



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

EASA COMPOSITE MATERIALS SAFETY STRATEGY

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FAA Workshop on Modifications and Alterations affecting
Composite Parts or Composite Structure,
July 2016,
Wichita

Your safety is our mission.



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EASA Composite Materials Safety Strategy

EASA Composite Materials Safety Strategy:

FAA Workshop on Modifications and Alterations affecting
Composite Parts or Composite Structure

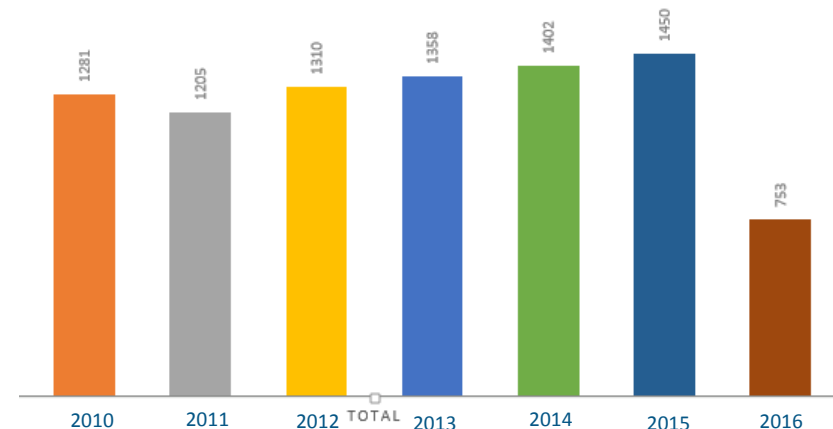
Scope:

- composite baseline structure
- composite addition to metal baseline structure
- metal addition to composite baseline structure
- composite addition to composite baseline structure

Content:

- Introduction
- Material and/or Process change
- Antenna
- Winglets/Sharklets
- Interiors
- Composite Seats
- Bonded Repair Size Limits (BRSL)
- Decals/vinyl wraps

MAJOR CHANGE/MAJOR REPAIR APPLICATIONS TO EASA
(ALL PRODUCT CHANGES/REPAIRS, NOT ONLY COMPOSITES)



Note: Many issues in common with metallic structure. Composites increase the configuration options



EASA Composite Materials Safety Strategy

Design philosophy for 'changes' e.g. metal to composite, or additive manufacturing:

Do not reduce the 'existing Level of Safety'

- show 'equivalence' to existing technologies, result of:
 - experience
 - reaction to incidents and accidents
 - R&D
 - 'engineering judgement'
 - regulations existing at the time of certification
 - Type Certificate Holder (TCH) in-house design practices

baseline structures,
changes, and repairs

Maintain robust 'aircraft level' design concept

- address all identified threats, e.g. manufacture, in-service
- similar to established metallic structure, e.g. T. Swift philosophy etc

Note: local damage may be different, but structural level failure may be driven by the similar failure mode, e.g. buckling



EASA Composite Materials Safety Strategy

Design Philosophy: robust design concept

- to be similar to established metallic structure except:
 - potentially different/more competing damage modes
 - some damage modes not readily detected

e.g. delamination, disbond, weak bonds

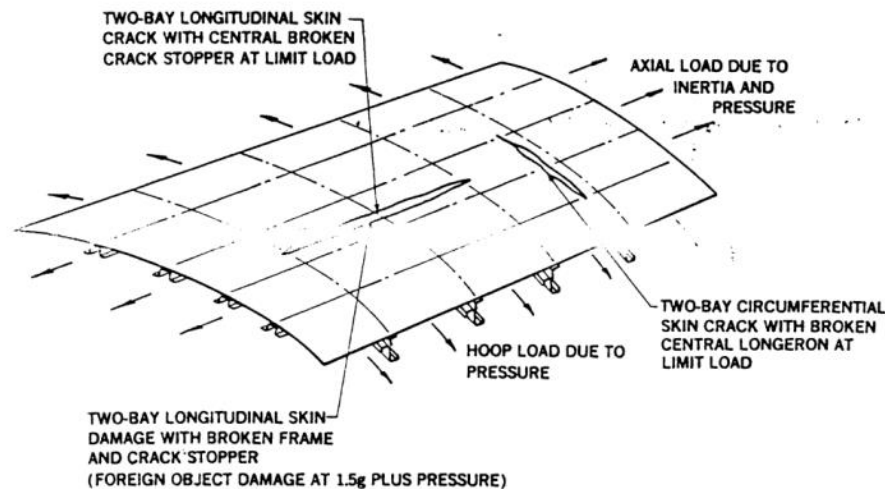


FIGURE 2. FUSELAGE DAMAGE TOLERANCE SIZES FOR STRUCTURAL DESIGN

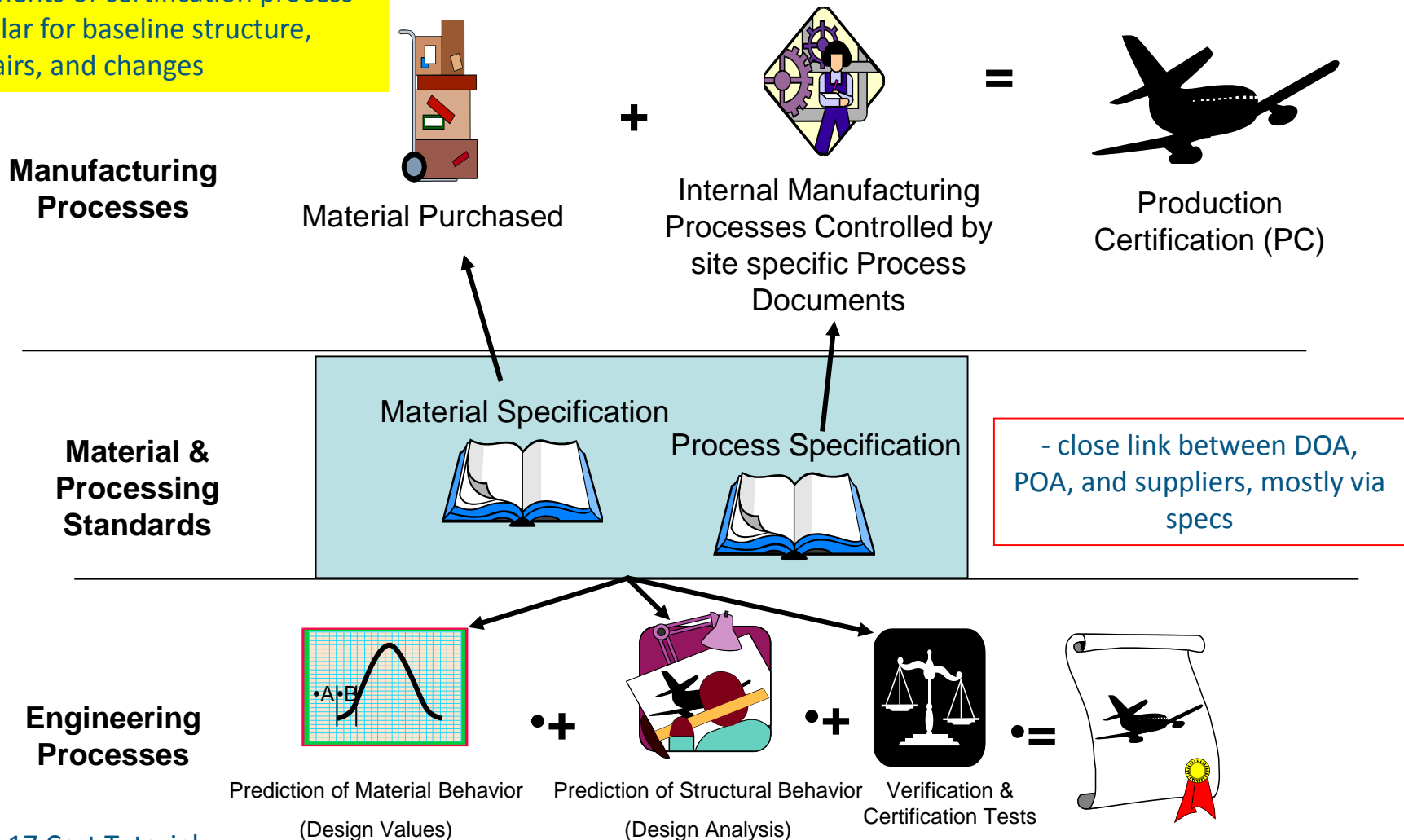
Metal Design - Design for Redundant Structures' - T. Swift

- additional consideration may be required for technologies which change design concepts



EASA Composite Materials Safety Strategy

- elements of certification process similar for baseline structure, repairs, and changes



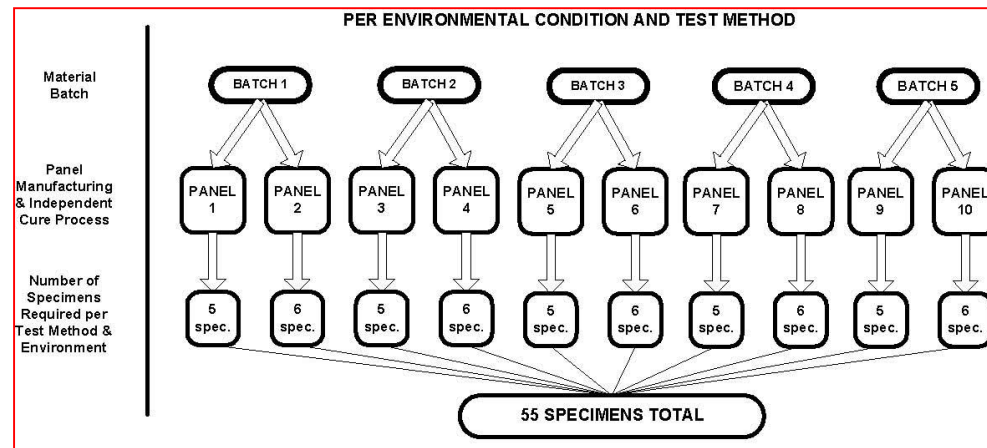


EASA Composite Materials Safety Strategy

Material and Process Changes: AMC 20-29 Appendix 3*:

Continued Airworthiness includes **managing material and process change**, e.g. due to material production changes ranging from change of production equipment through to fibre and matrix change, weight change mods etc

- defines statistics, i.e. batch numbers for re-test etc.



* Harmonised with AC 20-107B

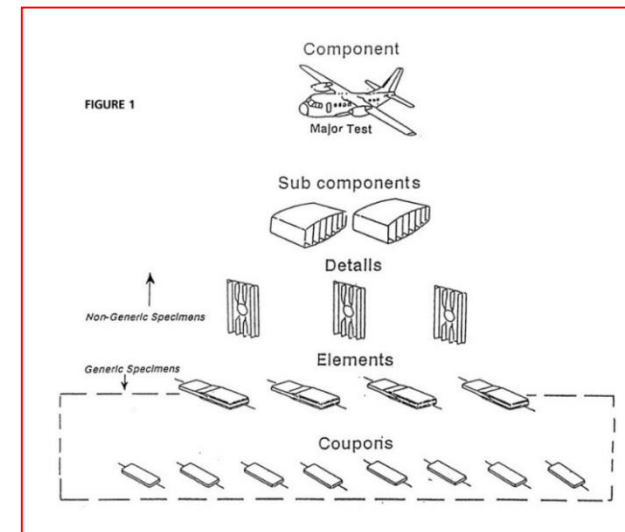
Traceability: Robust Data Set



EASA Composite Materials Safety Strategy

Classification of change important (defines extent of rework in pyramid)

- A - change in basic constituents (**new/alternative material**)
(e.g. fibre, resin, sizing etc)
- B - same basic constituents, but changed impregnation method
(**identical/replica materials**)
 - prepreg process (solvent bath, hot melt etc)
 - tow size (3k, 6k, 12k etc – same areal weight)
 - prepreg machine change (same supplier)
 - supplier change (licensed supplier)
- C - same material, modified process
 - cure cycle
 - tooling
 - lay-up method
 - environmental parameters



Change Examples: Redux 410/420 change (interiors – bonded inserts: mixed non-TCH approach to equivalence management...)

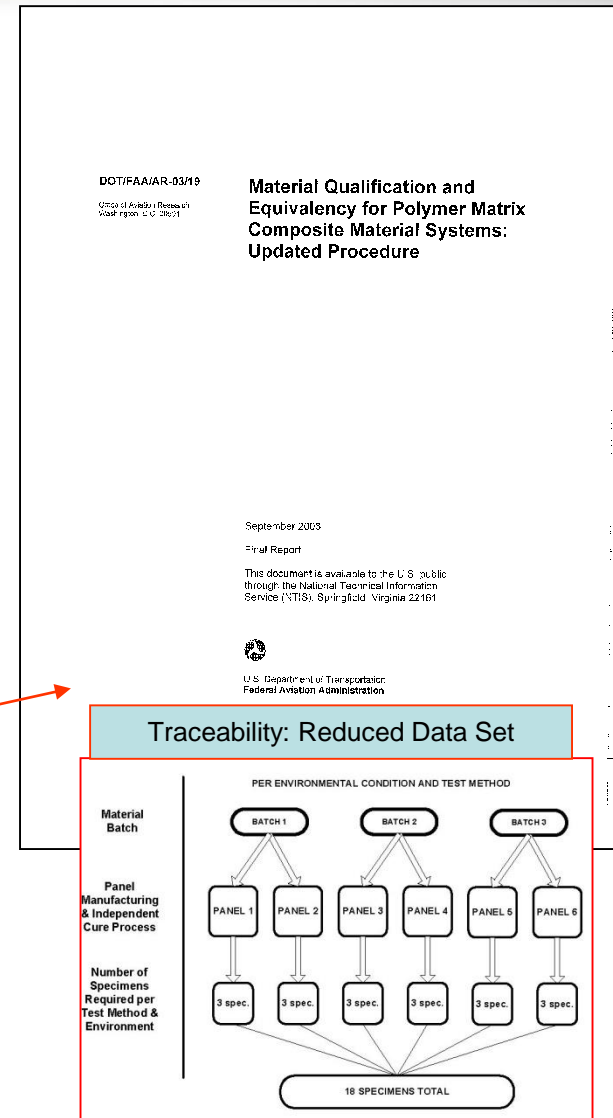


EASA Composite Materials Safety Strategy

Shared Databases:

- changes using **shared common data bases** (e.g. NCAMP etc)
- important for the GA, smaller CS25 etc
- potential benefit to non-TCH supported changes (subject to following the usual regulatory paths)
- EASA CM: 'Acceptance of Composite Specifications and Design Values Developed using the NCAMP Process':

https://www.easa.europa.eu/system/files/dfu/certification-memoranda-import-final%20EASA%20CM-S-004%20Issue%2001_Composite%20Materials%20%20Shared%20Databases_PUBL.pdf





Recent EASA structures experience*:

- Antenna (many large), Interiors (VIPs, monuments etc), Composite Seats, and Repairs
- meet all regulations, including composite guidance (AMC 20-29/AC20-107B)
- key subject areas:
 - Loads
 - Aeroelasticity (incl. Vibration & Buffeting)
 - Static Strength
 - Fatigue & Damage Tolerance
 - Materials & Processes
 - Crashworthiness
 - Decompression
 - Impact Conditions (bird strike, engine/wheel/tyre debris,...)

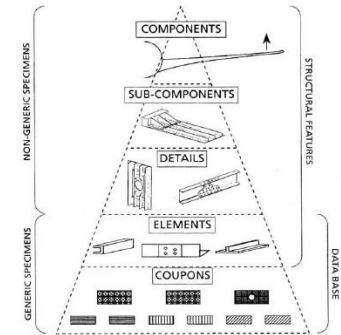
* EASA STC Structural Substantiation Workshop 2014: <https://www.easa.europa.eu/newsroom-and-events/events/stc-structural-substantiation-workshop-antenna-installation-damage>



EASA Composite Materials Safety Strategy

Test, or analysis supported by test:

- three basic compliance philosophies:
 - » Similarity (engineering judgement required)
 - » Analysis, supported by (subcomponent) tests
 - » Full-scale tests
(with material and process variability “overload” factor)
- each approach has its own benefits and drawbacks, e.g.
 - » Similarity claim needs to properly address (compare) all relevant critical design parameters
 - » Analysis needs to be validated, and subcomponent test data base needs to be established*
 - » Full-scale tests can be complicated and expensive, and time-consuming*



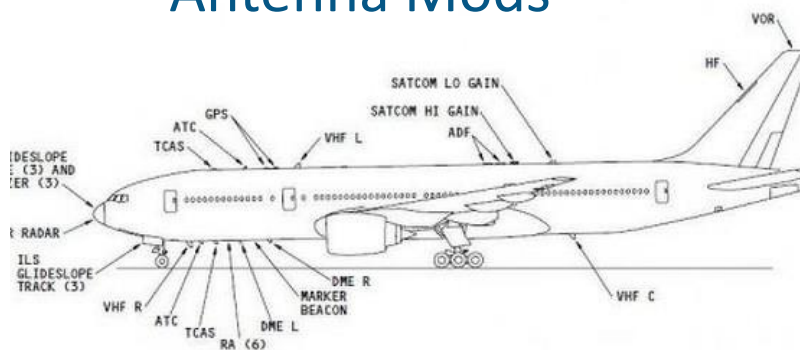
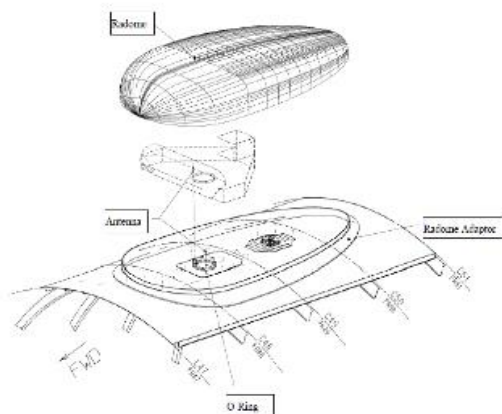
pyramid definition -
subjective activity, typically
unknown to non-TCH
supported projects

*a particular challenge for non-TCH STC community



EASA Composite Materials Safety Strategy

Antenna Mods



- pressure hull penetrations
- added items of mass
- air load changes

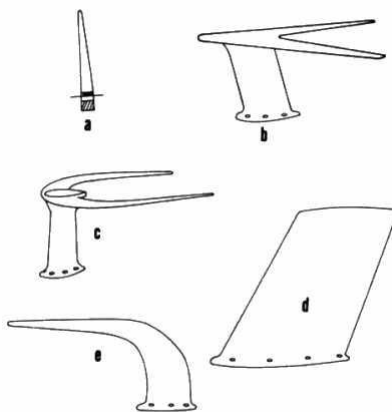
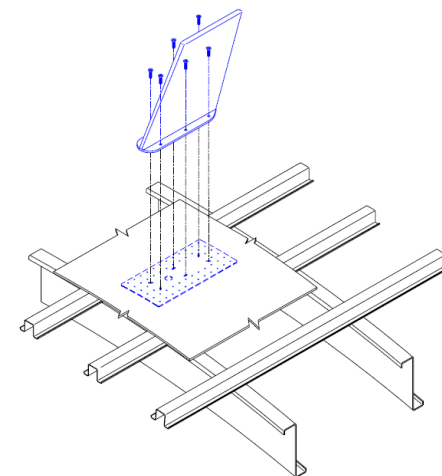


FIGURE 3.4.—Typical rigid antennas.



Recent increase in STC applications for large antenna installations



EASA Composite Materials Safety Strategy

Regulatory framework:

Currently, EASA has defined two Generic CRI's for large antenna installations on CS-25 aircraft:

- » "Structural certification criteria for large antenna installations*"
- » "Vibration & buffeting compliance criteria for large external antenna installations"

When is flight test required? Icing?

- both CRI's are based on FAA Generic IP's, with similar (but not identical) content

FAA Policy Statement (PS-ANM-25-17, "Structural Certification Criteria for Antennas, Radomes, and Other External Modifications") for public comment

EASA is working on a Certification Memorandum (CM) (mostly focusing on CS-25), to be published for public comment towards the end of 2016

* for non-PSEs, need to standardise expectations for damages which should be included and extent of testing



EASA Composite Materials Safety Strategy

Main **compliance issues encountered** when applying these two Generic CRI's:

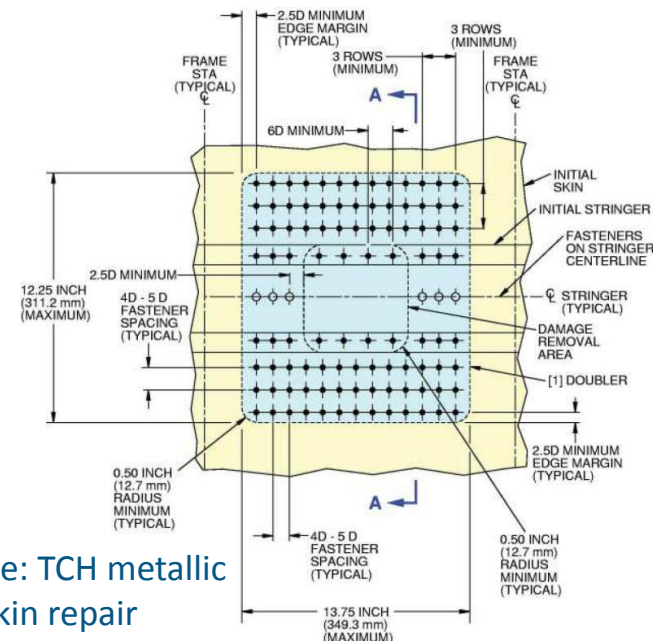
- Lack of TCH data / support, in particular in static strength and fatigue & damage tolerance substantiation of modified airframe structure
 - For example, installations on a composite fuselage rely upon more product specific data, much of which is proprietary, often requiring OEM data / support
 - Some example approaches taken by STC applicants for installations on a **metallic fuselage***:
 - Develop and validate FEM model of fuselage barrel, apply conservative external loads
 - Conservative critical crack length (e.g. between two fasteners)
- * not adequate for composite – IP data



EASA Composite Materials Safety Strategy

Limited 'reverse engineering' possibilities available:

- match existing bolted joint loads (for items of mass as per common metal practice)
(note additional reinforcement introduces load redistribution/potential unknowns, e.g. local load/damage modes)
- adapt existing SRM metal skin and frame repairs* to composite, within repair limits (existing small penetration locations), **only if**:
 - small antenna
 - no significant additional items of mass



Example: TCH metallic skin repair

* reduces problem to a metallic issue



EASA Composite Materials Safety Strategy

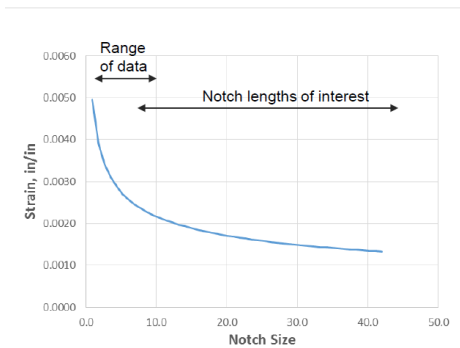
Limited 'reverse engineering' options available:

- reduced strain arguments limited...

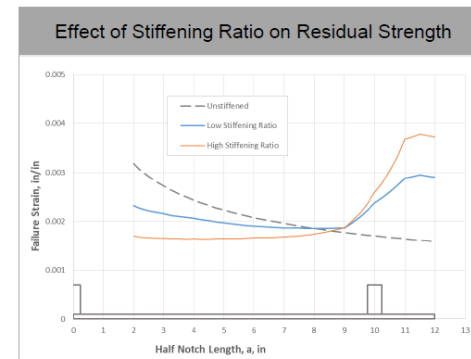
...how low is low enough for any particular material, process, configuration, and load application combination?

... is the same reference damage mode maintained (initiation and growth)?

... how can the change (damage, repair, mod...) be modelled?



Unconfigured*



Configured*

* 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 Composite Materials Safety Strategy

Current EASA Antenna Generic CRI text includes:

Statement of Issue:

[Applicant] has applied for EASA approval of a Supplemental Type Certificate (STC) that includes installation of the structural mounting provisions and radome. On similar projects, questions have been raised regarding the applicable structural requirements and acceptable means of compliance. The purpose of this CRI is to identify these requirements and provide a medium by which the compliance to these requirements is documented.

*Note: This CRI primarily addresses large installations installed on metallic structures. However, it should be noted that **any modifications, large or small, to composite fuselage structures which are not already directly supported by the TCH and which add new penetrations, or which extend penetrations relative to those defined in existing TCH published data, would best be directed to the TCH for guidance and approval. This includes modifications which add reinforcements intended to reduce strain local to skin cut-outs and/or redistribute loads resulting from such reinforcements or the addition of large items of mass. EASA considers this action to be necessary because non-TCH applicants are unlikely to have the appropriate configuration specific data available, e.g. regarding potential failure modes etc, considered to be necessary to allow completion of such modifications.***



EASA Composite Materials Safety Strategy

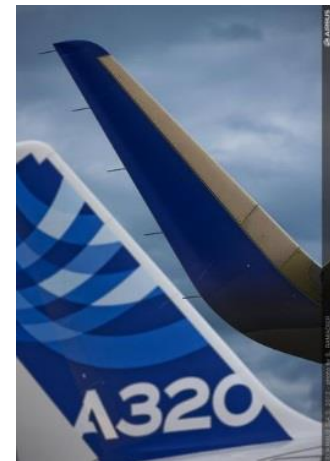
EASA Composite Winglets/Sharklets:

- many configurations
(experience – composite or metallic winglets on metallic baseline structure ... mods to composite baseline structure not yet seen)
- many applicants
- intent of appropriate sections of AMC 20-29/AC 20-107B applied to winglet (AMC 20-29 will apply to composite baseline PSE structure, when proposed)

Key subjects:

- loads, reinforcement, and F&DT for baseline structures...
- classification of winglet (Part Departing Aircraft issue?)
- addressed as PSE*(F&DT)
- bird strike
- flutter

* for non-PSEs, need to standardise expectations for damages which should be included and extent of testing





EASA Composite Materials Safety Strategy

EASA Composite Interiors* /Monuments:

- many configurations (VIPs etc)
- many applicants
- intent of appropriate sections of AMC 20-29/AC 20-107B applied

Key subjects:

- loads, reinforcement, and F&DT for baseline structures...
- testing (use of UL tested interiors in service aircraft – damage detection?)
- decompression (use of many small enclosed living spaces – CRI TBD)
- floor structure (new baseline configs)
- bonded inserts



* see also GAMA Pub.No.13

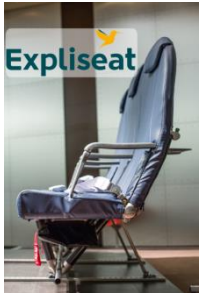


EASA Composite Materials Safety Strategy

EASA Composite Seats: Passenger Critical Structure

(static and dynamic):

- 'Typically' many seats installed Post-TC by ETSO/TSO + STC
- many applicants (some with limited/no composite experience)
- many configurations (previously well established metallic history/configs)
- need to standardise recognised (SAE WG formed)
- intent of appropriate sections of AMC 20-29/AC 20-107B applied as supplement to ETSO (EASA generic draft CRI, FAA draft IP)



Key subjects:

- Material and Processes
- Maintain 'Fit, Form, Function' for life of part (understand manufacturing and in-service damage threats. and damage modes etc)
- appropriate test/analysis pyramid (short pyramid, Boundary Conditions for static and dynamic test?)
- post dynamic test application of load (locate hidden damage, protect living space and escape route)
- continued airworthiness (includes inspection tasks and fleet leader expectations to validate assumptions)
- 'equivalence'– strength and stiffness (pulse), noting competing damage modes



EASA Composite Materials Safety Strategy

EASA Composite Adapter Plates (generic CRI): **Passenger Critical Structure** (static and dynamic):

- many configurations, some complex material configs, attachment locations etc (need to determine if part of floor or seat)
- a stiff adapter plate can move the problems created by floor deformation from the seat to track interface to the adapter to floor interface
- plinth (part of seat subject to dynamic 2x.562 test) or pallet
- many applicants (some with limited/no composite experience)
- intent of appropriate sections of AMC 20-29/AC 20-107B applied

Key subjects:

- classification – some 'engineering judgement' required (typically, installation with more attachments to seat than floor is a plinth)
- test v analysis options (new, similar-new, similar etc)
- what damages should be included in static or dynamic test?



EASA Composite Materials Safety Strategy

EASA Composite ULDs (ETSOs):

- many configurations (previously well established metallic history)
- many applicants (some with limited/no composite experience)
- intent of appropriate sections of AMC 20-29/AC 20-107B applied

Key subjects:

- Materials & Processes
- practical maintenance program (Fit, Form, Function, for life of item etc)
- what damages should be included in static or dynamic test?
- flammability



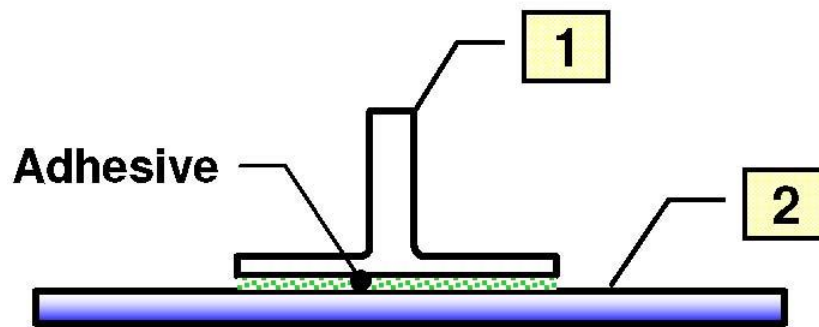


EASA Composite Materials Safety Strategy

Bonded Structure: AMC 20-29 Para.6. **MATERIAL AND FABRICATION DEVELOPMENT**

C. STRUCTURAL BONDING

- important existing rule regarding **Bonded Structure – 23.573*(a)(5)**
- approach used in other specifications, CS25, 27, 29, CS-P etc (now broader use formally recognised in AMC 20-29)



Structural Bonding:

- extremely sensitive to process
- particular caution is required if item 1 and/or 2 is pre-cured or metal, requiring:
 - **surface protection, cleaning, preparation etc**

* Note: reorganisation of CS23/PART23 in progress, basic intent retained



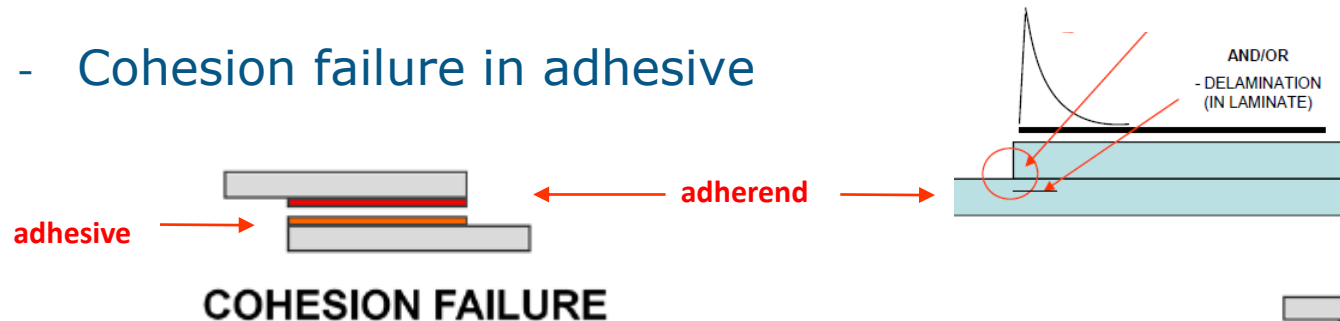
EASA Composite Materials Safety Strategy

AMC 20-29 Para.6. **MATERIAL AND FABRICATION DEVELOPMENT**

C. STRUCTURAL BONDING

Acceptable failure modes (one dominant repeatable mode preferred):

- Adherend failure (preferred)
- Cohesion failure in adhesive



- **ADHESION FAILURE – UNACCEPTABLE** (disbond*)
(at interface between adhesive and adherend)
 - contamination, compatibility etc



Poor Process!

*'disbond' and 'debond' used interchangeably in lit.
However, 'disbond' – accidental, 'debond' – intended (access.

MIXED-MODE FAILURE

- non-TCH STC databases typically more limited than TCH





EASA Composite Materials Safety Strategy

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

*variable quality data

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

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



EASA Composite Materials Safety Strategy

AMC 20-29 Para.8. PROOF OF STRUCTURE - FATIGUE AND DAMAGE TOLERANCE

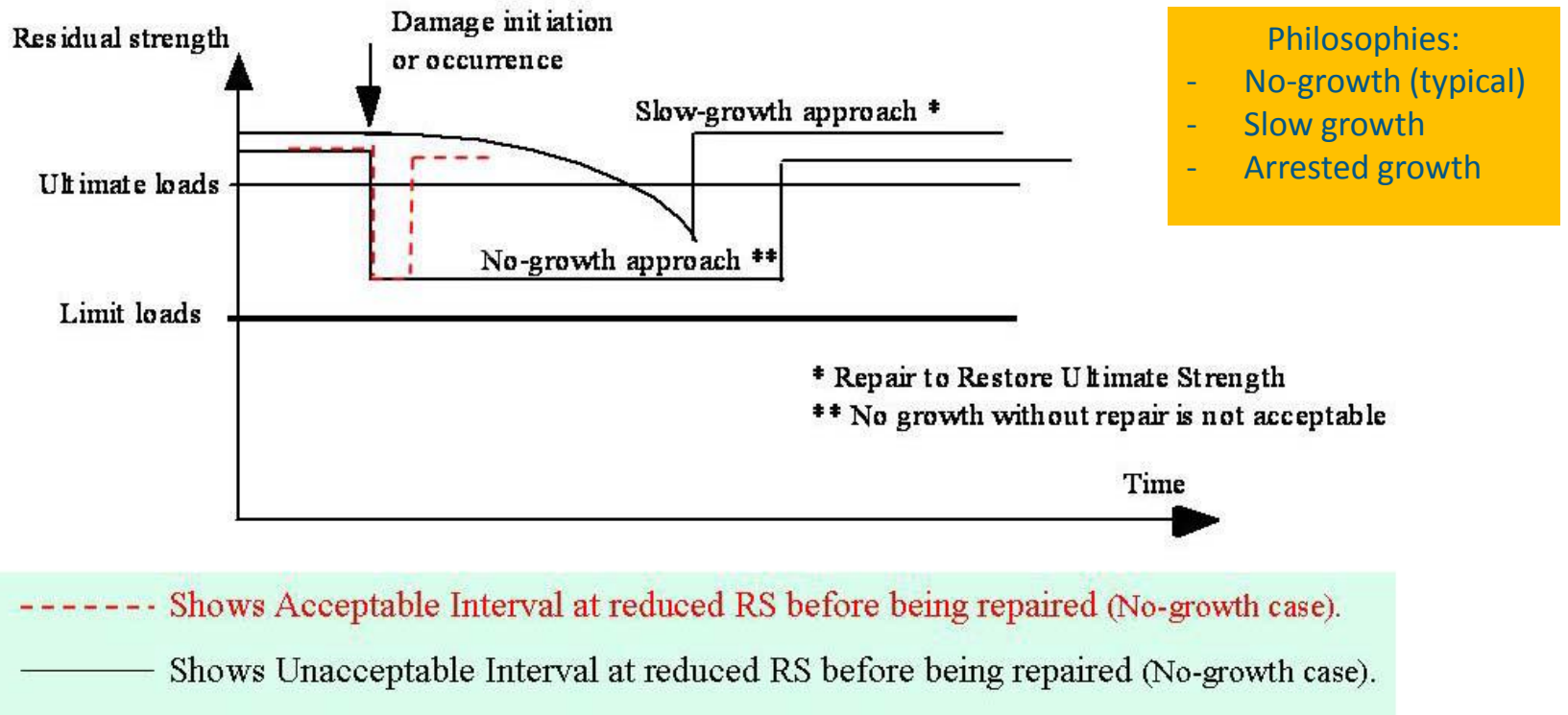


Figure 4 - Schematic diagram of residual strength illustrating that significant accidental damage with “no-growth” should not be left in the structure without repair for a long time.

applies to baseline structures, changes, and repairs



EASA Composite Materials Safety Strategy

Standardisation of Certification Requirements for Composites

23.573(a)(5): 'For any bonded joint, the failure of which would result in catastrophic loss of the aeroplane, the limit load capacity must be substantiated by one of the following methods:

(i) The maximum disbonds of each bonded joint consistent with the capability to withstand the loads in paragraph (a)(3) (i.e. critical limit flight loads considered ultimate) of this section must be determined by analysis, tests, or both.

Disbonds of each bonded joint greater than this must be prevented by design features; or

Not to be used to address poor process, poor process is unacceptable, ref. 2x.605
or

(ii) **Proof testing** must be conducted on **each production article** that will apply the **critical limit design load** to each critical bonded joint;

Not practical for large aircraft, does not address degradation, loading process damage

or

(iii) **Repeatable and reliable non-destructive inspection techniques** must be established that ensure the strength of each joint.'

'Weak Bonds' and 'Tight Disbonds'

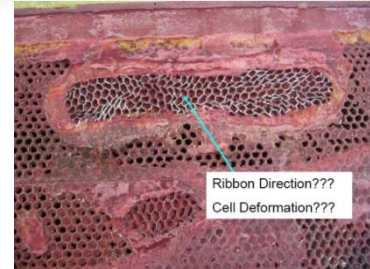
- cannot be reliably detected by Visual Inspection
- have not been shown to be reliably detected by NDI at a production scale



EASA Composite Materials Safety Strategy

EASA Bonded Repair* Size Limits CM:

applies to baseline structures, changes, and repairs



- limit field repairs to repaired baseline structure > LL capability in repair failed condition
- 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 (harmonised with FAA PS)

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

* by inference, limits scope of 'rebuilt', ref. limited scope of PART145.A.42 para.7



EASA Composite Materials Safety Strategy

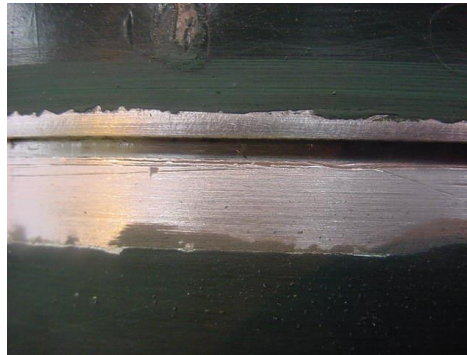
Further Post TC Challenges: Decals/Vinyl Wraps

- adds layer to surface - modify damage tolerance
 - reaction to damage threats
 - inspection capability...physical layer, colour* etc
(also consideration for metal)
- damage due to methods of installation/removal?

Metal: - scribe marks...

Composites:

- chemicals
- blast media



- material compatibility... chemical, galvanic etc
- **ensure F&DT philosophy not compromised** – ask TCH

* temperature may also be an issue





EASA Composite Materials Safety Strategy

Conclusions:

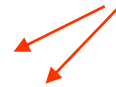
Metal History: relatively mature, available data allows some scope for non-TCH activity – reality is that it has worked for many decades

Composites: little shared allowable data available, e.g. open hole, closed hole, temperature, material compatability etc

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?)

pressure to take
'alternative'
approaches..





EASA Composite Materials Safety Strategy

Conclusions:

EASA 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
- **direct applicants to TCH** (for more critical structures)
- TCHs could consider providing further support relative to necessary user timescales and costs
 - need for more accessible guidance for the benefit of all concerned (pressure hull penetration, add items of mass etc)
 - template/guidance for data submission?
- FAA AC in development/this workshop*
 - * important to recognise and standardise potential significant issue before poor precedents are set



EASA Composite Materials Safety Strategy

Thank You...

QUESTIONS?



EASA Composite Materials Safety Strategy

Back-up slides



Antenna installations

- Generic CRI on structural certification criteria:
 - Means of Compliance
 - Provides guidance on most relevant applicable structural requirements:
 - CS 25.23, 25.301, 25.305, 25.365, 25.571, 25.581, 25.603, 25.605, 25.609, 25.613, 25.629, 25.631, 25.841, 25.901, 25.1419, 25.1529, and Appendix H



Antenna installations

- Generic CRI on structural certification criteria:
 - Means of Compliance
 - Provides guidance on most relevant applicable structural requirements:
 - CS 25.23, 25.301, 25.305, 25.365, 25.571, 25.581, 25.603, 25.605, 25.609, 25.613, 25.629, 25.631, 25.841, 25.901, 25.1419, 25.1529, and Appendix H



Antenna installations

- Generic CRI on vibration & buffeting compliance criteria:
 - Equivalent Safety Finding
 - Published by EASA for public comment (comment period closed 2 May 2016)
 - Applicant to show that original vibration & buffeting compliance demonstration remains valid
 - If not, flight testing up to Vdf/Mdf would be necessary
 - Evaluation through suitable combination of:
 - Similarity
 - CFD analysis
 - Vibration analysis
 - Flight testing up to Vmo/Mmo
 - Typically, compliance is based on combination of CFD analysis and flight testing up to Vmo/Mmo



EASA Composite Materials Safety Strategy

- Main compliance issues encountered (continued):
 - Validation of CFD analysis, for aerodynamic loads and vibration & buffeting compliance
 - Experience and proficiency of personnel involved
 - Comparison of flow field characteristics with (flight test, wind tunnel) data from a similar configuration up to V_{df}/M_{df}
 - If no significant flow field phenomena exist, comparison of another configuration that exhibits these phenomena



EASA Composite Materials Safety Strategy

- Main compliance issues encountered (continued):
 - Bird strike substantiation:
 - Determination whether bird can impact installation
 - All phases of flight (climb-out, cruise, descent and approach), from sea level to 20.000(*) feet, at the full range of certified design weights, CG limits, and the airspeeds defined in CS 25.631 (V_c , or $0.85 V_c$ at 8.000 ft), should be considered.
 - Probabilistic arguments (for example the likelihood of impact based on consideration of frontal area, flight phase, aircraft speed and altitude) are not acceptable to EASA
 - Test vs. analysis
 - Ref. CS 25.631: "Compliance may be shown by analysis only when based on tests carried out on sufficiently representative structures of similar design"
 - Tests may be expensive and have long lead time due to unavailability of test facilities
 - Validation, verification and extrapolation of explicit FE analysis is a tedious and complicated process

(*) under investigation