EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FUR FLUGSICHERHEIT

# Composite Safety Issues

## Industry/Regulator WG

## Damage Tolerance and Maintenance Workshop

## Montreal

## September 2015

**S.Waite, EASA,**
**Certification Directorate**

Your safety is our mission.

# Composite Safety Issues

## Damage Tolerance and Maintenance

15th Sept:

1/ **EASA Future/Developing activities**:

- **R&D**
  - Sandwich Disbond – Airbus/NASA/CMH-17 (R. Hilgers etc)
  - Ageing Composites – EASA – EU
  - HEWABI continuation – EASA - EU

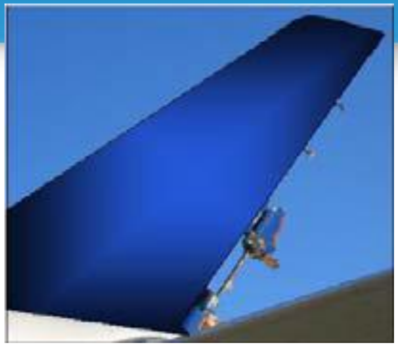
- **CMs** (Certification Memos)**/Generic CRIs** (Certification Review Items)
  - Safe Design and Use of Monocoque Sandwich Structures in Critical Structure Applications
  - non-TCH antenna Mods
  - composite seats

2/ **CM** – **BRSL** (Bonded Repair Size Limits) **–** Progress (ref. L. Cheng)

16th Sept:

3/ **EASA – HEWABI** (EASA - CODAMEIN phase III completion)

# Composite Safety Issues



**EASA Developing R&D:**

**1/** Sandwich Disbond – Airbus*/NASA/CMH-17

Support completion of tasks forming part of the established Airbus/NASA/CMH-17 sandwich disbond project…

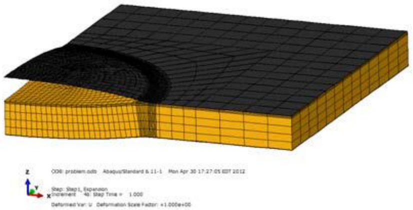
- CS25 configurations – Ground–Air-Ground (GAG)
- consider potential to develop for other configurations, e.g. rotorcraft

* Ralf Hilgers, and Roland Thevenin

# Composite Safety Issues

**EASA R&D:**

**European Honeycomb Sandwich Disbond Characterisation (EHSDC)**



Airbus Operations GmbH / Project Lead

Airbus Helicopter, Donauwörth

DTU – Technical University of Denmark

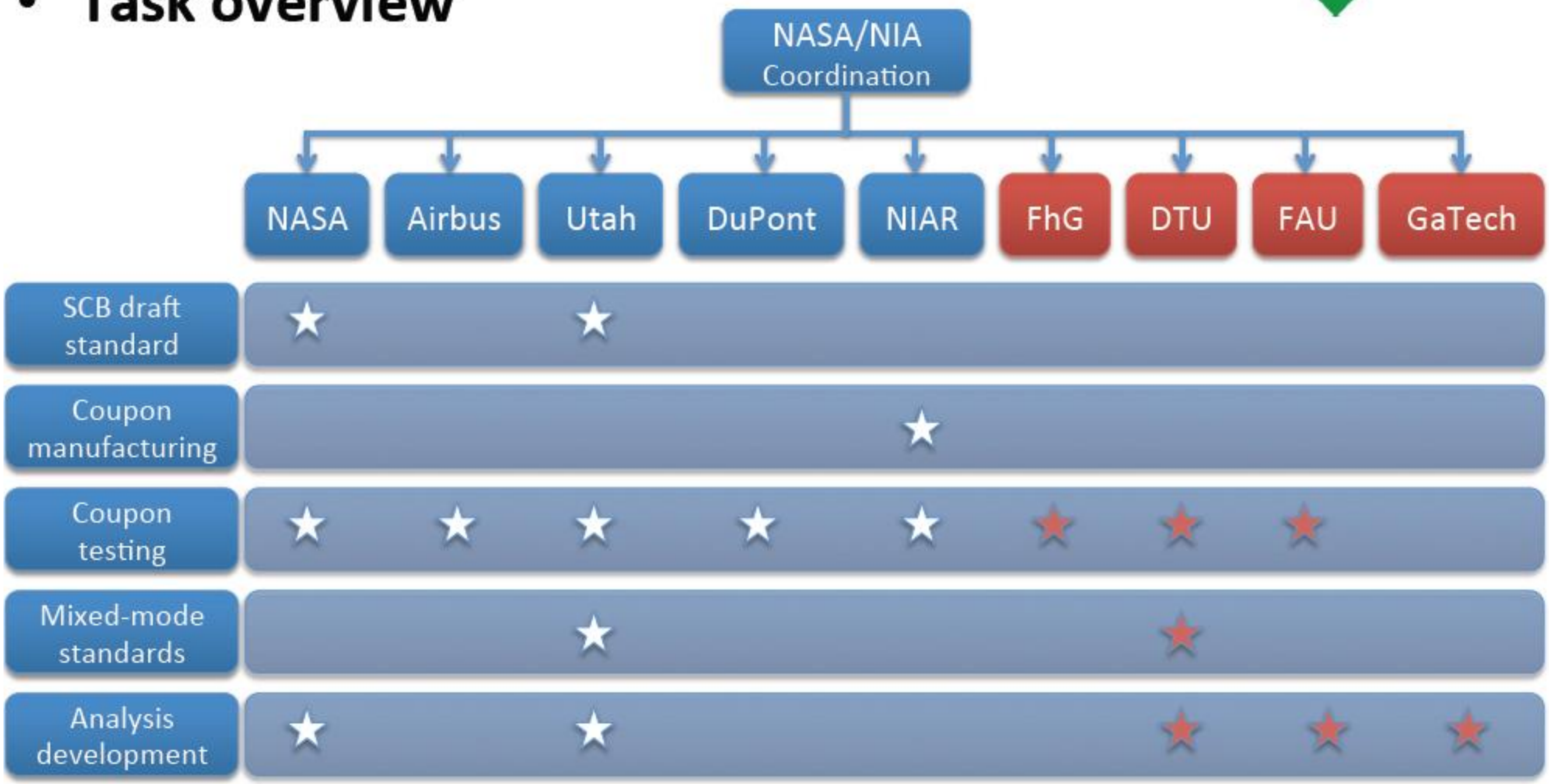
Fraunhofer Institute for Mechanics of Materials IWM

DuPont International Operations Sàrl, Geneva

AIRBUS Fraunhofer IWM DTU DUPONT

## EASA R&D: EHSDC

- **Task overview**



# Composite Safety Issues

**EASA Developing R&D:**

**1/** Sandwich Disbond – Airbus/NASA/CMH-17

**Progress:**

3yrs  3x Euro 100k to support existing Airbus led activity
- status:  passed 1st internal EASA filter (outcome TBD - start 2016 TBD)

# Composite Safety Issues

**EASA Developing R&D:**

**2/** Ageing Composites – EASA – EU

- Many extended composite applications entering service,
  - is there an ageing composite structure issue?

- Benchmark where we are and what might need to be done…

## EASA R&D:

## Ageing Composites

Bonded Joints and Structures - Technical Issues and Certification Considerations; PS-ACE100-2005-10038 Page 21:

**It is impractical to directly evaluate the long-term durability of bonded structures, which includes real-time environmental exposure, in large-scale tests before certification**. As discussed in Sections 3.1 and 3.2, aggressive environments and extreme loading (for example, cleavage forces) are used in smaller scale tests to expose bonded interfaces to conditions, which are known to accelerate degradation mechanisms for weak or contaminated bonds. Although this approach helps ensure good bonding processes, **the long-term durability of bonded production aircraft structure is validated by service experience**. As a result, close ties between the service and production departments of a manufacturer are essential.

Uncertainty supported by literature (see back-up slides):

e.g. engineering property variation resulting from:

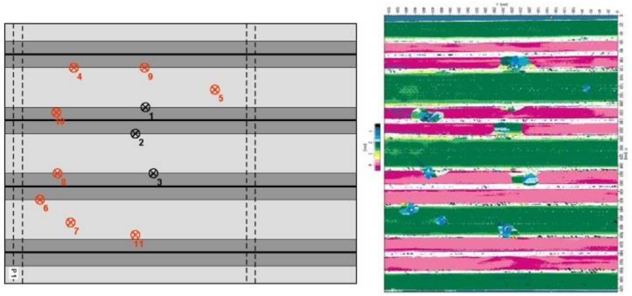
- prolonged exposure to sub-Tg temperatures
- thermal cycling at different sub-Tg temperatures

# Composite Safety Issues

**EASA R&D: issues of interest include:**

- reversed engineering assumptions wrt metallic experience
  - impact threat survey
- degradation mechanisms
  - artificial v real ageing
- hybrid structure
  - thermal aspects

    (real v cert assumptions)



- interaction multiple BVID, degradation, repair interaction

# Composite Safety Issues

## EASA R&D: issues of interest include:

- change to ED

CS25.571: ***Damage-tolerance & fatigue evaluation of structure***

*'(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, or accidental damage, will be avoided throughout the operational life of the aeroplane…'  (also see MSG3, e.g. para. 2.4.3)*

**Current Situation:** composite threat likely to be AD/ED*  (metal experience - Fatigue/ED)

- significant extended application of composites, particularly in structures likely to be subject to impact, e.g. fuselage
- limited in-service experience with these materials in these extended application

**TC acceptance based upon:**

- extensive test, analysis supported by test
- robust design strategy

25.571 building block
for ageing aircraft issues

Note:  AMC 20-20 not called in 25.571, and is metal based

# Composite Safety Issues

## EASA R&D: issues of interest include:

CS25.571: ***Damage-tolerance & fatigue evaluation of structure***

Reminder:

The PSE definition – need for improvement…

*‘2.2 Identification of Principal Structural Elements. Principal structural elements are those which contribute significantly to carrying flight, ground, and pressurisation loads, and whose failure could result in catastrophic failure of the aeroplane.’*

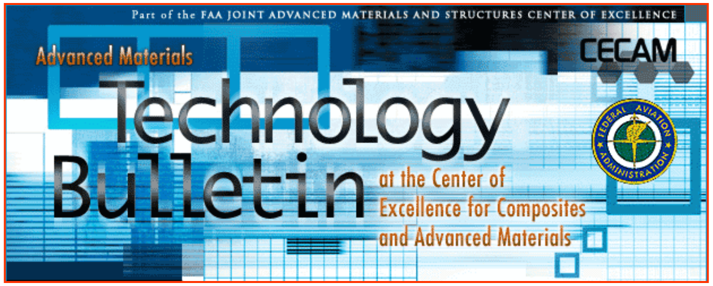
- does not refer specifically to fatigue or metallic structures…
- could be improved (e.g. system structures included etc)
- seats?
- part departing aircraft?

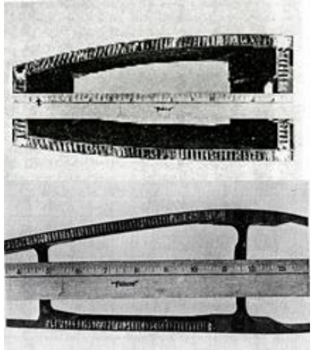
# Composite Safety Issues

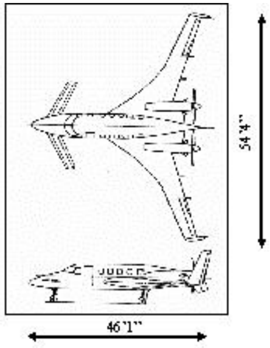
Increasing efforts to understand aging composites include, e.g. FAA, NIAR, and work by A.Baker*, M. Davies**

***Aging Composites:***

- investigation of two aircraft structures, a decommissioned composite Boeing 737 stabilizer that had a commercial service history of 18 years and a Beechcraft Starship with 12 years of service…sub-tasks to understand the aging mechanisms of the structures.






* proposed approaches to detect degradation in service

** developing better understanding of disbond mechanisms

Conclusions: Little evidence of degradation. However, structures not representative of new exposed structure and impact threat environment, e.g. CS25 fuselage

# Composite Safety Issues

## EASA R&D: Objectives:

**Generic:**

**- Identify specific potential ageing composite aircraft structure issues (baseline structure (including bonded joints) and repairs) in existing (and developing) fleets in order to:**

**- provide a comprehensive reference point for EASA in developing international industry and regulatory ageing composite discussions, e.g. regarding the need for fleet leader/fleet sampling activities* beyond existing derived maintenance assumptions, e.g. level of visual inspection in current use etc  (e.g. chemistry)**

**- define potential EASA and/or EU R&D projects addressing ageing composite structures**

* technology application changes develop quicker than ability to develop extensive 'service experience'

(similarly argument could apply to Additive Technology)

# Composite Safety Issues

## EASA R&D: Objectives:

**Specific objectives** (also noting the existing long established use of composite structures in critical structure applications in the small fixed wing and the rotorcraft industries):

**- Literature review of issues identified in this proposal**

**- Literature review to identify any potential ageing composite issues additional to those already identified in this proposal**

**- Identify likely damage mechanisms**

**- Identify inspection/detection methods available which will allow detection of such mechanisms (e.g. visual inspection, structure cut-up, chemical sampling, the use of witness patches etc)**

**- Identify appropriate potential content for fleet leader/fleet sampling activities**

# Composite Safety Issues

**Objectives:**

**- Identify other appropriate potential inspection content, e.g. additional to existing MRB activities etc**

**- Identify potential R&D activities, e.g. identify need for appropriate ‘boneyard’ structure cut-ups, applying repairs to existing ageing structures etc**

**Measurable: Report to be issued addressing the points above**

**Attainable: Possible if EASA quickly identifies key TCH and material manufacturer contributors.**

# Composite Safety Issues

**EASA Developing R&D:**

**2/** Ageing Composites – EASA – EU

**Progress:**

- Phase I - 1 yrs  Euro 50-100k scope issue/define activity for Phase II
- Phase II - ? yrs Euro ??.
- status:  passed 1st internal EASA filter, submitted to EU (2016+ TBD)

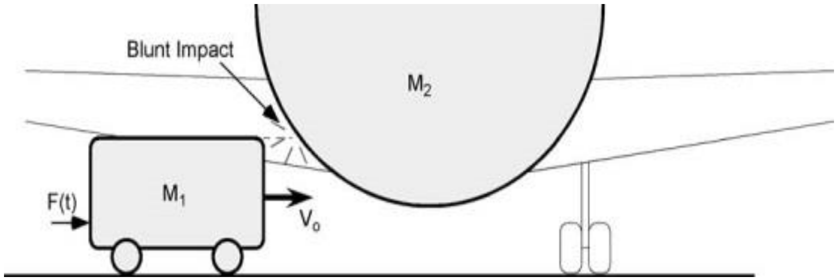
# Composite Safety Issues

**EASA Developing R&D:**

**3/** HEWABI continuation – EASA - EU

Continue the EASA CODAMEIN* work (discuss tomorrow)

- High Energy Wide Area Blunt Impact work run in parallel with FAA project (Hyonny Kim)




- Hyonny Kim: Composite structure (composite skins, stringers, frames)
- Bishop: Hybrid structure (composite skins, stringers, metallic frames)

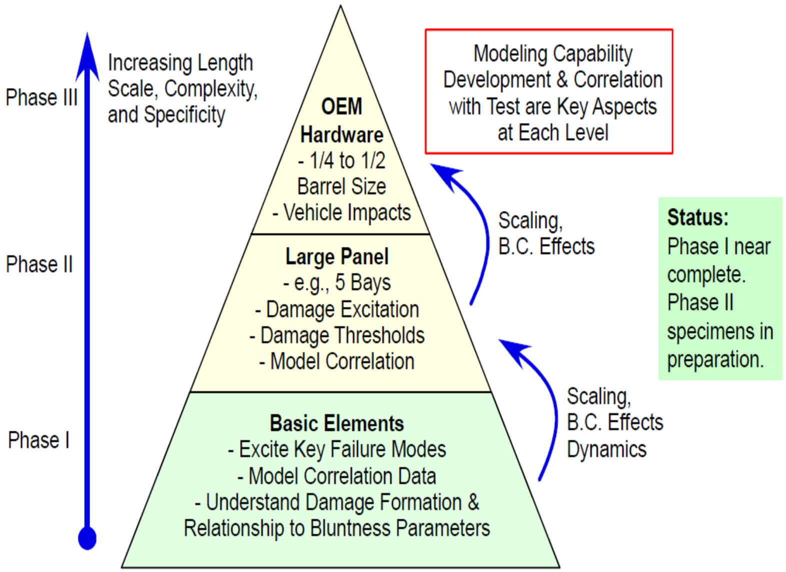
* Composite Damage Metrics and Inspection

*to be discussed tomorrow

**EASA R&D:**

**Composite Damage Metrics and Inspection (CODAMEIN IV)**

Current work (5 frame structure):
- improved (increased) BC identified (barrel + floors)
- test rig limitation (only 18% of planned stiffness achieved)
- marginal external damage indication
- address BC issue & higher pyramid structure



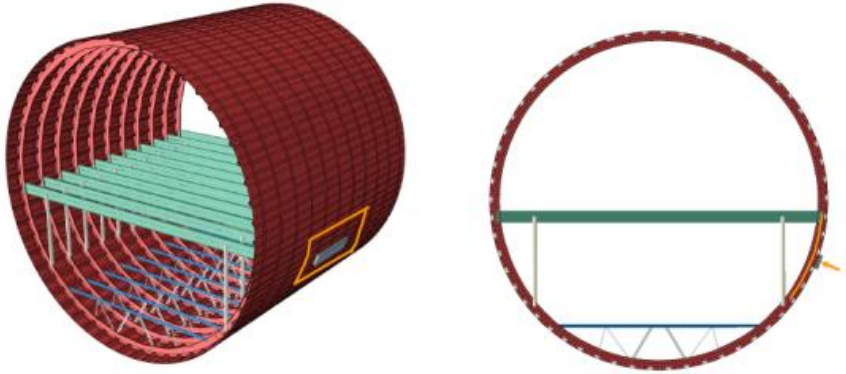



Figure 18 Full Fuselage Barrel FE Model

# Composite Safety Issues

**EASA Developing R&D:**

**3/** HEWABI continuation – EASA - EU

**Progress:**

- Phase IV – 1-3 yrs Euro ? move up test/analysis pyramid
(continue parallel work with H. Kim)
- status: passed 1st internal EASA filter, submitted to EU (2016+ TBD)

# Composite Safety Issues

**EASA Developing CMs/CRIs:**

‘The Safe Design and Use of Monocoque Sandwich Structures in Critical Structure Applications’

# Composite Safety Issues

EASA Developing **CM: The Safe Design and Use of Monocoque Sandwich Structures in Critical Structure Applications**

Background:

- rotorcraft tail boom collapse (primary load path monocoque sandwich*)
  - Cat 5 event, repaired, potentially catastrophic failure mode not detected (design, production, and CAW issues)
- various poor repairs/'remanufacture' and Transat etc… (less critical structure, config differences wrt rotorcraft noted)
- various failure mode, load, location development 'surprises'

Is it appropriate to use such a design concept for primary critical load path structure, particularly when undetectable and potentially catastrophic damage modes may exist?

*definition issues
- Is 'green' skin cured on core really a co-cured structure?
- Is such a configuration a bonded structure?

# Composite Safety Issues

EASA Developing **CM: The Safe Design and Use of Monocoque Sandwich Structures in Critical Structure Applications**

CM intent (for primary load path critical monocoque sandwich structure):

- ensure robust structure design

- explore potential for many damage modes e.g.

  - apply impact through range of impactor geometry configurations and energies, particularly if LL capability cannot be shown with extensive undetectable damage to one skin and/or core and/or the skin-core interface (ref. HBC development experience, e.g. hail threat etc)

- increase attention paid to such structure - teamwork issues (POA, DOA, CAW, interaction - OSD, SMS activities)

# Composite Safety Issues

**EASA Developing Cert Memos:**

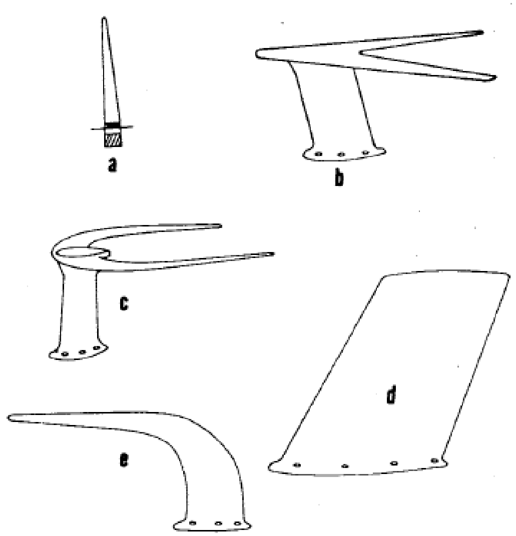
‘The Safe Design and Use of Monocoque Sandwich Structures in Critical Structure Applications’

**Progress:**

- intent and draft text agreed with ENAC Italy (A. Marzano, B. Moitre)
- evolving draft CM applied as CRI on several rotorcraft projects

**EASA Developing CM:**

Non-TCH Antenna Mods (small and large)




# Composite Safety Issues

**EASA concern:** Non-TCH mods, particularly antenna mods and other pressure hull penetration mods

- Metal History: relatively simple, available data allows some scope of non-TCH activity – reality is that it has worked for many decades
- Composites: no shared allowable data available, e.g. open hole, closed hole etc
  - non-penetration areas – holes introduce new potential structure configuration damage modes
  - penetration areas – hole size, geometry, and separation data not readily available
  - local reinforcement strain reduction proposals transfer loads elsewhere

Current TCH position (as EASA understands):

- some structural provisions in airframes
  (inevitably user industry comes up with other needs)
- completion centres/TCH support (cost - level of support?)
- individual applicant contracts with TCHs (cost – timescale issues?)

# Composite Safety Issues

**EASA concern:** Non-TCH mods, particularly antenna mods and other pressure hull penetration mods

Regulator position:

- reality - increasing applications for mods
- user industry expects to be able to complete similar activities in composite airframes as metallic airframes, but does not have data*
- TCHs need to be resourced to support this relative to necessary user timescales and costs
- EASA current position – direct applicants to TCH
- EASA suggests need for more accessible guidance for the benefit of all concerned

* See 'A Conceptual Framework for Practical Progressive Damage Analysis of Stiffened Composite Aircraft Structure with Large Notches Subjected to Combined Loading' – Tom Walker CMH-17, SLC March 2015, for a summary of the 'large notch' challenge

**EASA Developing AOB:**

Composite Seats: static and dynamic seats (pre and post JAR25 amdt.13)

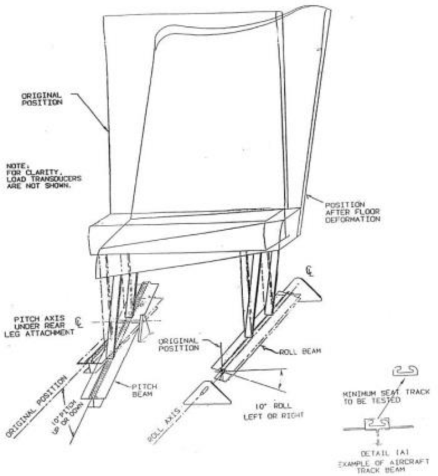



Figure 9-1. Schematic Floor Deformation Fixture—
Seat Legs Attached at Floor Level

# Composite Safety Issues

**EASA Developing AOB:**

Composite Seats (static and dynamic):

- many applicants
- many configurations
- need to standardise (SAE WG formed)
- intent of appropriate sections of AMC 20-29/AC 20-107B applied as supplement to ETSO
    - Manufacturing issues
    - DT - potential for damage to exist, include damage (sharp and blunt impact, disbonded critical joint in test etc)
    - appropriate test/analysis pyramid
    - Post dynamic test application of load (locate hidden damage)
    - continued airworthiness (includes inspection tasks and fleet leader expectations)
    - ‘equivalence’– strength and stiffness (pulse*)

*damaging pulses 20-40g (function of peak and duration).

- seat must be strong enough to not fail < 9g (static), or < 16g (dynamic), but not too strong/stiff resulting in excessive pulse

# Composite Safety Issues

**EASA Developing AOB:**

Composite Seats current Situation:

- first ETSO/TSO issued - pre-JAR 25 chg 13*, ‘static seat’

- SAE WG activity – (lead by Allan Abramowitz – FAA)
  - seems industry does not wish to share at standardisation level - regulators may need to initially address this alone

  *Note: NPA 2013-20 ‘Seat crashworthiness improvement on large aeroplanes — Dynamic testing 16g’ in progress:

  *‘(Part 26).. to add additional airworthiness requirements and specifications for operations in order to make the above CS 25.562 specifications applicable also to newly produced aircraft of already approved type.’*

* Note: crash strain rates typically below level of ‘typical’ significant property change (approaching ballistic), so similar failure mode might be expected (ref. WSU strain rate work etc)

# Composite Safety Issues

## EASA - Bonded Structures:

Disbond or delamination:

- **a disbond/weak bond/delamination exists**
- **< UL capability** (large damage/disbond, critical location)
- **damage/defect remains undetected**
- **load event > Residual Strength capability** (>LL)

- all of these can occur, but typically not together.....

- most events not significant safety issue*
  (most applications have not been significant)

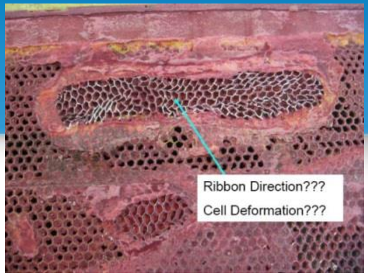
**1 incident 10^6 hrs**
**1 serious incident 10^8 /10^9 hrs**
No fatal accidents
(CAA-UK MOR & fleet data only)


**1 serious incident/accident**
**>10^8 hrs**
- EASA database

*variable quality data

- unclear if disbond is cause or witness (either situation suggests poor process)
- need to improve forensics and taxonomy

# Composite Safety Issues




## EASA Bonded Repair Size Limits CM - Update:

- Policy text in agreement with FAA PS (and previous WG agreement)
- status:
- Minor outstanding issue: European industry requested visibility of criteria allowing deviation from LL limitation, e.g. when TCH has adequate control/confidence/experience to show that the repair facility can achieve more (approaching production repair capability?)
- published 11th September 2015

http://easa.europa.eu/system/files/dfu/%27final%27%20CM-S-005%20Issue%2001_Bonded%20Repair%20Size%20Limits_PUBL.pdf

# Composite Safety Issues

## Further point: MRB (Maintenance Review Board) v ALS

Recent Activity Example: Discussed briefly with FAA, Airbus, Boeing at CMH-17 meeting (August 2014).

Level Playing Field*?:

needs standardisation?

e.g. existing product ALSs do not appear to be the same…

- What differences in design and substantiation justify such a difference?
- What differences in regulatory practice justify such a difference?
- What level and frequency of inspection is appropriate for ageing composite fleet?

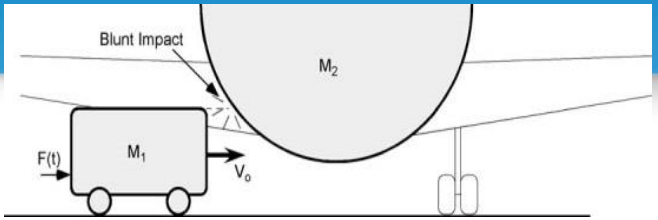
*Note: Too many interfaces between and within TCH/Regulators

- MRB Industry/EASA (MRBIE) – link Design Organisation Approval process to MRB activities (within organisations and EASA)
  - process trial 4 TCHs engaged
- function wrt Bilateral Agreements - TBD

# Composite Safety Issues

Questions?

# Composite Safety Issues




## EASA R&D:

## Composite Damage Metrics and Inspection (CODAMEIN – Phase III completion)

See Bishop Phase III completion presentations

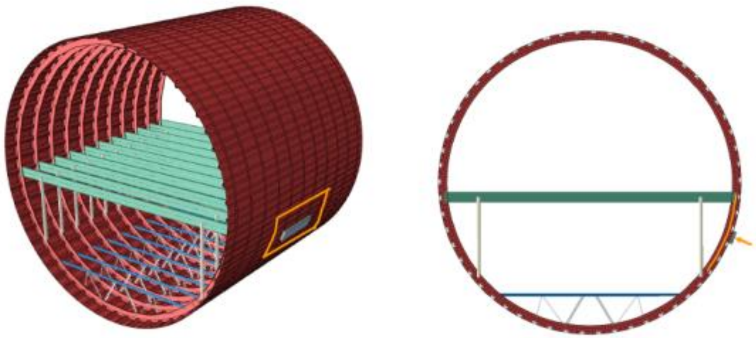
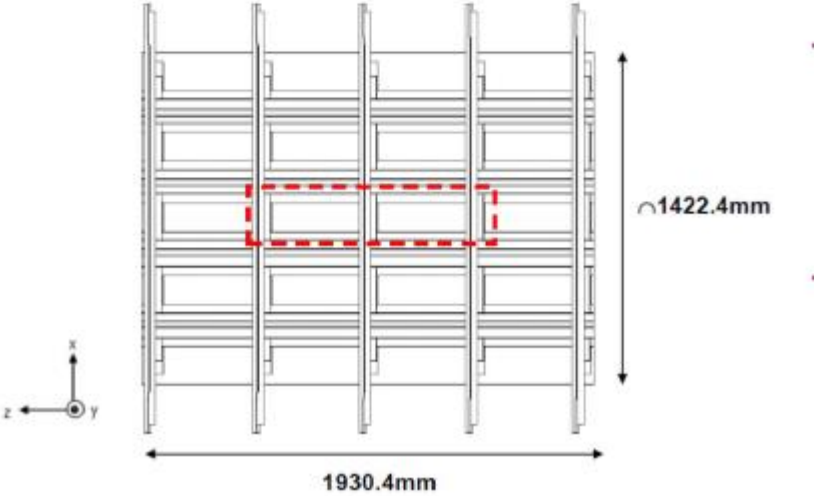


Figure 18 Full Fuselage Barrel FE Model



**EASA R&D:**

**Composite Damage Metrics and Inspection (CODAMEIN – Phase III completion)**

See Phase III closing presentations

**Conclusions/recommendations:**

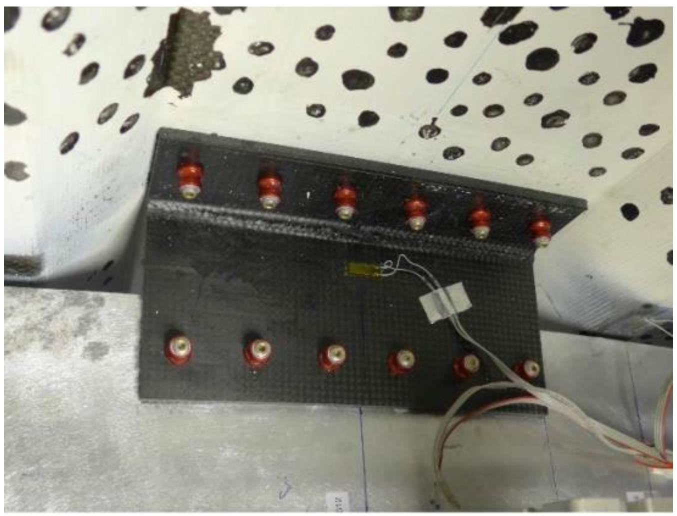
1/ significant internal damage produced with limited external damage being evident

notes:

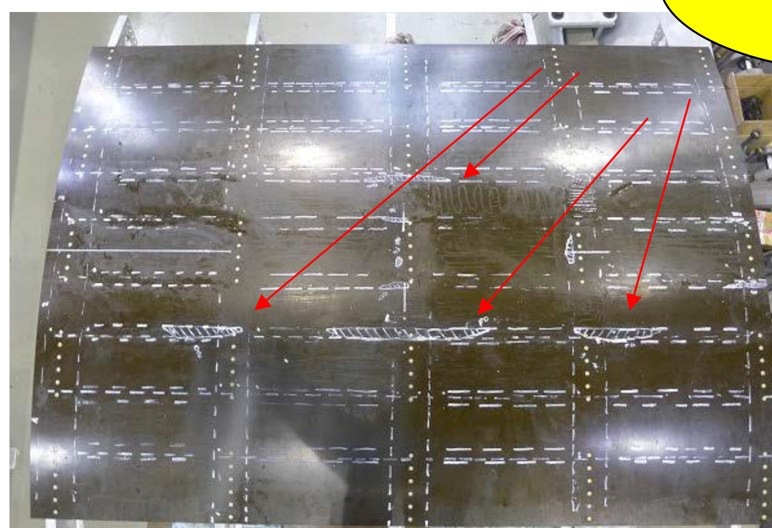
- although improved stiffer BCs defined (included floor structure etc), test equipment only permitted 18% of intended rotational stiffness to be achieved

- although project aimed to test 'worst case' scenario, the actual externally evident damage was the result of contact between the skin and a local bolt attaching the rubber bumper to the impactor (suggests difficultly trying to intentionally produce undetectable damage). However, significant shear tie damage resulted from lower level load case – no external damage

## EASA R&D:



externally visible crack
- bumper attach
fastener contact



extensive delamination
- stringer feet
- shear ties

# Composite Safety Issues

**EASA R&D:**

2/ evolved modelling from Phase I and II (+ working with H.Kim) allowed reasonable prediction (approx. 7% ) of initial internal damage initiation

Model: Non-linear, explicit, dynamic (ABAQUS)

- continuum shell (was shell)
- cohesive elements (to address delamination, e.g. between co-cured elements, and within shear ties (only 2 layer))
- failure criteria added (Hashin)
- fasteners represented

- damage much as Phase I and II, shear tie failures, followed by frame bending

# Composite Safety Issues

**EASA R&D:**

Hypothetical Summary wrt Cert requirements:

'reverse engineering' suggests impacts > 140J* occur < 10-9 flt/hr
it does happen, but is it always reported (ground event)?
– hence need for the developing policy.

Summarising Phases I, II, III

| | |
|---|---|
| 1st internal damage (shear tie) | 946J |
| multiple shear tie and stringer feet delam damage (+ some frame bending) | 2000J** |

** externally visible (only due to local fastener contact)

Can this be managed as an extended Cat 2 local to door cut-outs?

# Composite Safety Issues

Bishop GmbH Aeronautical Engineers

## Load Level- Detectible Damage

| Specimen ID | Load Cycle | Shear Tie t [mm] | Bumper Displacement [mm] | Max Load [kN] | Energy Level [J] | Failure detected |
|---|---|---|---|---|---|---|
| CODAMEIN 1 | - | 2,5 | Bumper | - | - | None |
| CODAMEIN 2 | Pre1 | 2,5 | fully | 20 | 707 | None |
| CODAMEIN 3 | 1 | 5,28 | compressed | 27,6 | 726 | None |
| CODAMEIN 1 | 1 | | 126 | 46,7 | 1269 | Centre Shear Tie unfolding |
| CODAMEIN 2 | 1 | | 119 | 39,2 | 969 | Centre Shear Tie cracked |
| CODAMEIN 3 | 1 | | 110 | 27,6 | 726 | No failure all intact |
| CODAMEIN 1 | 2 | | 136 | 57 | 1601 | Centre Shear Tie cracked |
| CODAMEIN 2 | 2 | | 130 | 57 | 1409 | Significant Shear Tie crack |
| CODAMEIN 3 | 2 | | 126 | 66,3 | 1445 | No failure all intact |
| CODAMEIN 1 | 3 | | 153 | 83 | 2020 | All Shear Tie cracked Frame twist |
| CODAMEIN 2 | - | | - | - | | |
| CODAMEIN 3 | 3 | | 154 | 133,6 | 4319 | Centre Shear Tie cracked Frame permanent deformation |
| UCSD FRAME#1 | final | | 75,5 | 57,4 | | Frame crack |
| UCSD FRAME#2 | final | | 55,9 | 71 | | Frame crack |

| Structure Stiffness | Threshold | Test Load Level | Energy Plateau | Detectible damage |
|---|---|---|---|---|
| Low | 1 | 20-27 kN | 700 J | **No failure** Bumper fully compressed **Undetectable damage** |
| Low | | 39-46 kN | 1000 J | Local Shear Tie unfolding, Skin intact **Undetectable damage** |
| Medium | 2 | 57-66 kN | 1500 J | Local Shear Tie damage, Skin intact **Undetectable damage*** |
| Medium | | 66-83 kN | 2000 J | All Shear Tie damage, Skin intact **Undetectable damage** * |
| High | 3 | > 83 kN | >2000 J | Shear Tie, Frame permanent deformation, Skin crack **Detectable damage** |

*** Undetectable damage from Outside, Detectible damage Inside when incident reported**

# Composite Safety Issues

Possible MoC:

Further to a basic robust design strategy…

1/ Explicitly require 'fail-safe' design in high threat areas

and/or

2/ Extended analysis, + limited additional 'book case' reference testing:

- identify structure at 'high' risk of HEWABI
- select 'typical' high risk configuration(s)
- analysis impact with representative impact energy/impactor which might result in no external damage (1000-2000J/rubber bumper)
- validate model with representative impact energy/impactor (1000-2000J/rubber bumper) 'book case' test which is expected to exercise the dominant damage modes
- ensure damage modes and extents supported by Cat 2/3 work (residual strength/substantiated inspection intervals)

# Composite Safety Issues

HEWABI – evolving related regulations:

Further to AMC 20-29/AC 20-107B:

> ‘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’

*EASA Basic Regulation EC No 216/2008 Annex II says (draft amendment):*

*D. Ground handling services:*

*(b) the provider shall ensure that movements of vehicles and persons in the movement area and other operational areas are coordinated with movements of aircraft in order to avoid collisions and damage to aircraft;*

# Composite Safety Issues

HEWABI – evolving related regulations:

New Rules/AMC: Improve operating environment and training, e.g.

ADR.OPS.B.025 Operation of vehicles:

*'The aerodrome operator shall establish and implement procedures for the training, assessment and authorisation of all drivers operating on the movement area'*

Supported by, e.g.

Ramp Resource Management (RRM) – Ground Training Syllabus: http://easa.europa.eu/essi/ecast/wp-content/uploads/2013/01/RRM-training-syllabus-supporting-document-NLR-TR-2012-483-tr.pdf

# Composite Safety Issues

HEWABI – European NAA activities/fleet leaders:

Further to CAA-UK Composite Workshop (26/4/13 London Gatwick), intended to address arrival of the new large composite pax aircraft fleets: (CAA, BA, Virgin, Thompson, EASA, Boeing, Cranfield University, Service Air)

Actions:

CAA will re-engage with operators within 1-2 years to review ground handling reports across all fleets;

CAA will engage with EASA to discuss:

- share data regarding HEWABI events
- reviewing any data on ad-hoc strip downs of a/c that might reveal undetected internal damage.
- CAA will investigate the current in-house training regimes/needs for the surveyor community with regard to understanding the differences in composite damage versus metallic structural damage.

Next meeting to be organised by CAA-UK

# Composite Safety Issues

HEWABI – need to improve databases:

- current databases limited – ground events not well captured

EASA ADREP Database 2007-2014: CS25 Worldwide occurrences reported by Accident Investigation Boards (mainly accidents and serious incidents).

| Sum of Number | Column Labels | | | |
|---|---|---|---|---|
| Row Labels | Accident | Incident | Serious incident | Grand Total |
| Collision - Vehicle with Another Vehicle | 1 | | | 1 |
| Collision - Vehicle with Standing Aircraft | 2 | 1 | 1 | 4 |
| Ground Collision with Building | 7 | | 1 | 8 |
| Ground Collision with Lighting | 2 | 2 | | 4 |
| Ground Collision with Moving Aircraft | 23 | 6 | 8 | 37 |
| Ground Collision with Other Ground Object | 8 | 13 | 3 | 24 |
| Ground Collision with Parked Aircraft | 19 | 8 | 4 | 31 |
| Ground Collision with Vehicle/ Equipment | 15 | 6 | 9 | 30 |
| Grand Total | 77 | 36 | 26 | 139 |

1.7E-08 impacts/cycle

# Composite Safety Issues

## ECCAIRS European Central Repository 2007-2014: CS25 EASA MS Occurrences reported by operators to the NAAs through their Mandatory reporting systems.

| Sum of Number | Column Labels | | | |
|---|---|---|---|---|
| Row Labels | Accident | Inciden t | Serious incident | Grand Total |
| Collision - Towed aircraft with Object | 1 | 1 | | 2 |
| Collision - Vehicle with Another Vehicle | | 2 | | 2 |
| Collision - Vehicle with Standing Aircraft | 5 | 39 | 5 | 49 |
| Ground Collision with Building | 3 | 17 | 1 | 21 |
| Ground Collision with Lighting | 1 | 19 | 2 | 22 |
| Ground Collision with Moving Aircraft | 9 | 31 | 5 | 45 |
| Ground Collision with Other Ground Object | 3 | 49 | 4 | 56 |
| Ground Collision with Parked Aircraft | 5 | 23 | 5 | 33 |
| Ground Collision with Vehicle/ Equipment | 19 | 137 | 7 | 163 |
| Grand Total | 46 | 318 | 29 | 393 |

9.65E-07 impacts/cycle

Database improvements:

- extend database access (improvements planned in November 2015)
- improve taxonomy

# Composite Safety Issues

Questions?

# Composite Safety Issues

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Support Slides

# Composite Safety Issues

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**EASA Developing R&D:**

**1/** Sandwich Disbond – Airbus/NASA/CMH-17 (R. Hilgers etc)

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## EASA R&D: EHSDC

### Partners Involved

- James Ratcliffe/ NASA
- Ralf Hilgers/Airbus
- Sönke Fimmen/Airbus
- Dan Adams/ Utah
- Ralf Schäuble / FhG*
- Waruna Seneviratne/NIAR
- Christian Berggreen/DTU*
- Yannick Albertone/ DuPont
- Ley Richardson/ DuPont USA – D30.09 co-chair
- Ronald Krueger/NIA – CMH-17 Disbond/Delam co-chair
- Leif Carlsson/ FAU*
- George Kardomateas/ GATech*

# Composite Safety Issues

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**EASA Developing R&D:**

**2/** Ageing Composites – EASA – EU

Support Slide

degradation beyond the direct Tg issue

Questions Regarding Accelerated Ageing: Example

**Interfacial ageing of high temperature carbon/bismaleimide composites** Adrian Lowe, Bronwyn Fox, Vincent Otieno-Alego

Ageing studies were performed on a carbon fibre–bismaleimide (CBR320/328) system developed by the CSIRO in Australia, with a fibre volume fraction of 55%. This material has a glass transition temperature of 302 °C and the effect of ageing at 204 and 250 °C on the interfacial region was studied. A variety of test techniques were employed to characterise interfacial property changes (mode I delamination, SEM, Raman); chemical changes due to ageing (Raman, FTIR); changes in glass transition temperature (DMTA) and weight loss. The results showed that both interfacial and resin degradation mechanisms differed between the two temperatures. It can, therefore, be concluded that accelerated ageing is not applicable to this system.

- potentially different ageing responses
- how do you select appropriate accelerated ageing?
- does it matter for lower cure airframe systems?

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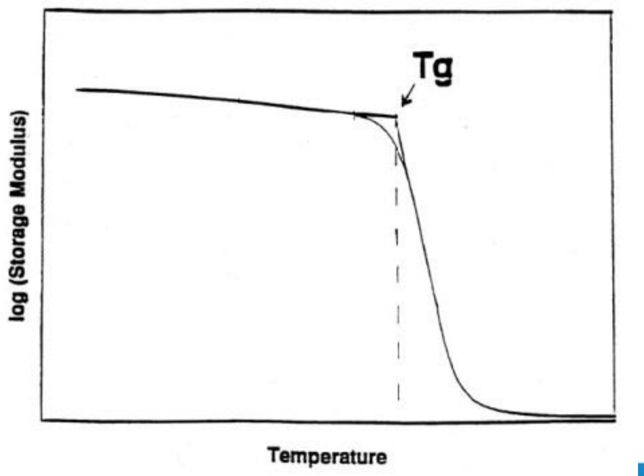
**Physical Aging of Epoxy Polymers and Their Composites**
G.M. Odegard and A. Bandyopadhyay
*Journal of Polymer Science Part B: Polymer Physics* 49(24) 1695-1716 (2011)

- it is clear that physical aging involves the simultaneous reduction of free volume and conformational changes of the crosslinked molecular structure when exposed to **sub-*Tg* temperatures** for extended periods of time. The changes in the molecular structure result in bulk-level responses of epoxies. Specifically; mechanical, thermodynamic, and physical properties of epoxies are influenced in a manner that significantly alters the overall response of these materials.

degradation beyond the direct Tg issue

- matrix properties
- important for shear and compression



# Composite Safety Issues

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G.M. Odegard and A. Bandyopadhyay

*Journal of Polymer Science Part B: Polymer Physics* 49(24) 1695-1716 (2011)

Several studies have been conducted on the physical aging of fiberous epoxy composites.25,44,45,49,86,123,124 In general, these studies indicate that the composite material response to physical aging is very similar to the corresponding response of neat epoxy resin. The presence of glass or carbon fibers has little influence on the physical aging characteristics. It is also clear that physical aging has little influence on the strength of the fiber/epoxy interface,124 which indicates that physical aging does not alter the load-transfer characteristics of fiber-reinforced composites.

- significance needs to be quantified for engineering purposes