industry are not standardized
  - ID reliable bonded structural design details
  - ID key characteristics & process parameters
- Address NTSB Safety Recommendations A-08-25 to -29, including a need for updates in guidance to address long-term durability testing of metal-bonded joints
  - Also needed for composite bonded joints
- Identification of emerging risks for expanding structural applications of bonding (guidance & training needs)
- Enabling insertion of new composite technologies

Outcome

- Research helps characterize bonded joint integrity, evaluate industry practices & standardize as appropriate
- Key outcomes include regulatory guidance, industry standards, workshops and related course content
- New bonded composite standards & guidance
  - Metal-bonded joint durability test standard (2013)
  - Update composite guidance in AC 21-26 (2014)
- Composite detailed standards document updates (e.g., CMH-17), training materials & workshops, including other SIC research areas (2012 - 2014)
- Structural Eng. Safety Awareness Course Module (2012)
- Manufacturing Safety Awareness Course Module (2014)

Outputs

- Evaluations of bonding practices for composite structure currently in service and near-term applications
  - Evaluate in-process quality control procedures to mitigate risks of "weak bond" conditions, which can not be reliably detected by post-process NDI
- Update guidelines and standards for environmental durability tests of metal- & composite-bonded joints
  - Evaluate accelerated versus real-time testing
  - Study surface preparation and processing parameters known to affect bond quality
- Bonded joint fatigue and damage tolerance test protocol
- Related safety awareness course developments

Funding

Priority 3: Composite Maintenance Practices

- Study process variables and human factors contributing to repair process variability in both bonded and bolted repairs
- Resolve the effects of surface moisture exposure and drying of bonded repairs
- Identify inconsistencies and problems in other maintenance practices as well as control key process parameters and characteristics
- Focus on repair processing and proof of structure to reduce poorly performed major repairs with insufficient structural substantiation
- Consider repairs performed on pressurized shell structure to ensure structural integrity
- Evaluate the potential of new technology in health monitoring to support maintenance and mitigate safety risks
- Develop training standards including distance learning

Composite Maintenance Practices, SIC-12-03

Drivers/Rationale

- Study process variables and human factors affecting the reliability of representative field repairs for composite aircraft structure
  - Identify sources of repair defects and repair key characteristics & process parameters to control
- Field problems with composite repair are known to exist and industry practices have not been standardized
  - Evaluate repair processing mistakes found in the field and seek long-term solutions with industry
- Identification of emerging risks (see 2/5/09 CAST review of risks associated with workforce guidance & training needs for expanding composite applications)
- Enabling insertion of new composite technologies

Outcome

- Research helps characterize field repair problems, evaluate industry practices & standardize as appropriate
- Key outcomes include regulatory guidance, industry standards, workshops and related course content
- New composite maintenance guidance
  - Composite repair structural substantiation (2013)
  - Updates to AC 145-6 (2015)
- Composite detailed standards document updates (e.g., SAE CACRC), training materials & workshops, including SIC research areas (2012-2015)
- Update Maintenance Safety Awareness Course Standard AIR 5719 & include case studies of field problems (2012)
- Structural Eng. Safety Awareness Course Module (2012)

Outputs

- Evaluations of maintenance procedures for composite structure currently in service and near-term applications
- Bonded repair assessments considering variables in field working conditions, technician skill levels, and processing parameters important to structural integrity
  - Structural data to evaluate bonded repair
- Bolted repair assessments considering variables in field working conditions, technician skill levels, and processing parameters important to structural integrity
  - Structural data to evaluate bolted repair
- Repair fatigue, durability & damage tolerance test protocol
- Related safety awareness course developments

Funding

Priority 4: Environmental and Aging Effects for Composite Structures

- Identify environmental and aging factors affecting the performance and airworthiness of composite materials (e.g., study sensitivities to service environments and aircraft fluids including real-time interactions with loads)
- Support maintenance practices and establish criteria for structural retirement
- Conduct tear down inspection and laboratory tests on retired aircraft structures.
- Evaluate control surfaces in sandwich and metal-bonded sandwich structures.
- Determine realistic structural temperature exposures and moisture contents in comparison to current worst-case assumptions.
- Evaluate the composite materials in high temperature locations to investigate the effects of exposure to possible heat damage and establish field inspection procedures to detect the level and extent of damage

Environmental & Aging Effects, SIC-12-04

Drivers/Rationale

- Identify environmental and aging parameters affecting the long term performance of composite aircraft structure
- Investigate structural integrity of composite and bonded aircraft parts that have had significant time in service
    - ID dependency on design and process details
    - ID real-time and accelerated test differences
- Identification of emerging risks for expanding composite structural applications (guidance & training needs)
- Enabling insertion of new composite technologies

Outcome

- Research helps characterize real-time environmental effects and aging threats to support more accurate accelerated test standards & design criteria
- Key outcomes include regulatory guidance, industry standards, workshops and related course content
- Composite guidance on environmental effects & aging
    - Advance beyond the general AC 20-107B guidance that was just released (2014)
- Composite detailed standards document updates (e.g., CMH-17), training materials & workshops, including SIC research areas (2012 - 2014)
- Structural Eng. Safety Awareness Course Module (2012)

Outputs

- Perform nondestructive and tear-down inspections of composite & bonded aircraft structure retired from service
    - Contrast the environmental & aging resistance of sandwich and skin-stiffened design details
    - Perform mechanical tests when possible
    - Compare real-time degradation/property changes with that from accelerated test methods & industry design criteria for environmental exposure
    - Assess the quality and structural integrity of repairs mandated by airworthiness directives
- Assess parts subjected to high temp. for heat damage
- Document case studies for the safety awareness courses

Funding

Priority 5: Cabin Safety Issues Unique to Composite Materials

- Investigate composites in airframe structures crucial to cabin safety under crash conditions which must not reduce the level of safety
- Study composite materials and associated airframe structural details that may lead to changes in aircraft crashworthiness
- Perform both analysis and test evaluations to seek in substantiating crashworthiness for new composite airframe designs.
- Assess crashworthiness effect of structural scale and boundary conditions for building block tests, including assessment of strain rate sensitivity for typical composite material properties and their resulting structural behavior
- Evaluate existing analysis methods used to predict the crashworthiness of composite structures and develop test standards to measure the energy absorption of composite details.

Priority 6: Specifications for Material Control and Test Standards for Advanced Materials

- Establish information critical to composite material and process control such as specification requirements and reliable test standards.
- Focus on quality controls for material constituents and effectiveness of statistical process control procedures
- Evaluate material and process control for chopped fiber composites and possible TSO applications to achieve in more efficient structural substantiation procedures
- Develop a material and process control module for structural safety awareness course

Priority 7: Fatigue & Damage Tolerance for Dynamic Composite Structure Applications

- Address fatigue and damage tolerance in dynamic service environments, damage conditions and loads.
- Identify damage growth mechanism for metal-bonded and composite rotorcraft parts and investigate control through damage tolerant design and maintenance practices.
- Define test and engineering protocol for damage growth and arrestment options
- Conduct impact surveys to better understand the potential threat to dynamic rotorcraft parts.

Priority 8: Advanced Materials & Processes

- Study new structural materials (e.g. textile material forms, nano-particle enhanced resins, chopped fiber composites)and processes (e.g. resin-molding processes, stir friction welding, automated ply lay-up and machining processes) to identify the necessary quality controls and structural substantiation protocol
- Study high temperature applications (e.g., ceramic matrix composites)
- Develop an advanced material and processes module for structural safety awareness course.