COMMENT RESPONSE DOCUMENT (CRD) TO NOTICE OF PROPOSED AMENDMENT (NPA) 2009-06

for amending the Executive Director Decision No. 2003/14/RM of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for normal, utility, aerobatic and commuter category aeroplanes (« CS-23 »)

and

for amending the Executive Director Decision No. 2003/2/RM of 17 October 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for large aeroplanes (« CS-25 »)

and

for amending the Executive Director Decision No. 2003/15/RM of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for small rotorcraft (« CS-27 »)

and

for amending the Executive Director Decision No. 2003/16/RM of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for large rotorcraft (« CS-29 »)

and

for amending the Executive Director Decision No. 2003/12/RM of 5 November 2003 on general acceptable means of compliance for airworthiness of products, parts and appliances (« AMC-20 »)

"Composites"

Explanatory Note

I. General

1. The purpose of the Notice of Proposed Amendment (NPA) 2009-06, dated 10 July 2009 was to propose an amendment to Decision 2003/14/RM, 2003/2/RM, 2003/15/RM, 2003/16/RM and 2003/12/RM of the Executive Director of the European Aviation Safety Agency. It proposes the introduction of a new AMC 20-29 giving an acceptable means of compliance and guidance material on composite aircraft structures.

II. Consultation

2. The draft Executive Director Decision was published on the web site (http://www.easa.europa.eu) on 13 July 2009.

   By the closing date of 13 October 2009, the European Aviation Safety Agency ("the Agency") had received 151 comments from 20 National Aviation Authorities, professional organisations and private companies.

III. Publication of the CRD

3. All comments received have been acknowledged and incorporated into this Comment Response Document (CRD) with the responses of the Agency.

4. In addition to comments received as part of the NPA consultation process, the Agency has reviewed AC 20-107B published by the FAA on 08 September 2009. Where the Agency has determined it appropriate, the text of AMC 20-29 has been amended to provide greater harmonisation with AC 20-107B. Remaining differences compared to AC 20-107B (excluding minor editorial differences and those specific to the regulatory environment) are identified in the Attachment to this CRD.

5. In responding to comments, a standard terminology has been applied to attest the Agency's acceptance of the comment. This terminology is as follows:

   - **Accepted** – The comment is agreed by the Agency and any proposed amendment is wholly transferred to the revised text.
   - **Partially Accepted** – Either the comment is only agreed in part by the Agency, or the comment is agreed by the Agency but any proposed amendment is partially transferred to the revised text.
   - **Noted** – The comment is acknowledged by the Agency but no change to the existing text is considered necessary.
   - **Not Accepted** - The comment or proposed amendment is not shared by the Agency

6. The Executive Director Decision will be issued at least two months after the publication of this CRD to allow for any possible reactions of stakeholders regarding possible misunderstandings of the comments received and answers provided.

7. Such reactions should be received by the Agency not later than **2 May 2010** and should be submitted using the Comment-Response Tool at http://hub.easa.europa.eu/crt.

IV. CRD table of comments, responses and resulting text

(General Comments)	-

comment	*1* comment by: *LAMA* The Light Aircraft Manufacturers Association (LAMA) USA is the leader and advocate of the Light Sport Aircraft (LSA) Community in both the USA and Overseas. As the Light Sport industry, (in which the majority of European manufactures enjoy the majority of their sales of these 2-place training and recreational airplanes in the USA) benefits from the ASTM airworthiness standards created by the FAA, interested public persons, and the LSA industry itself, LAMA sees no value or purpose for EASA to pursue complicated airworthiness issues, such as "design, QA and repair of composite structurers" for these kind of aircraft. We plead to EASA to come to the same conclusion many other countries in Afica, Asia, Australia, SouthAmerica and China have come to, and for uniformity, for industry self-regulation, we plead for EASA to adopt the ASTM airworthiness standards for light sport aircraft. Respectfully submitted: Larry Burke, Founder and Chair Emeritus Light Aircraft Manufacturers Association
response	*Noted* This document provides one ‘Acceptable Means of Compliance’. Other acceptable means can be used, including appropriate experience. The intent of this AMC is not specifically aimed at aircraft identified in the LAMA comment, e.g. those addressed by CS-VLA. For the purposes of the aviation community represented by LAMA, this AMC could be considered to be an aid to the thought process, particularly for those without established experience of composite structure design. The Agency recognises the need to simplify the regulation of light sport aeroplanes and is currently pursuing this under a separate rulemaking activity (MDM.032). Detailed proposals were published in NPA 2008-07 in April 2008 and comments received are currently being reviewed prior to publication of the CRD.

comment	*38* comment by: *Luftfahrt-Bundesamt* The LBA has no comments on NPA 2009-06.
response	*Noted*

comment	*57* comment by: *Swedish Transport Agency, Civil Aviation Department (Transportstyrelsen, Luftfartsavdelningen)* The Swedish Transport Agency, Civil Aviation Department is supporting the content of NPA 2009-06
response	*Noted*

comment	*98* comment by: *Dassault Aviation* General remark: It is noted numerous differences (e.g. sections or sentences or terms present in one text but not in the other or referenced document differences or supplemental definitions) between EASA AMC 20-29 and FAA AC 20-107B texts but with no main impact. And as underlined in Explanatory note section A. I. 5., the text "is *technically equivalent and harmonized with FAA AC 20-107B."* Is it possible at the end of iterations to get the same text, eventually with only main differences put in evidence if any are remaining?
response	*Partially accepted* AMC 20-29 and FAA AC 20-107B originate from a joint rulemaking process. However, text differences have been introduced due to differences in rulemaking procedures and timescales between the Agency and FAA. The Agency and FAA have met in an attempt to resolve these differences and proposed changes have been identified in both documents. Proposed changes to AMC 20-29 are incorporated in this CRD. Some differences will remain and simply reflect the different regulator framework. There are no substantive differences between the two documents.

comment	*125* comment by: *Diamond Aircraft Industries (Austria)* Since the NPA is technically equivalent with the proposed FAA AC20-107B, it is suggested that EASA consider the GAMA comments (and perhaps other comments) to this proposed FAA AC.
response	*Partially accepted* The Agency can only respond directly to comments submitted in response to the NPA. Comments provided to FAA are indirectly addressed through the harmonisation process.

comment	*126* comment by: *Diamond Aircraft Industries (Austria)* A situation in which the applicant is forced to "show compliance with the AMC" should be avoided. It should thus be clarified in the front matter of the AMC that mandatory requirements are laid down in the CS's only and the AMC is only guidance material; the applicant may elect to take a different approach that is acceptable to the authority.
response	*Partially accepted* None of the Agency's CS's (including the airworthiness code and AMC), are mandatory under EU law. It is an accepted principle that AMC is just one means of showing compliance, and this was stated in the explanatory note accompanying the initial issue of AMC-20. However, as it is recognised that this may not be readily visible to stakeholders, further clarification is given in AMC 20-29 Section 1. Purpose.

comment	*127*	comment by: *Diamond Aircraft Industries (Austria)*
	The NPA should include a statement to the effect that existing practices that have proven to produce reliable structures may be continued to be employed for similar certification programs.	
response	*Not accepted* AMC 20-29 has been established to provide a common acceptable means of compliance and is based on certification experience and good design practice. As composites technology and knowhow has advanced, existing practices may no longer represent an acceptable approach. AMC 20-29 allows credit to be given to any appropriate experience on similar structure, as stated in AMC 20-29 paragraph 6(a)(7) and elsewhere.	

comment	*128*	comment by: *Diamond Aircraft Industries (Austria)*
	The document identifies numerous difficulties and raises many questions, but then leaves the applicant alone. It would be expected from AMC material to offer simple and conservative methods to answer the questions raised.	
response	*Noted* AMC 20-29 aims to provide general acceptable means of compliance and guidance material for certification of composite structures. It reflects the themes of typical discussions between the applicant and the Agency/NAA during a certification programme. It is not intended as a comprehensive design guide, but provides links to more detailed guidance elsewhere, e.g. CMH-17.	

comment	*129*	comment by: *Diamond Aircraft Industries (Austria)*
	Rules that are appropriate to category 25 aircraft may be over-burdensome for category 23. There is no evidence of structural problems directly associated with the use of composite material in category 23 aircraft. Hence the question arises why the rules should become significantly stricter. Economic aspects should be taken into consideration. The introduction of unduly strict and costly rules during phases of economical stagnation has the potential of impeding the development of new aircraft that could replace older and perhaps unsafer aircraft. Examples include: • 6.b "[...] cleanliness of facilities are controlled to a level validated by [...] proof of structure testing". This would require means for the objective measurement and recording of the cleanliness of the production facilities, which would be an elaborate undertaking. • 6.d.(2) "[...] the effects of residual stresses that depend on environment must be addressed (e.g., differential thermal expansion of attached parts)." Since the thermal expansion of composite structure is highly dependent on the layup and geometry and is not isotropic, the evaluation of these effects on the whole structure would mean a great additional effort. The extent of this verification should be reduced to critical connections for CS 23 aircraft. • 6.e Protection of structure against erosion, abrasion, UV radiation: "Suitable protection against and/or consideration of degradation in material properties should be provided for conditions expected in	

	service and demonstrated by test." The experimental demonstration of the suitability of protective means for all mentioned environmental influences seems excessive for a part 23 aircraft. • 7.b A building block approach with 5 different levels of complexity seems excessive for a part 23 aircraft. • 8.a Five damage categories shall be defined, damage growth data for category 3 should be obtained by repeated load cycling, in residual strength assessments the first four categories should be considered, etc. No such requirement exists in CS 23, so why introduce it via guidance material? • App. 3: Due to the relatively small amounts of material purchased for CS 23 aircraft, experience shows the importance of flexibility regarding materials, especially carbon fiber. According to the classification, a change in fabric supplier delivering fabric of equal areal weight, weave-style, tow size and equivalent (but not identical) fiber would be dealt with as an "alternative material intended to create truly new structure", with the need of creating new design values, etc. In practice, such a change is intended to certify an identical material intended to create a replica structure. It would cause excessive effort to conduct the whole structural substantiation for certification of an alternative supplier. For CS 23 such changes should be dealt with as minor changes, and equivalency sampling tests only at lower levels would suffice.
response	*Partially accepted* AMC 20-29 is not a "rule" and there is no intent in this document to enhance design standards. It has been established to provide common guidance and acceptable means of compliance and is based on certification experience and good design practice applicable to different aircraft types. While the Agency encourages the use of AMC 20-29, it remains just one acceptable means of compliance and alternative means can be proposed by the applicant. The Agency has the following responses to the individual points raised: 6.b. The environment and cleanliness levels in production areas must remain at a level used to qualify the process and parts. How this is achieved will be dependent on the type of parts and their criticality but it should be recognised that this is simply good practice to ensure consistent and repeatable part production and should not impose any additional burden on industry. 6.d(2) Text is considered to be sufficiently generic as compliance is dependent on a number of design variables. "must" is replaced by "should". 6.e Additional wording is added to clarify that experience can negate the need to perform testing. 7.b provides an example of a building block approach. It is not essential to have 5 different levels of complexity. 8.a. New text has been added to AMC 20-29 paragraph 8(a)(1)(c) (See also comment #14 Appendix 3: A change in fibre supplier reputed to supply a replica material must be treated conservatively, fibre being the prime strength provider in the material (see Appendix 3 paragraph 6. c.).

comment	*134* comment by: *Gulfstream Aerospace Corp* There is no guidance for secondary structure. Secondary structure should not have to meet the same criteria as primary structure. Provide detail guidance for secondary structure. Damage tolerance strain cutoffs may not be necessary.
response	*Noted* AMC 20-29 is primarily targeted at 'Critical Structure', as defined in Appendix 2, although many aspects are applicable to secondary structure. Note that other documentation exists for secondary structure, e.g. 'Substantiation of Secondary Composite Structures" PS-ACE100-2004-10030, April 2005.

comment	*135* comment by: *European Sailplane Manufacturers* The European sailplane manufacturers have the following general comments regarding NPA 2009-06 „Composites“: Within this NPA and also within the proposed changes to existing regulation the scope of aircraft covered by CS-22 (sailplanes and powered sailplanes) is not included. Similarly very small aeroplanes covered by CS-VLA are not included. The European sailplane manufacturers point out that this exclusion has been made with good sense and they agree that CS-22 (and also CS-VLA) aircraft should be exempted from the proposed rulemaking changes of NPA 2009-06. Since introduction of composites into sailplanes in the years after 1960 several thousand sailplanes have been built using glass, carbon and other fibres. The manufacturers have – in close co-operation with the aviation authorities, the suppliers of those composites materials and with research organisations – developed a successful and efficient system to prove the initial and continuing airworthiness of composites structures for sailplanes. When these types of construction where later introduced to small aeroplanes (covered today by CS-23 and CS-VLA) several efforts were made to transfer this knowledge to these types of aircraft. Due to historical reasons (partly caused by the stakeholders involved and partly caused by different certification approaches coming from commercial or military aviation) the certification processes for sailplanes could be applied to aeroplanes (e.g. the case within VLA aircraft) or have been modified (e.g. for parts of the certification processes used for FAR / CS 23 aircraft). It is understood that the proposed text for NPA 2009-06 and the included AMC 20-29 has been synchronized with the proposed FAA AC20-107B and therefore the European sailplane manufacturers will not comment this NPA regarding the specific topics within the content. Nevertheless is should be pointed out that the paragraph 12 on page 4 of the NPA regarding aircraft falling under CS-22 or CS-VLA must not be interpreted that NPA 2009-06 or AMC 20-29 should be applied for such aircraft.
response	*Noted* Paragraph 12 of the NPA explanatory note is repeated within the applicability

	section of AMC 20-29 (Section 3). However, in this case, it is preceded by an explicit statement that the AMC is an acceptable means of compliance with CS-23, CS-25, CS-27 and CS-29. The intent is therefore clearly stated that AMC 20-29 is not specifically directed at sailplanes.

comment	*136* comment by: *European Sailplane Manufacturers* Regarding the structure and the content of the AMC 20-29 the European sailplane manufacturers observe that in most cases the important aspects are explained and the proper “questions” are given. Nevertheless for applicants (i.e. manufacturers seeking approval for their products) it would be very useful if the AMC material would also offer possible “answers” (i.e. accepted means of compliance like simple calculation and/or testing methods to show compliance).
response	*Noted* AMC 20-29 aims to provide general acceptable means of compliance and guidance material for certification of composite structures. It reflects the themes of typical discussions between the applicant and the Agency/NAA during a certification programme. It is not intended as a comprehensive design guide, but provides links to more detailed guidance elsewhere, e.g. CMH-17.

comment	*138* comment by: *European Sailplane Manufacturers* In general this NPA tries to offer common AMC material for a wide range of aircraft spanning from a quite small CS-23 aircraft to an airliner designed for commercial air transport. The European sailplane manufacturers feel that some procedures outlined in this AMC 20-29 seem quite onerous for a small single-engine aeroplane which will be designed and built and operated quite similar to a sailplane or powered sailplane or very light aeroplane. As there seems no technical reason for such onerous certification procedures for small aircraft we herewith propose to include wording that very small aircraft should be able to use other, less onerous methods for showing of compliance against according CS-23 paragraphs. As useful definition of aeroplanes falling under CS-23 but still eligible for simpler accepted means of compliance the definitions of ELA 1 or ELA 2 are herewith proposed. At least aircraft falling under the ELA 1 definition should not be forced to use as onerous certification regulations as airliners. (Remark: definition of ELA 1 according to Part-M in commission regulation (EC) 1056/2008 amending regulation (EC) 2042/2003: ‘(k) “ELA1 aircraft” means the following European Light Aircraft: (i) an aeroplane, sailplane or powered sailplane with a Maximum Take-off Mass (MTOM) less than 1 000 kg that is not classified as complex motorpowered aircraft; (ii) a balloon with a maximum design lifting gas or hot air volume of not more than 3 400 m3 for hot air balloons, 1 050 m3 for gas balloons, 300 m3 for tethered gas balloons; (iii) an airship designed for not more than two occupants and a maximum design lifting gas or hot air volume of not more than 2 500 m3 for hot air airships and 1 000 m3 for gas airships;)

	Justification: EASA and the European Commission have in recent years pointed out that the "one-size fits all" approach to rulemaking should not be continued especially to avoid too stringent regulation for small aviation like sport and recreational flying. The certification procedures and according accepted means of compliance used on sailplanes and VLA have proven to result into safe products without problems regarding initial and/or continuing airworthiness of composites structures. Therefore it seems not justified to introduce onerous procedures regarding AMC material for very small aircraft like single-piston aeroplanes used for sporting and/or recreational purposes. A useful definition for such small aircraft is the ELA definition as introduced in Part M.
response	*Noted* AMC 20-29 is not a "rule" and there is no intent in this document to enhance design standards. It has been established to provide common guidance and acceptable means of compliance and is based on certification experience and good design practice applicable to different aircraft types. While the Agency encourages the use of AMC 20-29, it remains just one acceptable means of compliance and alternative means can be proposed by the applicant. The Agency recognises the need to simplify the regulation of light aircraft and is currently pursuing this under a separate rulemaking activity (MDM.032). Detailed proposals were published in NPA 2008-07 in April 2008 and comments received are currently being reviewed prior to publication of the CRD.

A. Explanatory Note - IV. Content of the draft decision p. 4-5

comment	*60* comment by: *Pilatus* General: Pilatus Aircraft Ltd. supports this NPA as the proposed AMC provides an overview of the certification aspects to be considered at the beginning of the development of composite parts and it summarizes common acceptable means of compliance for composite parts very well. It further provides a good basis for the entire life cycle (development, certification, modifications and maintenance) of composite parts.
response	*Noted* Supporting comment noted

comment	*76* comment by: *Sell GmbH* Sell welcomes the EASA effort to standardize the design and qualification of composite aircraft structures and in particular the effort of harmonization with FAA AC 20-178B. To assure that composite aircraft structures designed and qualified i.a.w. new AMC 20-29 will be commonly acceptable by FAA the AMC 20-29 should be harmonized with FAA AC 20-178B as finally issued by FAA.
response	*Partially accepted*

AMC 20-29 and FAA AC 20-107B originate from a joint rulemaking process. However, text differences have been introduced due to differences in rulemaking procedures and timescales between the Agency and FAA.

The Agency and FAA have met in an attempt to resolve these differences and proposed changes have been identified in both documents. Proposed changes to AMC 20-29 are incorporated in this CRD.

Some differences will remain and simply reflect the different regulator framework. There are no substantive differences between the two documents.

A. Explanatory Note - V. Regulatory Impact Assessment p. 5-7

comment *72* comment by: *Ludger Duelmer, Extra Flugzeugproduktion*

A. V 17. Summary and Final Assessment:

It is assumed that this proposed AMC 20-29 addresses some issues that go beyond the scope of those requirements of small airplanes (Part CS-23). Compliance with this proposed AMC may be considered impractical for an applicant for a small airplane of 6000lbs or less MTOW to be certified under CS-23.
So it is in doubt that the knowledge of what the Agency will require for compliance by means of this proposed AMC and GM will minimize certification cost. It will definitely address all (or most) technical aspects regarding composite design to be considered for certification but compliance to all of the issues will be an economic burden.
An applicant will be able to substantiate that this extensive AMC material would result in additional significant effort required to demonstrate compliance that are not commensurate with the possible safety benefits.

Sometime the proposed AMC 20-29 reads more as an Appendix to the related specification (CS-23, CS-25, CS-27, CS-29) which includes detailed requirements than an AMC & GM.. Common understanding is that an AMC & GM should provide detailed information as well as examples how the applicable requirements of those specifications complied with.
Although it is expressed that the Agency does not certify material and processes alternate approaches should be given in general, which could be expressed: “In the absence of test data and/or more rational analysis the following detailed values/factors/means must be considered: …..“

response *Noted*

AMC 20-29 is not a "rule" and there is no intent in this document to enhance design standards. It has been established to provide common guidance and acceptable means of compliance and is based on certification experience and good design practice applicable to different aircraft types. While the Agency encourages the use of AMC 20-29, it remains just one acceptable means of compliance and alternative means can be proposed by the applicant.

AMC 20-29 reflects the themes of typical discussions between the applicant and the Agency/NAA during a certification programme. It is not intended as a comprehensive design guide, but provides links to more detailed guidance elsewhere, e.g. CMH-17.

Regarding material certification, AMC 20-29 paragraph 6 (a)(7) states that materials and processes are included in the aircraft approval. The supporting references provide guidance regarding the content of the appropriate specifications etc. Furthermore, considering the increasing range of materials available, and the variation in properties with material and process, it is becoming increasingly important not to provide generic target factors/values because they may not be appropriate to every material and process combination and/or application.

B. DRAFT RULES	p. 8

comment	*111* comment by: *Swiss International Airlines / Bruno Pfister* GENERAL COMMENT SWISS Intl has no comment to add to this NPA.
response	*Noted*

B. DRAFT RULES - I Draft Decision CS-23 - Book 2 - AMC 23.573(a)(1)&(3)	p. 8

comment	*87* comment by: *Austro Control GmbH* The continuation of testing to rupture does not seem to show much benefit. Testing up to ultimate load to verify the damage growth of unrepaired damage would provide valuable data for the instructions of continued airworthiness.
response	*Noted* This comment does not relate to any change introduced by this NPA. Testing to failure can increase confidence in the structure's design if failure load, mode, and location are correctly predicted (particularly for low margins). The Agency agree's that testing to UL can be used to help verify damage growth of unrepaired damage. This forms part of AMC 20-29 paragraph 8, and in supporting references.

B. DRAFT RULES - I Draft Decision CS-23 - Book 2 - AMC 23.613	p. 8-9

comment	*53* comment by: *LHT DO* We recommend substituting the obsolete MIL-HDBK-xx references by the effective document references, e.g. CMH-17, MMPDS. Former document names may be added in parentheses for information. Example: “CMH-17 (formerly MIL-HDBK-17)”
response	*Accepted*

comment	*112* comment by: *UK CAA* Page No: 8 **Comment:** The original title of the AMC 23.613 does not reflect the title of the

CS 23.613 paragraph and should read "~~Metallic~~ <u>Material</u> strength properties and design values".
The original text of AMC 23.613 attempts to address to requirements CS 23.603 and 23.613 and fails to give clear guidance. CS 23.613 specifically addresses material design values whereas the first paragraph of the AMC gives guidance with regard to material specifications. This paragraph is at variance with 23.603 as it uses the term "should" and the requirement (23.603) states that material must meet approved specifications. Additionally, obsolescent and superseded US documents are referenced see below. The proposed NPA text does not address these points.

Mil-HDBK-5 withdrawn and superseded by MMPDS Handbook

Mil-HDBK-17 withdrawn and superseded by "The Composite Materials Handbook" CMH-17.

ANC-18 last published in the 1950's is no longer supported by the US government and thus must be considered as obsolescent.

ESDU 00932 "Metallic Materials Data Handbook" is a European equivalent to MMPDS accepted for use in design of large transport aircraft but is not referenced in CS 23.

It is noted that the NPA does not amend the text of AMC 25.613. As CS 25.613 requirement is essentially the same as CS 23.613 with some slight variations, and AMC 25.613 gives clear detailed guidance, it is recommended to use this text for AMC 23.613 with some minor changes, thus negating the necessity to reference AMC 20-29. There is additionally benefit to this approach in giving consistence of approach across the Certification Specifications.

Justification:

Proposed Text (if applicable):
~~Metallic~~ <u>Material</u> strength properties and design values

1. Purpose. This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-23 related to material strength properties and material design values.

2. Related Certification Specifications.
CS 23.603 “Materials”
CS 23.613 "Material strength properties and material design values”

3. General.

CS 23.613 contains the requirements for material strength properties and material design values.

4. Material Strength Properties and Design Values.

4.1. Definitions.
Material strength properties. Material properties that define the strength related characteristics of any given material. Typical examples of material strength properties are: ultimate and yield values for

compression, tension, bearing, shear, etc.

Material design values. Material strength properties that have been established based on the requirements of CS 23.613(b) or other means as defined in this AMC. These values are generally statistically determined based on enough data that when used for design, the probability of structural failure due to material variability will be minimised. Typical values for moduli can be used.

Aeroplane operating envelope. The operating limitations defined for the product under Subpart G of CS23.

4.2. Statistically Based Design Values.

Design values required by CS 23.613(b) must be based on sufficient testing to assure a high degree of confidence in the values. In all cases, a statistical analysis of the test data must be performed.

The "A" and "B" properties published in "The Metallic Materials Properties Development and Standardization (MMPDS) handbook" or ESDU 00932 "Metallic Materials Data Handbook" are acceptable, as are the statistical methods specified in the applicable chapters/sections of these handbooks. Other methods of developing material design values may be acceptable to the Agency.

The test specimens used for material property certification testing should be made from material produced using production processes. Test specimen design, test methods and testing should:

(i) conform to universally accepted standards such as those of the American Society for Testing Materials (ASTM), European Aerospace Series Standards (EN), International Standard Organisation (ISO), or other national standards acceptable to the Agency, or:

(ii) conform to those detailed in the applicable chapters/sections of "The Metallic Materials Properties Development and Standardization (MMPDS) handbook", "The Composite Materials Handbook" CMH-17, ESDU 00932 "Metallic Materials Data Handbook" or other accepted equivalent material data handbooks, or:

(iii) be accomplished in accordance with an approved test plan which includes definition of test specimens and test methods. This provision would be used, for example, when the material design values are to be based on tests that include effects of specific geometry and design features as well as material.

The Agency may approve the use of other material test data after review of test specimen design, test methods, and test procedures that were used to generate the data.

4.3. Consideration of Environmental Conditions.

The material strength properties of a number of materials, such as nonmetallic composites and adhesives, can be significantly affected by temperature as well as moisture absorption. For these materials, the effects of temperature and moisture should be accounted for in the determination and use of material design values. This determination should include the extremes of conditions encountered within the aeroplane operating envelope. For example, the maximum temperature of a control surface may include effects of direct and reflected solar radiation, convection and radiation from a black runway surface and the maximum ambient temperature. Environmental conditions other than those mentioned may also have significant effects on material design values for some materials and should be considered.

4.4. Use of Higher Design Values Based on Premium Selection.

Design values greater than those determined under CS 23.613(b) may be used if a premium selection process is employed in accordance with CS 23.613(e). In that process, individual specimens are tested to determine the actual strength properties of each part to be installed on the aircraft to assure that the strength will not be less than that used for design.

If the material is known to be anisotropic then testing should account for this condition.

If premium selection is to be used, the test procedures and acceptance criteria must be specified on the design drawing.

4.5. Other Material Design Values.

Previously used material design values, with consideration of the source, service experience and application, may be approved by the Agency on a case by case basis (e.g. "S" values of "The Metallic Materials Properties Development and Standardization (MMPDS) handbook" or ESDU 00932 "Metallic Materials Data Handbook").

4.6. Material Specifications and Processes. Materials should be produced using production specifications and processes accepted by the Agency.

response *Accepted*

However, cross reference to the AMC will be retained because the content of CS/AMC 25.613 only addresses concepts commonly associated with the base of the test/analysis pyramid. However, more complex material forms, e.g. braided structure VARTM, etc., may develop their reference properties higher up the test pyramid requiring different statistical approaches and consideration of other design issues.

resulting text

AMC 23.613
~~Metallic~~ Material strength properties and design values

1. Purpose. This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-23 related to

material strength properties and material design values.

2. Related Certification Specifications.
CS 23.603 “Materials”
CS 23.613 “Material strength properties and material design values”

3. General.

CS 23.613 contains the requirements for material strength properties and material design values.

4. Material Strength Properties and Design Values.

4.1. Definitions.
Material strength properties. Material properties that define the strength related characteristics of any given material. Typical examples of material strength properties are: ultimate and yield values for compression, tension, bearing, shear, etc.

Material design values. Material strength properties that have been established based on the requirements of CS 23.613(b) or other means as defined in this AMC. These values are generally statistically determined based on enough data that when used for design, the probability of structural failure due to material variability will be minimised. Typical values for moduli can be used.

Aeroplane operating envelope. The operating limitations defined for the product under Subpart G of CS-23.

4.2. Statistically Based Design Values.

Design values required by CS 23.613(b) must be based on sufficient testing to assure a high degree of confidence in the values. In all cases, a statistical analysis of the test data must be performed.

The "A" and "B" properties published in "The Metallic Materials Properties Development and Standardization (MMPDS) handbook" or ESDU 00932 "Metallic Materials Data Handbook" are acceptable, as are the statistical methods specified in the applicable chapters/sections of these handbooks. Other methods of developing material design values may be acceptable to the Agency.

The test specimens used for material property certification testing should be made from material produced using production processes. Test specimen design, test methods and testing should:

(i) conform to universally accepted standards such as those of the American Society for Testing Materials (ASTM), European Aerospace Series Standards (EN), International Standard Organisation (ISO), or other national standards acceptable to the Agency, or:

(ii) conform to those detailed in the applicable chapters/sections of "The Metallic Materials Properties Development and Standardization

(MMPDS) handbook", "The Composite Materials Handbook" CMH-17, ESDU 00932 "Metallic Materials Data Handbook" or other accepted equivalent material data handbooks, or:

(iii) be accomplished in accordance with an approved test plan which includes definition of test specimens and test methods. This provision would be used, for example, when the material design values are to be based on tests that include effects of specific geometry and design features as well as material.

The Agency may approve the use of other material test data after review of test specimen design, test methods, and test procedures that were used to generate the data.

4.3. Consideration of Environmental Conditions.

The material strength properties of a number of materials, such as non-metallic composites and adhesives, can be significantly affected by temperature as well as moisture absorption. For these materials, the effects of temperature and moisture should be accounted for in the determination and use of material design values. This determination should include the extremes of conditions encountered within the aeroplane operating envelope. For example, the maximum temperature of a control surface may include effects of direct and reflected solar radiation, convection and radiation from a black runway surface and the maximum ambient temperature. Environmental conditions other than those mentioned may also have significant effects on material design values for some materials and should be considered.

4.4. Use of Higher Design Values Based on Premium Selection.

Design values greater than those determined under CS 23.613(b) may be used if a premium selection process is employed in accordance with CS 23.613(e). In that process, individual specimens are tested to determine the actual strength properties of each part to be installed on the aircraft to assure that the strength will not be less than that used for design.

If the material is known to be anisotropic then testing should account for this condition.

If premium selection is to be used, the test procedures and acceptance criteria must be specified on the design drawing.

4.5. Other Material Design Values.

Previously used material design values, with consideration of the source, service experience and application, may be approved by the Agency on a case by case basis (e.g. "S" values of "The Metallic Materials Properties Development and Standardization (MMPDS) handbook" or ESDU 00932 "Metallic Materials Data Handbook").

4.6. Material Specifications and Processes. Materials should be produced using production specifications and processes accepted by the Agency.

For composite structure AMC 20-29 contains acceptable means of compliance and guidance material relevant to the requirements of CS 23.613.

B. DRAFT RULES - III Draft Decision CS-27 - Book 1 - Subpart D - CS 27.603 p. 9

comment	*40* comment by: *Eurocopter* A reference to AMC 20-29 is proposed to be inserted in CS 27.603 section. There is no real need for such an insertion: - up to now no reference is made to AMC materials in CS-27 Book 1. - AMC 20-29 is relevant for CS 27.603 but not only. - the existing AMC, namely AC 27-1B MG8 which covers the requirements of § 27.603, already makes reference to AC 20-107 with which AMC 20-29 is harmonised. A reference to AMC 20-29 under CS 27.603 is useless.
response	*Not accepted* Inclusion of the cross reference to AMC 20-29 is considered to be appropriate at this time. Once AC 27-1B and AC 29-2C are updated with a reference AC 20-107B and these have been formally adopted in Book 2 of CS-27 and CS-29, then consideration will be given to removing the reference.

B. DRAFT RULES - IV Draft Decision CS-29 - Subpart D - CS 26.603 p. 10

comment	*41* comment by: *Eurocopter* A reference to AMC 20-29 is proposed to be inserted in CS 29.603 section. There is no real need for such an insertion: - up to now no reference is made to AMC materials in CS-29 Book 1. - AMC 20-29 is relevant for CS 29.603 but not only. - the existing AMC, namely AC 29-2C section AC 29.603, already makes reference to AC 20-107 and AC 29 MG8 with which AMC 20-29 is harmonised. A reference to AMC 20-29 under CS 29.603 is useless.
response	*Not accepted* Inclusion of the cross reference to AMC 20-29 is considered to be appropriate at this time. Once AC 27-1B and AC 29-2C are updated with a reference AC 20-107B and these have been formally adopted in Book 2 of CS-27 and CS-29, then consideration will be given to removing the reference.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 p. 10

comment	*77* comment by: *Sell GmbH* Title may be misunderstood that this AMC is applicable on aircraft structure,

i.e. airframe, only.
To assure a uniform application of this AMC to all composite parts installed on aircraft please add to the title also "..., Parts and Appliances".

response *Not accepted*

The prime focus of AMC 20-29 is upon 'Critical Structure', as defined in Appendix 2. However, as Sell correctly implies, many of the practices in this document could be applied to other structures, e.g. secondary structure, parts and appliances.
Further development of the AMC to specifically include this aspect will lead to additional text, and at 36 pages (relative to the original 11), the AMC has been criticised by some commentators as being far too long. AMC20-29 is considered to be a reasonable compromise between competing needs. However, future revisions may allow development of this subject.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - ToC p. 10-11

comment *59* comment by: *LHT DO*

In contradiction to the applicability (only CS) there are tasks for maintenance, production and continuous airworthiness organisations included in this AMC. How can these organisations show compliance with AMC 20-29 if they are not addressed in the paragraphs and its applicability. Please note that our NAA´s asks its CAMO organisations for compliance with all AMC 20. Therefore exclusion in the AMC 20 Chapters is appreciable.

response *Noted*

AMC 20-29 is aimed at design and airworthiness certification and is
therefore applicable primarily to design organisations. However, due to the specific characteristics of composite structures, interfaces between the various functions are more integrated, necessitating the designer to have greater knowledge and awareness of production and continued airworthiness issues. AMC 20-29 therefore covers in detail these interface activities. Specific tasks required by other organisations (maintenance, production, continued airworthiness) have been removed from this document and this has created a difference with FAA AC 20-107B.

comment *113* comment by: *UK CAA*

Page No: 10

Paragraph No: AMC 20-29

Comment:
The title of the AMC should truly reflect the scope thus it is recommended that the title is changed to "Composite Aircraft Structures (Polymeric Matrix Composites)".

response *Not accepted*

The AMC retains its previous title because its scope has not changed relative to the original document, which has been accepted and is commonly understood. Note that the scope of AMC 20-29 also includes bonded structure and sandwich panels.

comment | *114* comment by: *UK CAA*

Page No: 10

Paragraph No: AMC 20-29

Comment:
The purpose and scope of AMC 20-29 appears confused and unclear. The definition of a composite material/structure has been generally accepted by the industry and regulators as "*A combination of two or more materials, differing in form or composition on a macro scale. The constituents retain their identities; that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. Composite materials are usually man-made and created to obtain properties that cannot be achieved by any of the components acting alone*". Although the AMC is entitled "Composite Aircraft Structures", the Purpose restricts the scope of it to "fibre reinforced materials, e.g. carbon and glass fibre reinforced plastics". However, the content covers various areas of materials technology, for example paragraph 6 references "All composite materials", paragraphs 6a 1-3 and 5-7 are non-specific and applicable to all materials and 6c discusses bonded structures. The AMC needs a clearly defined scope and the text needs to adhere to this scope.

It is suggested that the scope of the AMC is fibre reinforced polymeric matrix composites and the text should explain the specific differences between polymeric matrix composites and conventional metallic structures so it is clear that methodologies used in substantiation of metallic structures are not valid. The text should also give specific detail on acceptable methods to substantiate polymeric matrix composites.

response | *Partially accepted*

The text of “Purpose” is amended to clarify that Carbon and glass fibre reinforced plastics are only given as examples.

Although not the purpose of the document, differences relative to metallic structure are identified throughout the document when significant, e.g. Paragraphs 7 and 8. Paragraph 5b already identifies the key composite property behaviours, some of which differ with respect to metals.

comment | *115* comment by: *UK CAA*

Page No: 10

Paragraph No: AMC 20-29

Comment: The AMC should give clear concise guidance on how an applicant can show compliance with the applicable regulatory requirements (Certification Specifications). In general the text of this AMC is not well targeted, is repetitive and uses terminology that only informed composite materials specialist would fully understand. It is far too long at 35 pages to be of any real use to the industry. It is recommended that it is totally re-written with the specific remit to inform an applicant on how to show compliance with the regulatory requirements for polymeric matrix composite structures.

response	*Not accepted* AMC 20-29 has been developed to address the themes typically experienced by the Agency/NAAs during initial discussions with applicants, and extends the guidance previously given in other AMC. It has been written as a harmonised document and extensive rewriting at this time will result in de-harmonisation, with no obvious benefit. This document is considered to be a reasonable compromise between competing needs.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 1. Purpose p. 11

comment	*3* comment by: *AIRBUS* Airbus suggests to complement the paragraph with: "As with all AMC material, the information contained herein is for guidance purposes and is not mandatory or regulatory in nature." It is useful to remind that an AMC is not regulatory material.
response	*Partially accepted* None of the Agency's CS's (including the airworthiness code and AMC), are mandatory under EU law. It is an accepted principle that AMC is just one means of showing compliance, and this was stated in the explanatory note accompanying the initial issue of AMC-20. However, as it is recognised that this may not be readily visible to stakeholders, further clarification is given in AMC 20-29 Section 1. Purpose.

comment	*52* comment by: *Eurocopter* Considering the objective of this NPA as stated in explanatory note item 13c. "enable designers to anticipate the Agency's acceptance of composite structures", and considering that the regulations associated with each aircraft product type may be different, it is of utmost importance to include, in the AMC, a general statement modulating its applicability to the various types of aircraft addressed. AC 20-107B states: "The information contained herein is for guidance purposes and is not mandatory or regulatory in nature." . A similar statement should be inserted to confirm that the AMC does not change regulatory requirements and does not authorize changes in applicable regulatory requirements.
response	*Partially accepted* None of the Agency's CS's (including the airworthiness code and AMC), are mandatory under EU law. It is an accepted principle that AMC is just one means of showing compliance, and this was stated in the explanatory note accompanying the initial issue of AMC-20. However, as it is recognised that this may not be readily visible to stakeholders, further clarification is given in AMC 20-29 Section 1. Purpose.

comment	*137* comment by: *Gulfstream Aerospace Corp*

	... composite aircraft structures involving fibre reinforced materials, e.g. carbon and glass fibre reinforced plastic" - Recommend changing the word "plastic". The legacy term is more associated with thermoplastic matrices. Suggest using more generic terms like "matrices, polymers or composites". Recommend the use of more generic terms like "matrices, polymers or composites".
response	*Not accepted* The legacy term given in the fibre reinforced material 'example' is considered to be commonly used and reasonably well understood in the context of this document and aviation material utilisation.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 3. Applicability p. 11

comment 28 comment by: *Eurocopter*

The AMC is declared technically harmonised with FAA Advisory Circular AC 20-107B (Note refers). This harmonisation could be completed by inserting some additional details included in FAA AC 20-107B dated September 8, 2009:

- § 6a(1): use of batch acceptance testing or statistical process controls.
- § 6b: Manufacturing Implementation not limited to design considerations (additional considerations for manufacturing records and new suppliers qualification).
- § 6c: Structural Bonding (general considerations for process qualification).
- § 6c(3)(b): demonstration of long-term environmental durability.
- § 6c(4): emphasis on adhesion failures.
- § 6d: Environmental Considerations (identification of critical environmental conditions).
- § 6d(1): special attentions (worst case environment w.r.t. failure modes; accelerated tests).
- § 6e: Protection of Structure (more general considerations about fasteners).
- § 7a(3): alternate means to account for environment.
- § 8a(6): potential for missed inspections.
- § 10c(2): record keeping requirement for operators and maintenance repair organisations.
- § 11b(5): exterior fire protection (reference to § 25.856(b) standards as benchmark for large aeroplanes).
- § 11b(6): reduction of glass transition temperature by moisture absorption.
- § 11c: Lightning Protection effectiveness demonstration by tests or analysis supported by tests.

response *Partially accepted*

In preparing this CRD, the published version of AC 20-107B has been reviewed and compared with draft AMC 20-29 and some changes aimed at improving harmonisation have been included.

Note that some European industry comments were also directed into the FAA public comment process (some repeated in this CRD), and have been dispositioned under a joint working arrangement. As the published AC has already benefitted from public scrutiny, it is more representative of the final harmonised position than NPA 2009-06.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 4. Related regulations and guidance p. 11

comment *4* comment by: *AIRBUS*

The first paragraph reads: " The material contained herein applies to aircraft to be type-certificated under CS-23, 25, 27, 29; and <u>it is produced in compliance with PART 21</u>"
The Part 21 does not lay down the rules driving the production of AMCs.

response *Accepted*

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 5. General p. 11-12

comment *5* comment by: *AIRBUS*

The objective of this AMC should be clarified further adding the underlined text in first sentence:
"The procedures outlined in this AMC provide [...] guidance material for composite structures <u>that are essential in maintaining the overall flight safety of the aircraft ("critical structure", according to definition of appendix 2)</u> and are considered acceptable..."
It is understood the procedures outlined in this AMC are applicable to critical structures (see definition in appendix 2).
The term "Critical structure" appears in §6(a)(3), 7(b)(1) and 8(a)(2).
This will provide a harmonized text with AC20-107B.

response *Accepted*

comment *62* comment by: *Boeing*

Page 12;
Para 5.b.

Delete the word "critical" from the sentence:

Comment
"For example, the environmental sensitivity, anisotropic properties and heterogeneous nature of composites can make the determination of ~~critical~~ structural failure loads, modes and locations difficult."

Rationale
<u>Any</u> failure load or mode is difficult to determine.

Recommendation
Delete "critical."

response	*Accepted*

comment	*74* comment by: *Ludger Duelmer, Extra Flugzeugproduktion*
	B. 5: General: A definition of “similar structure” accompanied by examples should be given (assessment for the similarity approach).
response	*Not accepted* The determination of what is ‘similar structure’ will vary on a case by case basis. Inclusion of this term is simply intended to indicate to industry that the Agency can give appropriate credit to previous experience.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 6 Materials and fabrication development p. 12-16

comment	*6* comment by: *AIRBUS*
	Paragraph 6a(6): The second sentence: "[...] prior to completing all the material and process qualification tests and final development of associated specifications "should be modified into: "[...] in a way shown to be consistent with the material and process qualification tests and development of the associated specifications." Material and process qualification tests are developed together with design principles and associated manufacturing processes, integrating all the technical issues (design, manufacturing, structural performance). This will provide a harmonized text with AC20-107B.
response	*Accepted*

comment	*7* comment by: *AIRBUS*
	Paragraph 6a(7): The second sentence should be changed into: "However, the materials and <u>process specifications are part of the type-design subject to the type-certification</u>."
response	*Accepted*

comment	*8* comment by: *AIRBUS*
	Paragraph 6b: Two sub-paragraphs have been deleted compared to AC20-107B paragraph 6(b). The technical content of paragraphs 6(b)(2) and 6(b)(3) is relevant to this guidance material. EASA should consider re-inserting paragraphs 6(b)(2) and 6(b)(3) from AC 20-107B.
response	*Partially accepted*

	Paragraph 6(b)(2) and (3) have been re-formatted to make them more applicable to design and included in AMC 20-29.

comment	*9* comment by: *AIRBUS* Paragraph 6c: It is surprising to find a reference to “metal-to-metal bonding” in an AC material devoted to composites. EASA should delete the reference to “metal-to-metal bonding”.
response	*Not accepted* Many of the aspects discussed are applicable to metal-metal bonding. Ideally, EASA would wish to develop a separate AMC for metal-metal bonding when resources permit.

comment	*10* comment by: *AIRBUS* Paragraph 6c(3)(a): The intent of §23.573(a) should be clarified with the addition of a note: "Note: <u>This requirement does not apply to bonding within sandwich structure</u>."
response	*Not accepted* Ideally EASA would also wish to develop a separate AMC for sandwich structure, when resources permit. However, until such time, many of the aspects of this AMC are applicable to Sandwich structure. Note that new industry guidance material (CMH-17) is due for release soon and Volume 6 will be dedicated to sandwich structure.

comment	*11* comment by: *AIRBUS* Paragraph 6c(3)(b): Last sentence should be complemented: "Such technology has not been reliably demonstrated at a production scale <u>to date</u>."
response	*Accepted*

comment	*44* comment by: *Bombardier Aerospace* 6.a. Material and Process Control (2) Comment: Suggest to reverse the order of the following two sentences. “Once the fabrication processes have been established, any changes should undergo additional qualification, including testing of differences before being implemented (see Appendix 3). It is important to establish: (i) processing tolerances, (ii) material handling and storage limits, and (iii) key characteristics of the final product.” Proposed Text: “It is important to establish: (i) processing tolerances, (ii) material handling and storage limits, and (iii) key characteristics of the final product. Once the fabrication processes have been established, any changes

	should undergo additional qualification, including testing of differences before being implemented (see Appendix 3)." Rationale: for clarity
response	*Not accepted* The proposed change is not considered to justify de-harmonisation. A difference between AC and AMC texts may also result in confusion regarding the reason why.

comment	*45* comment by: *Bombardier Aerospace* 6.a. Structural Bonding Affected Text: The first sentence "The discrepancies permitted...." Recommendation: Change to "The tolerances permitted...." Rationale: Risk of misinterpretation. "Discrepancies" may be interpreted as something un-planed happened. "Tolerances" sounds like there are targets with acceptable ranges.
response	*Accepted*

comment	*46* comment by: *Bombardier Aerospace* 6.c. Structural Bonding Affected Text: The first sentence "Bonded structures include multiple interfaces (e.g., composite-to-composite, composite-to-metal, or metal-to-metal), where at least one of the interfaces requires additional surface preparation prior to bonding." Recommendation: Suggest to provide a description of what it does not include or to provide examples of structures that are not considered as bonded (co-cured?). Rationale: The way that the bonded joint is defined here may be understood as an example only "it includes ...". This is subject to interpretation because it does not say if the case where there is no interface requiring additional surface preparation is or it is not considered as a bonded joint.
response	*Not accepted* Although the comment is well made and understood, the Agency does not believe this to be the correct location in which to develop the discussion. Therefore, the text simply cautions those new to the subject that existing cured surfaces, requiring preparation etc, present potentially the greatest risk.

comment	*47* comment by: *Bombardier Aerospace*

	6.c. Structural Bonding (3)(b) Comment: Regarding the fail safety (design feature) approach for bonded joint, it is not specified if the disbond shall be detectable by the schedule inspections. Recommendation: Regarding the acceptability of the fail safety approach, a condition regarding the disbond detectability during inspections should be added. Rationale: The original text can be interpreted as: it is acceptable to have bonded joints where the design features cannot support ultimate load but can support limit load, without considering if potential disbonds are going to be detectable or not by scheduled inspections.
response	*Not accepted* The Agency agrees with the technical concern, but believes that the remainder of the paragraph and the subsequent F&DT section addresses the concern (e.g. via the categorisation paragraph 8(a)(1)(c), which links inspection/detection to severity).

comment	*54* comment by: *LHT DO*
	ad c), page 14 1st section: Metal-metal-bondings should be covered in a dedicated AMC. Should EASA consider the effort for such AMC to be excessive, we agree adding these bondings to the AMC 20-29. In this case we recommend amending the Draft Decisions for CS-2x, Subparts D, by adding to the relevant paragraphs (e.g. “Materials and workmanship”) a suitable reference to AMC 20-29, for example: “For structural bondings involving metallic substrates, also see AMC 20-29”. In any case, please delete ***chemically:*** Chemical activation is not the only suitable process to prepare a metallic bond interface; in some specific cases it is not applicable. We recommend amending as follows: “***For all*** bonding interfaces, ***regardless if on metallic or previously cured composite substrates***, a qualified surface preparation is needed to activate their surface for chemical adhesion.”The sentence “All metal interfaces...” can be deleted when previous sentence is amended as proposed
response	*Accepted* Many of the aspects discussed are applicable to metal-metal bonding. Ideally, the Agency would wish to develop a separate AMC for metal-metal bonding when resources permit. Amended text accepted.

comment	*61* comment by: *Boeing*
	Page 12; Para 6, first paragraph **Comment**

	Revise the text to read as follows: "*All composite materials and processes used in ~~critical~~ structure are qualified through enough fabrication trials and tests to demonstrate a reproducible and reliable design. ~~One of the unique features of composite construction is the degree of care needed in the procurement and processing of composite materials.~~*" ***Rationale*** Delete word "critical": Critical or not, all structures follow this definition. Delete last sentence: Care in procurement and processing is not unique just for composites. ***Recommendation*** Revise text by deleting words as indicated.
response	*Partially accepted* Reference to 'critical' is deleted. The Agency agrees that the care regarding procurement etc is not unique to composites. However, most of the text is retained to remind the reader of the importance of the issue, but 'unique' is to be replaced by 'important'.

comment	*63*	comment by: *Boeing*
	Page 12; Para 6.a.(1) **Comment** Revise the text to read as follows: "*... Material specifications are required to ensure consistent material is being procured, **<u>and batch acceptance testing or statistical process controls are used to ensure material properties do not drift after qualification. ...</u>**"* ***Rationale*** Text should be added for clarification concerning postproduction. ***Recommendation*** Add text as indicated (underlined).	
response	*Partially accepted* Intent accepted. Change in wording is in accordance with AC 20-107B.	

comment	*64*	comment by: *Boeing*
	Page 12; Para 6.a.(2) **Comment** Define the term "key characteristics" in the sentence that states: "*... (ii) material handling and storage limits, and (iii) key characteristics of the*	

final product."

Rationale
For clarity and consistency, this term should be defined in the appendix.

Recommendation
Add definition "key characteristics."

Page 12;
Para 6.a.(3)

Comment
Define or delete the word "critical" in the text that reads:

" … Qualification data must cover all properties important to the control of materials (composites and adhesives) and processes used for production of critical composite structure. …"

Rationale
Qualification data requirements apply to all materials that are structural, not just "critical." For clarity and consistency, we recommend either defining in this section what is meant by "critical," or deleting the word "critical.

Recommendation
Define or delete the word "critical."

Page 13; Para 6.a.(4)

Comment
Revise the text to read as follows:

"… variables should include ~~extreme service temperature and moisture content conditions.~~ ***the limits of the in-service temperature and moisture content conditions affecting material properties, as well as typical in-service environmental effects on long-term durability****. …"*

Rationale
In-service temperatures should be understood according to the probability of the load occurrence, and not always the "extreme."

Recommendation
Change text as indicated (underlined).

Page 13; Para 6.a.(6)

Comment
Add a new second sentence to read as follows:

"… Structural performance, which is affected by discrepancies permitted per the specification, should fall within the statistical confidence of the allowables developed under nominal processes. Structure produced consistently at the edge of the process parameters or with consistent specification permitted discrepancies shall have allowables or design values adjusted to reflect the process capability. …"

Rationale
Clarification is needed for situations when properties are consistently at the edges of the controlling specifications.

Recommendation
Add new text as indicated.

Page 13; Para 6.b.

Comment
Not harmonized to AC20-107b??

Rationale
Why is this not harmonized to the AC.

Recommendation
Change text if harmonization is desired

Page 14; Para 6.c., first paragraph

Comment
Define the word "qualified" as used in the text that states:

" ... In the case of bonding composite interfaces, a ***qualified*** *surface preparation of all previously cured substrates is needed to activate their surface for chemical adhesion. ..."*

Rationale
For clarity and consistency, the word "qualified" should be clarified or defined, such as:

"Documented and demonstrated repeatable and reliable process. It entails understanding the sensitivity of structural performance based upon expected variation permitted per the process. Characterization outside the process limits is recommended to ensure process robustness."

Recommendation
Define "qualified" as used in this section of the AMC.

Page 14; Para 6.c., first paragraph

Comment
Delete the word "critical" from the text so that the sentence reads as follows:

" ...~~Critical~~ ***__A__****pplications require stringent process control and a thorough substantiation of structural integrity."*

Rationale
Critical is implied and is difficult to define. The sentence applies to all applications.

	Recommendation Delete the term "critical." Page 14; Para 6.c.(1) **Comment** Change text of the first sentence to read as follows: *"~~Most~~ **Many** bond failures and problems in service have been traced..."* ***Rationale*** We disagree with use of the word "most" in this context without substantiating data. "Many" is more appropriate. ***Recommendation*** Change text as indicated. Page 15; Para 6.f., first paragraph **Comment** Revise the text to read as follows: *" ... Data used to derive design values must be obtained from stable and repeatable material, which are procured per a mature material specification and processed per a* ***representative*** *production process specification. ..."* ***Rationale*** Some test parts use a modified production specification required to build a test part. ***Recommendation*** Add qualifying word to text as indicated (underlined). Page 16; Para 6.g. **Comment** Define the word "metrics" as used in the text: *" ... In the absence of specific* ***metrics*** *for composite structural damage states such as caused by foreign impact damage threats ..."* ***Rationale*** For clarity and consistency in application, we request that "metrics," as used in this context, be defined. ***Recommendation*** Include a definition or description of what constitutes "metrics" in this context.
response	*Partially accepted*

6.a(2) - Not accepted. 'Key characteristics' is considered to be a generally understood concept and may vary from material to material.

6.a(3) - Accepted. 'critical' is deleted.

6.a(4) - Partially accepted. Text is aligned with AC 20-107B

6.a(6) - Not Accepted. AC 20-29 is intended to outline general guidance for composite aircraft structure. The recommended change is at a detailed level that implies more specific guidance on the approach that needs to be used by an applicant in quantifying the effects of process discrepancies. A process consistently providing data at the edge of the specification limits suggests that the basic intent of the original sentence has not been satisfied.

6.b - Partially Accepted. Paragraph 6(b)(2) and (3) have been re-formatted to make them more applicable to design and included in AMC 20-29.

6.c - Accepted

6.c(1) - Accepted

6.f - Accepted

6.g - Partially Accepted. Text is aligned with AC 20-107B.

comment *78* comment by: *Sell GmbH*

Comment to 6. a. (1) and (3):
Please harmonize the specifications listed to assure a common understanding of specifications required and to prevent the burden of unneeded documents. Therefore this is to propose that "procurement specification" as listed under (3) is replaced by "material specification", as material specifications include respective requirements to ensure that consistent material can be procured.

response *Not accepted*

The Agency agrees that unnecessary documents should be avoided.
The use of the term 'procurement specifications' in 6a(3) is only intended to highlight this aspect of a material specification, not necessarily imply a separate document. See also AC 23-20 in the reference list for guidance.

comment *79* comment by: *Sell GmbH*

Comment to 6. a. (1) last sentence:
The wording "as closely as possible" is not a clear specification and will lead to ambiguous application. To ensure a reproducible and reliable design the process parameters should be within the tolerance band qualified and specified in respective fabrication procedure.
Therefore please replace "as closely as possible" by "… should be within the tolerance band of process parameters to be used in manufacturing actual production parts."

response *Partially accepted*

Additional text is added in line with AC 20-107B, to clarify the intent.

comment	*80*	comment by: *Sell GmbH*
	Comment to 6.a.(5): Please add reference to respective CS requiring the overall quality control plan and specify the contents of the overall quality control plan.	
response	*Not accepted* 'Quality control plan' is used in a generic sense to imply a quality control plan/system in accordance with Part 21 Subparts G (Production Organisation Approval), or Subpart J (Design Organisation Approval).	

comment	*81*	comment by: *Sell GmbH*
	Comment to 6.d.: To assure a uniform consideration of environmental conditions it is recommended to add a reference to the globally recognized environmental testing guidance for airborne equipment, RTCA DO-160 / EUROCAE ED-14, as guidance to develop appropriate test conditions for environmental exposures.	
response	*Accepted* Reference added to Appendix 1. Although a useful document, the low operating temperature of -55C (Table 4-1) may not be adequate for Polar Cap routing.	

comment	*82*	comment by: *Sell GmbH*
	Comment to 6.d.(1): The definition of "a high degree of confidence" is missing and would therefore lead to ambiguous applications. A clear specification of the required degree of confidence should be added.	
response	*Not accepted* 'High degree of confidence' is used in 6d(1) in the generic sense in relation to identifying the critical environment. Once defined, the design values or allowables should be determined using statistical levels of confidence, e.g. iaw 25.613. The Agency believes that the existing text functions adequately in the context of the other paragraphs.	

comment	*88*	comment by: *Austro Control GmbH*
	6. a. (7) - Comment The Agency should be responsible for the certification/assessment of new or alternative processes and changes thereof. If a TC holder changes a process a change (minor/major) i.a.w. Part-21 should be initiated. -> Refer to Appendix 3, (1).	
response	*Noted* The applicant should be using this AMC in conjunction with Part 21 and should be driven to the appropriate classification and modification processes accordingly.	

comment	*89* comment by: *Austro Control GmbH* 6. a. (7) – Added wording Note that materials and processes used in European technical standard order (ETSO) articles or authorisations must also be qualified and controlled for the particular product to be certified.
response	*Not accepted* Existing text is considered adequate because materials and processes associated with ETSO require ‘qualification and control’ at the part and product levels.

comment	*90* comment by: *Austro Control GmbH* 6. e. – Comment The protection of the structure (e.g. paint) should provide sufficient elastic behaviour up to ultimate load taking into account dynamic effects. If the protection barrier is broken during service, maintenance should be responsible for the detection.
response	*Noted* The Agency agrees with the technical point, but considers it of a generic nature and not just related to composites. The issue would therefore need to be addressed as a new rulemaking task, possibly by providing additional AMC to 25.609.

comment	*102* comment by: *CAA-NL* e. Protection of Structure We suggest including the treat of micro biologicals (e.g. fungus) into this paragraph by including the words 'micro biologicals' into the first sentence.
response	*Not accepted* The Agency has no evidence to indicate that microbiological organisms represent a safety threat through deterioration in composite structures.

comment	*116* comment by: *UK CAA* **Page No:** 12 **Paragraph No:** Paragraph 6 - Material and Fabrication Development **Comment:** The first sentence of the paragraph *"All composite materials and processes used in Critical Structures are qualified through enough fabrication trials and tests to demonstrate a reproducible and reliable design."* is at variance with the requirement CS 2X.603. CS 2X.603 states "*The suitability and durability of materials used for parts, the failure of which could adversely affect safety, must be established on the basis of experience or tests*". It is not clear that the term "*Critical Structures*" equates to "*parts the failure of which could adversely affect safety*". The use of different terms to mean the same thing will lead to confusion and the incorrect interpretation of the requirements.

	Additionally, due to the use of the word "*are*" this sentence is a statement that an applicant can infer that no action is required, because the composite materials and processes are already qualified. It is unclear what is meant by the term "*All composite materials*" in this sentence. Is it just polymeric matrix composites or does it include metal bonded structures, metal matrix composites and composite laminates? Finally, what is unique to composite materials? The intent of this sentence is applicable to all materials, structural adhesives, glass, poly-methyl-methacrylate, aluminium alloys used in the construction of civil aircraft. The second sentence "*One of the unique features of composite construction is the degree of care needed in the procurement and processing of composite materials*" gives the reader little useful information as well as being factually incorrect. The term "care" is subjective. One can carefully hit a composite with a 5kg sledgehammer. Would it be fit for purpose after this operation? The term quality control or quality assurance has significantly more meaning than "care", as it infers that the critical material and processing parameters have to be identified, monitored and controlled. This comment is also applicable to the fourth sentence, which opens with the term "special care". Most metallic alloys are significantly more sophisticated than a polymeric matrix composite and the quality control measures required to ensure compliance with recognised national specifications are well beyond those required for the production of a polymeric matrix composites. The remainder of this paragraph does not give concise understandable and useable guidance to an applicant; additionally the guidance given is not unique to composite materials. Recommend deletion of the paragraph.
response	*Partially accepted* AMC 20-29 has been developed to address the themes typically experienced by the Agency/NAAs during initial discussions with applicants, and extends the guidance previously given in other AMC. It does not change definitions used in CSs. It has been written as a harmonised document and extensive rewriting at this time will result in de-harmonisation, with no obvious benefit. This document is considered to be a reasonable compromise between competing needs. Regarding the use of the word ‘are’: The Agency does not consider there to be any alternative meaning to that intended. ‘Are’ could be considered to better close the meaning than other alternatives, i.e. the existing sentence ‘requires’ that the material be qualified. Regarding the use of the term ‘all’, this point is true for many materials used in significant aviation applications, not just composites, so it functions in an introductory sentence. Accepted. ‘unique’ to be changed to ‘important’. This AMC is not intended to understate the importance and complexity of metals (although, composite raw material production (often using proprietary complex chemistry) is probably comparable to metal alloy production), but

recognises that many of the significant 'engineer properties' are developed later in production/repair processes than metals, i.e. the balance of material property awareness and final property development has shifted to a new audience relative to metal structure. Other than surface treatments, heat treatments, and some other handling aspects, this is generally not the case for metals. Even for castings, when the properties are also developed in the final part form, this activity occurs earlier in the process, relative to composite structures.

Regarding the use of the word 'care', its meaning should be clear in the context of the repeated message regarding the need for quality control and quality assurance throughout the document and in references. Such word variation is considered to be reasonable for the purposes of legibility and to aid communication of new ideas to a community (DOA, including repair organisations) which may not be so familiar with them. The supporting reference list should be consulted for further guidance.

comment *117* comment by: *UK CAA*

Page No: 12

Paragraph No: Paragraph 6a Material and Process Control

Comment:

Sub-paragraphs 6a(1) - 6a(7) are too verbose, give little specific useful detailed guidance to an applicant and will leave an applicant confused. The intent of all the paragraphs is applicable to all structural materials including aluminium alloys, glass, etc. It is noted that some aspects of paragraph 6a(4) are specific to polymeric matrix composites. Making a special case for polymeric matrix composites implies either the applicants are ignorant of the regulatory requirements covering materials in general or the requirements only have to be applied to polymeric matrix composites: both are incorrect.

It is recommend that these paragraphs are either deleted or re-written to ensure that it is clear that, in principal, all the guidance is applicable to any structural material use in parts, the failure of which could adversely affect safety. If re-written the text needs to be clear concise and useable, which it is not in its current form.

response *Not accepted*

AMC 20-29 has been developed to address the themes typical experienced by the Agency/NAAs during initial discussions with applicants, and extends the guidance previously given in other AMC.

Extensive rewriting at this time will result in de-harmonisation, with no obvious benefit. This document is considered to be a reasonable compromise between competing needs.

comment *118* comment by: *UK CAA*

Page No: 12

Paragraph No: 6a

Comment:
The use of the term "fabrication" is not consistent with the dictionary definition "manufacture product from semi-finished stock". Fabrication operations are basically assembly of components into a product, part or appliance, thus fabrication of a polymeric matrix composite part would imply joining composite components together by mechanical fastening, or adhesive bonding. It would appear that the term fabrication is used in the proposed AMC to mean the manufacture/production of polymeric matrix composite materials/components from their constituents, i.e. carbon fibre and epoxy resin monomer, as well as assembly of composite components into products, parts and appliances. This leads to reader confusion.

Recommend the terminology used in this AMC is consistent with what the material industry uses in general and that the AMC consistently uses the terminology.

response *Not accepted*

2X.605 is entitled ‘Fabrication Methods’, and includes a broad range of examples such as ‘gluing, spot welding, or heat treating’. Therefore, bonding and other processes are implied. Furthermore, the broad range of materials and processes available for the production of composite structure has resulted in broader, and often interchangeable, use of such terms. ‘Fabric’ also forms part of the identification for some composite materials, e.g. ‘woven fabric’ (in a prereg, wet-lay-up, Braided RTM etc), such that the term ‘fabrication’ could be linked to all stages of a composite production. The composite industry is still maturing. Until the industry standardises its terminology, The Agency considers that this terminology functions for the purpose of this document and is commonly understood. Further refinement of the definition may be possible in future revisions of the AMC.

comment *119* comment by: *UK CAA*

Page No: 12

Paragraph No: 6a

Comment:
The AMC uses the terms "material specification", "process specification", and "fabrication specification". It is unclear what is meant by these terms. With metallic materials typically the material specification will defined the chemical composition of the alloy, critical mechanical properties, the method of manufacture of the alloy as well as the method of manufacture of the product form (forging, bar, sheet, plate, tube etc.), the heat treatment processing parameters, etc. If for example the method of manufacture changes between two chemically identical steels, air melting, as opposed to vacuum re-melting, there will be two separate material specifications. A material specification should be self-contained so as to produce a defined product from defined feedstock using a defined methodology. The AMC over complicates the situation with "material specification", "process specification", and "fabrication specification" and will leave the reader confused to what the purpose of these separate documents are.

response *Not accepted*

Terminology such as ‘material’ and ‘process’ specifications are accepted definitions and are used to highlight specific concepts within the fabrication procedures. Also, the structural behaviour may be defined by the fabrication procedures (which may, or may not include mechanical fastening, bonding etc). Also see AC 23-20 and PS-ACE100-2001-006 and associated references.

comment

120 comment by: *UK CAA*

Page No: 13

Paragraph No: Paragraph 6b Design Considerations for Manufacturing Implementation

Comment:
This paragraph is written for the informed reader and thus the guidance detailed in it will already be understood. It will not help an uninformed reader to become informed on how to comply with the requirements. This can be said of much of the AMC.

First sentence "*Process specifications and manufacturing documentation are needed to control composite fabrication and assembly*" does not add any guidance with regard to CS 2X.603 which requires the materials used for parts, the failure of which could adversely affect safety, meet approved specifications that ensure the strength and other properties assumed in the design data. As stated by the requirement all materials have to comply with CS 2X.603a(2).

Second sentence "*The environment and cleanliness of facilities are controlled to a level validated by qualification and proof of structure testing*". To the uninformed reader this is an unexpected statement. Why does the environment and cleanliness of production facilities for polymeric matrix composites need controlling? The AMC should give details of methods to show compliance with the requirements and thus this sentence should read "*The environment and cleanliness of the composite manufacturing facilities need to be controlled in a manner that will ensure that the quality of product defined by the material/component specification is consistently met*".

The third and fourth sentences "*Raw and ancillary materials are controlled to specification requirements that are consistent with material and process qualifications. Parts fabricated should meet the production tolerances validated in qualification, design data development, and proof of structure tests*" do not give any essential information and the fourth sentence is incorrect. The parts manufactured should meet the production tolerances defined in the design drawings, which must quote directly or indirectly all the essential manufacturing quality control measures with appropriate acceptance criteria.

Recommend deletion of this paragraph. The paragraphs 6a and 6b should be replaced with text following the principles of AMC 25.621 (c)(1) "Premium Castings"

response

Partially accepted

The reader should only require basic knowledge to be able to start to understand this document. As indicated in the comment responses above, e.g. response to comment 115, other regulatory activities are in progress to improve and standardise knowledge levels, This AMC should be viewed in the context of such.
Paragraphs 6(a) and (b) are brief paragraphs which summarise elements of the reference documents. Although the composite production process may show

similarities to castings, for some of the reasons identified in the Agency's responses to the commentators other comments, they are not the same as castings. The similar aspects, i.e. properties being built into the part etc, need to be addressed to a different and broader audience.

Reference to drawing added in 6.b(1).

comment | *121* | comment by: *UK CAA*

Page: 13

Paragraph No:
Paragraph 6c Structural Bonding

Comment:

This paragraph is not within the defined scope of this AMC and thus should be deleted.

The paragraph has little structure and does not give clear guidance on how an applicant may show compliance with 2X.605(a) "*The methods of fabrication used must produce a consistently sound structure*" for bonded structures. The paragraph implies that every bonding process must undergo a qualification procedure. However it neglects to mention the requirement that enforces this practice 2X.605(b) "*Each new aircraft fabrication method must be substantiated by a test programme*". Thus the whole paragraph should be deleted or totally re-written so that effective guidance is given. It is recommended that the structure of this paragraph should basically follow that laid down in AMC 25.621 (c)(1) "Premium Castings".

The first paragraph contains irrelevant text, examples of which are "The general nature of technical parameters that govern different types of bonded structure are similar" and "Many technical issues for bonding require cross-functional teams for successful applications". It is believed that the intent of the paragraph is to state that one of the most important parameters in bonding processes is surface preparation. This can be stated concisely.

6c(1) the first sentence of this paragraph is factually incorrect: the primary casual factor in bond failures and in service problems is not invalid qualification testing or the lack of quality control. The failures arose due to a lack of understanding of the critical parameters that affect the performance of bonded joints. The statement "Some type of peel test has proven more reliable for evaluating proper adhesion" does not assist an applicant in showing compliance. It is recommended this paragraph be deleted and replaced with simple statements that the qualification process should; identify all the critical process parameters that affect the critical properties of the joint; establish effective and reliable methods to monitoring and controlling these parameters.

6c(2) can be deleted as the requirement is clear concise and to the point. 2X.605(a) states "……...*If a fabrication process (such as gluing, ………) requires close control to reach this objective, the process must be performed under an approved process specification*".

6c(3) is a distraction from 2X.605, the primary requirement that has to be complied with in the case of bonded joints, and thus should be deleted.

response *Not accepted*

Bonded structure, e.g. bonded joints, can form part of the definition of a composite structure.

2X.605 is identified against this section in Appendix 1.
This text is intended to provide an adequate introduction with links to appropriate references.

The comment 'a lack of understanding of the critical parameters that affect the performance of bonded joints' seems to be making a similar point to that already made in the original text, i.e. 'invalid qualification testing or the lack of quality control' may form part of any failure to identify and/or manage key parameters. The importance of identifying key parameters is also identified elsewhere in the AMC.
This text provides guidance and linkage to other relevant requirements for which aspects of 2x.605 are particularly important. Note 2X.605 is identified in Appendix 1.

comment *122* comment by: *UK CAA*

Page No: 15

Paragraph No:
6d Environmental Considerations

Comment:

This paragraph is too long and the majority of the text does not add anything to the basic requirement detailed in 2X.603(c) "*Take into account the effects of environmental conditions, such as temperature and humidity, expected in service*". Additionally if paragraph 6 was replaced by text that followed the principles of AMC 25.621 (c)(1) "Premium Castings" this paragraph would not be needed.

response *Not accepted*

This text provides guidance and linkage to useful references.

comment *123* comment by: *UK CAA*

Page No: 15

Paragraph No:
6e Protection of Structure

Comment:

The initial half of this paragraph is applicable to all structural materials including steels, aluminium alloys, magnesium alloys, glass, poly-methyl-methacrylate, polycarbonate, polyvinyl-butyral, etc. So why does an applicant substantiating a polymeric matrix composite structure need guidance on what is required by 2X.609 but an applicant for a windshield STC does not? "*Weathering, abrasion, erosion, ultraviolet radiation, and chemical environment (glycol, hydraulic fluid, fuel, cleaning agents, etc.) may cause deterioration in a composite structure. Suitable protection against and/or consideration of*

	degradation in material properties should be provided for conditions expected in service and demonstrated by test. Where necessary, provide provisions for ventilation and drainage". The second half of the paragraph is very specific and could be more generalised. However the requirement 2X.609 is clear and concise and thus does not need any specific compliance guidance, thus deletion of the paragraph is recommended.
response	*Not accepted* This text provides guidance and linkage to references. This section exists for completeness in the AMC. Its omission would also be questioned. Also note that windshields represent a subset of composites which carry there own requirements and guidance material.

comment	*124* comment by: *UK CAA* **Page No:** 15 **Paragraph No:** 6f Design Values **Comment:** The initial text of this paragraph states the obvious; that the established design values must relate directly to the material/component used in serial production of the aircraft. Thus recommend that the text "Data used to derive design values must be obtained from stable and repeatable material that conforms to mature material and production process specifications. This will ensure that the permitted variability of the production materials is captured in the statistical analysis used to derive the design values. Design values derived too early in the material's development stage, before raw material and composite part production processes have matured, may not satisfy the intent of the associated rules" is deleted. The remainder of the paragraph is written in such a manner that the text can only be fully understood by an informed reader; it does not inform a reader on how to comply with the requirement. The paragraph should fully explain why the current AMC 25.613 is not applicable to polymeric matrix composites. It does not explain why allowances have to be used and how allowable can be converted into material design values. A good opportunity to inform the industry is being missed. Recommend the whole of this paragraph is re-written.
response	*Not accepted* Although much of the text is generic, the issue of particular interest is material variability. Therefore, the need for representative structure needs to be emphasised. Also see the references for further guidance regarding these themes. This text provides guidance and linkage to references. Note AMC 25.613 remains applicable and is referenced in Appendix 1.

comment	*130* comment by: *Diamond Aircraft Industries (Austria)*

	6.b (Design Considerations for Manufacturing Implementation): "Parts fabricated should meet the production tolerances validated in [...] proof of structure tests". This may be interpreted such that ALL production tolerances must be validated in proof of structure tests. The NPA should include a statement to the effect that only those tolerances which significantly affect safety are to be validated. In terms of safety this would be consistent for example with CS 23.301 (c) which requests only significant load redistributions due to deformation to be accounted for.
response	*Partially accepted* Text is amended to refer to drawing tolerances. (Also see Comment #120)

comment	*131* comment by: *Diamond Aircraft Industries (Austria)* 6.c.(1) (Structural Bonding): Fracture toughness should be addressed for the qualification of an adhesive, in particular for a damage no-growth or slow-growth approach. A strong but brittle adhesive does not necessarily lead to a safer structure than a weaker but more ductile adhesive.
response	*Noted* The Agency agrees with the importance of the technical point, but considers it to be a design selection issue which is addressed in industry standards and guidelines, e.g. CMH-17. Paragraph 8, Damage Tolerance, addresses the damage growth concepts.

comment	*139* comment by: *Gulfstream Aerospace Corp* Para. 6.a(2) *"Once the fabrication processes have been established, any changes should undergo additional qualification.* Additional qualification should be undertaken only when Key Process Parameters are affected. Recommend adding item (iv) to identify Key Process Parameters (KPP).
response	*Partially accepted* The Agency agrees with the importance of this point and has changed AMC text to remove “any” and to require that key characteristics of the process have been established. Note that Appendix 3 provides greater detail on re-qualification of material and process changes.

comment	*140* comment by: *Gulfstream Aerospace Corp* Para. 6.a(7) *"Appropriate certification credit may be given to products and organisations using the same materials and processes in similar applications subject to substantiation and applicability. In some cases, material and processing information may become part of accepted shared databases used throughout industry.* What organizations receive credit from EASA? NCAMP?, SAE? (AMS specs, NMS from P-17 committee, etc). Identify what major organizations receive credit from EASA.
response	*Noted* The shared database issue is developing rapidly, so providing specific information for this document, which may not be revised for 5 years, may not be appropriate at this time. However, The Agency is well aware of NCAMP and

	associated activities developing in Europe, and considers that it could be used with appropriate validation and early discussion with the Agency.

comment	*141* comment by: *Gulfstream Aerospace Corp* Para. 6.c(3) Structural Bonding. The only certification approach appears to be failsafe. Part 25.571 eliminated a failsafe approach. Part 23 includes Failsafe but Part 25 does not. Provide damage tolerance method of compliance.
response	*Noted* Fail safe cannot be replaced by a damage tolerance approach. This relates to the fact that weak bonds may occur and would not be quantified by repeatable testing or reliable analysis. Instead, the qualified bonded joints of a design must be shown to be damage tolerant and, in the event of a rare "weak bond" condition, also fail safe to ensure capability for rare cases when the process fails to meet the qualified benchmark and escapes factory quality measures. Remember that weak bonds may not be reliably detected by post-process NDI.

comment	*142* comment by: *Gulfstream Aerospace Corp* Para. 7.a-g Use of overload factors to account for **strength** degradations due to environmental factors is addressed. Section mentions that metal fittings/features/fixtures in design have to be able to take overloads. Need to address buckling of structure during overloading. Delineation between a failure due to strength, and due to limited post-buckled strength need to be drawn. Issue is drawn from experience with A700 certification testing, Horizontal tail specifically and boom bullet specifically. Address the effect of overload factors on buckling and post-buckling strength of structure.
response	*Noted* Although the importance of both strength and stiffness is identified at several points in the document, the necessary further discussion regarding buckling would be too detailed relative to the level of the AMC. However, future revisions to the AMC may expand upon this subject and/or provide appropriate reference.

comment	*143* comment by: *Gulfstream Aerospace Corp* Para. 6.g Structural Details. Point design may be useful for secondary structure. Expand Guidance
response	*Noted* The Agency agrees with the technical point. However, this document is primarily concerned with 'critical structure'. Future revisions to the AMC may expand upon this subject and/or provide appropriate reference.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 7. Proof of structure - static p. 16-19

comment	*12* comment by: *AIRBUS* Paragraph 7g:

	The term "significant" has a particular meaning in the context of Part 21, paragraph 21A.101. Airbus suggests to select the word "major".
response	*Accepted*

comment	*35* comment by: *Ludger Duelmer, Extra Flugzeugproduktion* e) Why is there a need for overloads in the component test in case there are no test data of detail and subcomponent tests available? The component under test includes the details and sub-components. Thus demonstration of structural substantiation by the component test (up to ultimate load) without a further overload should be sufficient for compliance with the requirement. f) Detailed information on impact damage details (VIDs vs. BVIDs, energy, detectability, damage size) should be included (or be referenced). What is the maximum limit of impact damage energy level (Joule) to be applied to stiff structural element (spar carry through section)?
response	*Noted* e) A test pyramid provides confidence regarding the understanding of loads and strains at many levels and can also strongly support analysis. This confidence is not available when relying upon a single component, requiring an additional factor to provide a margin to address these uncertainties. f) The Agency agrees that such information can be a useful guide. However, for the purposes of document length, such data is not reported here. This can be found in industry standards and guidelines, e.g. CMH-17 rev.G

comment	*65* comment by: *Boeing* Page 16; Para 7, first paragraph **Comment** Change text to read as follows: *" … material and process variability, ~~and~~ **<u>any</u>** defects ~~or service damage~~ that are not detectable or allowed by the quality control, manufacturing acceptance criteria, ~~or~~ **<u>and service damage allowed in the</u>** maintenance documents of the end product. …"* ***Rationale*** Clarification of the sentence is needed. ***Recommendation*** Change text as indicated (underlined) Page 16; Para 7.a.(2) **Comment** Change text to read as follows: *"… coupon, element and subcomponent test data ~~to assess the possible degradation of static strength after application~~* ***<u>may be used to determine</u>***

the effect *of repeated loading and environmental exposure* ***on static strength****. …"*

Rationale
Clarification of the sentence is needed.

Recommendation
Change text as indicated (underlined).

Page 17; Para 7.b.(1)

Comment
Change the third sentence to read as follows:

" …~~ Appropriate analysis validation at the~~ ***D****etail and subcomponent* *~~testing levels~~* ***tests*** *should* *~~demonstrate the confidence to predict local strains and ensure repeatable failure modes as required to meet the static strength rules for a reliable design~~* *validate the ability of the analysis methods to predict local strains and failure modes. …"*

Rationale
Clarification of the sentence is needed. The use of the word "validate" is typically used in this situation in certification activities.

Recommendation
Change text as indicated (underlined)

Page 18; Para 7.b.(2)

Comment
Change this entire paragraph to read as follows:

(2) A complete building block approach to composite structural substantiation addresses most critical structural issues in test articles with increasing levels of complexity such that many areas of reliable performance can be demonstrated prior to the component tests (e.g., effects of stress risers and impact damage). . The details and subcomponent testing should establish failure criteria and account for impact damage in assembled composite structures. Component tests are needed to provide the final accounting for combined loads and complex load paths, which include some out-of-plane effects. When using the building block approach, the critical load cases and associated failure modes would be identified for component tests using the analytical methods, which are supported by test validation.

Rationale
This paragraph would benefit from more focus and clarification. As stated in the proposed AMC, it reads more like a technical paper rather than guidance, as it is intended to be.

Recommendation

Revise text as suggested

Page 18; Para 7.e.

Comment

Revise the text to read as follows:

*" … When the detail, subcomponent and component tests show that local ~~stresses~~ **strains** are adequately predicted …"*

Rationale

Consistency is needed in the use of the terms "stress" and "strain." In this sentence, "strain" is the appropriate term.

Recommendation

Change text as indicated (underlined)

Page 19; Para 7.f.

Comment

Change the text to read as follows:

*" … Selection of impact sites for static strength substantiation should consider the ~~magnitude of local loads, competing failure modes, structural attachments (e.g., bonded details),~~ **the criticality of the impact site** and the ability to inspect a location. The size and shape of impactors used for static strength substantiation should be consistent with likely impact damage ~~scenarios~~ that may go undetected for the life of an aircraft."*

Rationale

We suggest that the sentence be simplified by just stating *"the criticality of the impact site"* rather than listing only certain items for consideration.

Recommendation

Change text as indicated (underlined)

Page 19' Para 7.g.

Comment

Revise the text to read as follows:

*"Any change to material and/or process **on existing certified structure,** will need to be assessed and significant material and process changes may require additional static strength substantiation (e.g., see Appendix 3)."*

Rationale

Appendix 3 applies to existing certified structure. This should be stated here to provide more clarity

Recommendation

Change text as indicated (underlined)

response *Partially accepted*

Text changed to match AC 20-107B

comment | 91 | comment by: *Austro Control GmbH*

7. f. - Comment
Definition of "detectability" of damages should be specified in detail.

response | *Not accepted*

Each OEM will define the threshold of delectability for their products, parts and appliances.

comment | 146 | comment by: *Gulfstream Aerospace Corp*

Pg. 16 & 19 Examples of use of test factors, in both static and repeated loading conditions, are completely missing from this document. Test factors have been used in past composite structure certification projects. Include examples of how factors are developed and used in the static and damage tolerance evaluation (including both static and repeated loading).

response | *Noted*

For the purposes of document length, such data is not reported here. This can be found in reference industry standards and guidelines, e.g. CMH-17, Static Strength Substantiation of Composite Airplane Structure PS-ACE100-2001-006. In all case, factors used must be substantiated.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 8. Proof of structure - fatigue and damage tolerance p. 19-26

comment | 13 | comment by: *AIRBUS*

Paragraph 8, Last bullet:
The sentence "High loads are needed to practically demonstrate the environmental capability and reliable static strength, fatigue and damage tolerance of composite aircraft structure [...]" should be modified into "Peak repeated loads are needed to practically demonstrate the fatigue and damage tolerance of composite aircraft structure [...]."
These "high loads" from third bullet are understood as the peak fatigue loads normally truncated in metal fatigue spectrum.
This chapter deals with F-DT, hence it is proposed to remove static strength and environmental capability which are addressed in other chapters (§7a and 6d).
This will provide a harmonized text with AC20-107B.

response | *Accepted*

comment | 14 | comment by: *AIRBUS*

Paragraph 8a(1)(c):
Another damage categorization may be used. Airbus therefore suggests to add the following note:
"(c) [...]
Note: Other categories of damage, which help outline a specific path to

	<u>fatigue and DT substantiation, may be used by applicants in agreement with the regulatory authorities.</u>" Airbus considers another damage categorization, accepted by EASA for A380 & A350 certifications: • Cat A: all realistic damages up to 1e-9 probability of occurrence (from undetectable to readily detectable damages). Residual strength requirement is UL for undetectable damages (for threat up to 1e-5 probability of occurrence), k x LL for detectable damages (k based on probabilistic assessment), accounting for repeated loads and environmental effect. • Cat B: Large Damage Capability criteria to provide design robustness i.e., to reduce the far field stress. Hence the requirement associated to Cat B is static strength only, accounting for environment. • Cat C: DSD equivalent to Cat 4 from this AC. In addition, Cat 5 damage is considered separately, out of the DT demonstration. As recognized by this AC, this is an issue to be addressed by engineering (to estimate possible damage scenarios), maintenance & operation procedures (to assure proper reporting, inspection and repair), plus training of relevant staff. This will provide a harmonized text with AC20-107B.
response	*Partially accepted* Text is amended to align with AC 20-107B

comment	*15* comment by: *AIRBUS* Paragraph 8a(1)(c): The paragraph "Category 1" should be modified as shown: "Category 1: [...] By definition, such damage is subjected to the requirements and guidance associated with <u>paragraph 7</u> of this <u>AMC</u>." Paragraph 7 instead of 6 should be quoted. "AC" should be replaced by "AMC".
response	*Accepted*

comment	*16* comment by: *AIRBUS* Paragraph 8a(5): It is proposed to modify the second sentence as shown: "Low amplitude load levels that can be shown not to contribute to damage growth may be omitted ~~(truncated)~~. Reducing maximum load levels ~~(clipping)~~ <u>(truncation)</u> is generally not accepted." Generally we use “omission” for low level clipping and “truncation” for high level clipping.
response	*Partially accepted* Recognising differences in terminology, the terms ‘truncated’ and ‘clipping’ will be delete, but the concept retained.

comment	*17* comment by: *AIRBUS*

Paragraph 8a(7):
It is proposed to modify the last sentence as shown:
"Some Category 4 damages may have high margins but they will likely still require suitable inspections because their detectability may not be consistent with the substantiations validated for Category 2 damage types."

This modification will avoid giving confusing information to engineers. We cannot know if there are high margins without first doing the assessment. In addition, high margin do not necessarily occurs for severe in-flight hail.

response *Accepted*

comment *18* comment by: *AIRBUS*

Paragraph 8a(8):
The last sentence should be modified in line with the text of AC 20-107B:
"Unless tested in the environment, appropriate environmental ~~overload~~ factors ~~for the static and fatigue test articles~~ should be derived and applied in the evaluation."

"Overload factors" are not systematically applied in static and fatigue test articles. Factors accounting for the environmental effects are substantiated for each failure mode and are accounted for in the analysis of test results.

response *Accepted*

comment *19* comment by: *AIRBUS*

Paragraph 8c:
The term "Structural life" in the last sentence should be replaced by the term "Service life" to be consistent with the wording used in the first sentence.

This will provide a harmonized text with AC20-107B.

response *Partially accepted*

Text is aligned with AC 20-107B.

comment *29* comment by: *Eurocopter*

- § 8a(1)(c): Category 1 damage - Ref to paragraph 6 should read ref to paragraph 7 (static substantiation).
- § 8a(1)(c): Category 4 damage - the "Get-Home" loads concept should be defined and clarified.

response *Accepted*

comment *36* comment by: *Ludger Duelmer, Extra Flugzeugproduktion*

There should be a defined standard for a damage thread assessment.

Details for the foreign object impact assessment have been defined and applied in the past (e.g. impactor shape). These definitions seem to be withdrawn with this AMC. This will result in a more comprehensive research (wide range of conceivable impacts) to be exercised by the applicant.

	Damage Category 2: "… residual strength retained … is sufficiently above limit loads capability." What is intended factor of safety?
response	*Noted* For the purposes of document length, such data is not reported here. This can be found in reference industry standards and guidelines. Also note that a harmonised rulemaking activity, and R&D, is in progress to define/review impact threats e.g. tyre, engine, hail etc. Future revisions to the AMC may expand upon this subject and/or provide appropriate reference. Regarding Category 2, residual strength should be between limit and ultimate load and the associated damage coupled with an appropriate inspection interval.

comment	*37* comment by: *Ludger Duelmer, Extra Flugzeugproduktion* 8 a. (4): should read " … specified design *limit* load (considered as ultimate), …"
response	*Not accepted* Existing text allows flexibility between OEMs regarding the relationship between residual strength and damage detection.

comment	*42* comment by: *Ludger Duelmer, Extra Flugzeugproduktion* 8 a. (5): For Part 23 Airplanes: A value accepted for omitting low amplitude load levels ("truncation") should be included (15% up to 30%). A load enhancement factor of 15% should be acceptable to allow demonstration of 2 lifes only. Clipping off the enhanced maximum load levels above limit load should be accepted.
response	*Noted* For the purposes of document length, such specific data and guidance is not reported here. This can be found in reference industry standards and guidelines, e.g. CMH-17.

comment	*48* comment by: *Bombardier Aerospace* 8.a. Damage Tolerance Evaluation (1)(c) Original Text: "Category 1: Allowable damage that may go undetected by scheduled or directed field inspection <u>or</u> allowable manufacturing defects." Recommendation: "Category 1: Allowable damage that may go undetected by scheduled or directed field inspection, <u>and</u> allowable manufacturing defects." Rationale: The fact that allowable manufacturing defects have to be considered should be stressed by replacing the "or" by "and".

response	*Accepted*

comment	*49* comment by: *Bombardier Aerospace*
	8.a. Damage Tolerance Evaluation (1)(c) Original Text “Category 1: Allowable damage that may go undetected by scheduled or directed field inspection or allowable manufacturing defects.” Recommended Text “Category 1: Damage that may go undetected by scheduled or directed field inspection, allowable damages <u>and</u> allowable manufacturing defects.” Rationale: It may be confusing to use to say that “Allowable damage may go undetected ...”. Usually allowable damages (manufacturing or in-service) are detectable and have to be included in the category 1 damage.
response	*Accepted*

comment	*50* comment by: *Bombardier Aerospace*
	8.a. Damage Tolerance Evaluation Original Text: (2)(a), 4th sentence: “Inspection intervals should be established such that the damage will have a very high probability of detection between the time it becomes initially inspectable and the time ..” (2)(b), 5th sentence: “This approach is appropriate for damage growth that is inspectable and found to be reliably arrested..” Recommendation: Change "inspectable" to "detectable" in both cases. Rationale: Is less prone to mis-interpretation for the less experienced people to say “detectable” instead of “inspectable”. From a semantic point of view, if a structure is inspectable, it usually is so from day one. However some damages may only become detectable when they reach a certain size.
response	*Accepted*

comment	*51* comment by: *Bombardier Aerospace*
	8.a. Damage Tolerance Evaluation (3), Figure 5 Comment: For the arrested growth curves, there are 3 damage size steps but there are only 2 strength steps on the corresponding strength curve. Recommendation: Clarification requested. Rationale: Confusing.

response

Noted

This figure is only shown to illustrate a concept, as stated in the text. Therefore, for the purposes of not creating confusion relative to the AC 20-107B harmonised document, this will not be changed for this revision. However, this may be changed for a future revision to the AMC.

comment

66 comment by: *Boeing*

Page 19; Para 8, first paragraph

Comment
Revise the text to read as follows:

" ... Such evaluation must show that catastrophic failure due to fatigue, environmental effects, ~~manufacturing defects~~ ***permissible manufacturing variability****, or accidental damage will be avoided throughout the operational life of the aircraft. ..."*

Rationale
The term "defect," as used here in the proposed AMC, is inappropriate when the anomaly is acceptable per the specification.

Recommendation
Change text as indicated (underlined) or clarify.

Page 19; Para 8, first paragraph, 3rd bullet

Comment
Define what is meant by "*specific sequence of loading"* in the text that states:

"Final static strength, fatigue and damage tolerance substantiation may be gained in testing a single component test article if sufficient building block test evidence exists to ensure the ***specific sequence of loading*** *is representative of that possible in service or is a conservative evaluation."*

Rationale
The phrase "specific sequence of loading" is not clear relative to this subject. It needs clarification to ensure understanding of the intent of the paragraph.

Recommendation
Clarify the text indicated

Page 19; Para 8, first paragraph, 4th bullet

Comment
We suggest combining the 4th bullet with the 3rd bullet, and explaining more clearly the intent of the material.

Rationale
The material in both bullets appears to be covering the basic issues involved in coming up with composite and metallic fatigue spectrums, or possible

overloads for static RTA (Room Temperature Ambient) tests to account for environment.

Recommendation
Combine as indicated or clarify the intent.

Page 20; Para 8.a.(1)

Comment
Revise the text to read as follows:

*" ... types and sizes of damage considering fatigue, environmental effects, ~~intrinsic~~ ~~flaws~~, **permissible manufacturing variability** and foreign object impact ..."*

Rationale
Use of the term "flaw" is inappropriate when the anomaly is acceptable per the specification.

Recommendation
Change text as indicated (underlined).

Page 20; Para 8.a.(1)(a)

Comment
Revise the text to read as follows:

" ... (e.g., long-term ~~wear-out~~ ***durability*** of bolted and bonded joints) ..."

Rationale
The term "durability" is the generally accepted term in this scenario.

Recommendation
Change text as indicated (underlined)

Page 21; Para 8.a.(1)(c), ***Category 1: description***
Comment
Revise the text as follows:
By definition, such damage is subjected to the requirements and guidance associated with paragraph ~~6~~ **7** of this advisory circular.

Rationale
Should be paragraph 7

Recommendation
Change 6 to 7

Page 21;

Para 8.a.(1)(c), Figure 3

Comment
In Figure 3, we suggest:
· "Category 3" box should not be pointing to limit load, but to a load between limit and continued safe life residual strength requirement.
· The VID requirement ("Category 2") is shown too close to the "Ultimate" load requirement; "Limit" is the requirement based on the regulations.

Rationale
"Category 3" is allowed to be less than limit load, depending upon time to detectability. "Category 2" requirement is based on limit load and is linked to §25.57(1)(b).

Recommendation
Change Figure 3 so that "Category 3" points between Limit and CSF; and so that "Category 2" points at Limit.

Page 21; Para 8.a.(1)(c),
Category 2: description

Comment
Revise the text as follows:

" ... Structural substantiation for Category 2 damage includes demonstration of a reliable inspection method and interval while retaining loads above limit load capability. ~~The residual strength for a given Category 2 damage may depend on the chosen inspection interval and method of inspection~~."

Rationale
As written in the proposed AMC, this could be misread as introducing new requirements. All this should be tied to limit load and the inspection must reliably find the damage per MSG-3 agreements.

Recommendation
Revise the text as indicated, to emphasize that the requirement is limit load.

Page 21; Para 8.a.(1)(c),
Category 2: description

Comment
Revise the text as follows:

" ... This type of damage should not grow or, if slow or arrested growth occurs, the level of residual strength retained for the inspection interval is ~~sufficiently~~ above limit load capability."

Rationale
The bottom-line requirement should be limit load.

Recommendation

Revise the text as indicated by deleting the word “sufficiently

Page 22; Para 8.a.(1)(c),
Category 3: description

Comment
Revise the text to read as follows:

“ … The primary difference between Category 2 and 3 damages are the demonstration of large damage capability at limit or near limit load for the latter after a ~~service~~ interval of time. …”

Rationale
As written in the proposed AMC, Category 3 implies it could be found in a walk-around, which is not a “service” inspection. This should be clarified.

Recommendation
Revise the text as indicated by deleting the word “service.”

Page 22; Para 8.a.(1)(c), ***Category 4: description***

Comment
Revise the text to read as follows:
“ …
Category 4 damage includes a demonstration of residual strength for ~~“Get-Home”~~ loads specified in the regulations. Some examples of Category 4 damage include rotor burst, ~~significant~~ bird strikes ***(as specified in the regulations),*** *~~exploding gear tires~~* ***tire bursts****, and severe in-flight hail.”*

Rationale
“Get Home” is not a phrase used in the regulations; we suggest it not be introduced here.

“Significant bird strike” has no definition; however, “bird strike” is specified in the regulations. We suggest the description of bird strikes be tied back to the regulations.

“Tire burst” is the more generally used term, rather than “exploding” gear tires.”

Recommendation
Change the text as indicated

Page 22; Para 8.a.(1)(c),
Category 5: description

Comment
Revise text to read as follows:

" … This damage is in the current guidance to ensure ~~sufficient designed-in damage resistance and field knowledge, which outlines the Category 5 events that are self-evident and require conditional inspections. As a result,~~ the engineers responsible for composite aircraft structure design …"

Rationale
Our suggested revision is meant to simplify the statement. Later statements in this section adequately cover the Category 5 description in this regard.

Recommendation
Revise text as indicated

Page 22; Para 8.a.(1)(c),
Category 5: description

Comment
Revise the text to read as follows:

*" … An interface is needed with engineering to properly define a suitable **<u>conditional</u>** inspection based on available … "*

Rationale
"Conditional" is the type of inspection of concern in this section.

Recommendation
Change text as indicated (underlined)

Page 23; Para 8.a.(2), Figure 4

Comment
We suggest that Figure 4 be clarified. All slow growth structure experiences crack growth. Figure 4 inappropriately implies that all no-growth structure experiences VID type damages. Structural safety is more complicated than this figure implies

Rationale
The curve in Figure 4 appears to imply that no-growth structure is less safe than slow growth structure. However, this is not the case.

Recommendation
Clarify Figure 4.

Page 24; Para 8.a.(4)

Comment
Revise the text to read as follows:

*" … The first four categories of damage should be considered based on the damage threat assessment **<u>and, for damage Category 3, also include that it must be caught while subject to walk-around inspection or</u>***

***<u>during the normal course of operations</u>**. …"*

Rationale

The text should be clear on where Category 3 applies.

Recommendation

Change text as indicated (underlined)

Page 25; Para 8.a.(4)(b)

Comment

Revise this paragraph to include information on how carbon fiber reinforced plastic (CFRP) and aluminum sandwich construction fit into the requirements of this statement.

Rationale

Clarification needed as to how the paragraph applies to CFRP and aluminum sandwich construction.

Recommendation

Clarify as requested.

Page 26; Para 8.c.

Comment

Revise the paragraph as follows:

"Generally, it is appropriate for a given structure to establish both an inspection program and demonstrate a service life to cover all detectable and non-detectable damage, respectively, which is anticipated for the intended aircraft usage. ~~As in metals, there is a limit on the useful service life of composite airframe structures, based on available data and analyses. All extensions in structural life should include evidence from component repeated load testing, fleet leader programs (including NDI and destructive tear-down inspections), and appropriate statistical assessments of accidental damage and environmental service data considerations.~~"

Rationale

We suggest deleting the last two sentences of the paragraph at this time. The deleted text appears to be describing "limit of validity (LOV)," a term that will not be officially defined and included within the regulations until the FAA/EASA releases the upcoming final rule on widespread fatigue damage. Once that is finalized, the corresponding language could be included in the AMC, and thereby provide the FAA/EASA means to ensure understanding, compliance, and interpretation is consistent with the regulatory meaning of the term.

We consider the guidance sufficient without the two sentences.

Recommendation

Delete text as indicated.

response	*Partially accepted* 8. (1st para) - Not accepted. Although the defect is permissible, it is still not wanted, so is a defect – as per AC 20-107B 8. (1st para, 3rd bullet) - Accepted 8. (1st para, 4th bullet) - Partially Accepted.Text to be changed to match AC 20-107B 8.a(1) - Not accepted. The Agency considers this to be acceptable terminology, also defined in Appendix 2. 8.a(1)(a) - Accepted 8.a(1)(c) Cat 1: Accepted 8.a(1)(c) Fig 3 - Not Accepted. The Agency considers that the figure is acceptable, icw the text. 8.a(1)(c) Cat 2. - Not accepted. The wording is considered adequate to allow for detailed differences in definition of Cat 2 and Cat 3 between OEMs. 8.a(1)(c) Cat 2. - Not Accepted. Linkage to limit load already exists. Note: This is only one acceptable means of compliance. 8.a(1)(c) Cat 3. - Accepted. 8.a(1)(c) Cat 4. - Accepted. 8.a(2) Fig 4. - Not Accepted. Change not considered necessary because this is a conceptual diagram intended to illustrate basic ideas. 8.a(4) - Accepted. 8.a(4)(b) - Not Accepted. The Agency considers that it is unnecessary to make this distinction here because the AMC is applicable to sandwich and monolithic structure. 8.c - Accepted 8.a(1)(c) Cat 5. - Accepted.

comment	*92* comment by: *Austro Control GmbH* 8. a. (5) – Comment and changed wording A necessary definition of flight spectrum is missing. Low amplitude load levels within the elastic regions that can be shown not to contribute to damage growth may be omitted (truncated).
response	*Not accepted* The intent of the comment is implicit. Further guidance can be found in reference industry standards and guidelines, e.g. CMH-17.

comment	*99* comment by: *Dassault Aviation*

§ 8. a. Proof of structure - Fatigue and damage tolerance / Damage tolerance evaluation
(1) (b)
Dassault Aviation suggests following re- wording**:**

"*... which has a goal of identifying the most ~~critical~~* severe *impacts possible (i.e. those causing the most ~~serious~~* critical *damage ~~but~~* comprising those that *are least detectable).*"
" *... (e.g. tension, compression or shear* or combined solicitation)".

response | *Not accepted*

Original text is considered to express the intent and the proposal does not change that.

comment | *103* comment by: *Dassault Aviation*

§ 8. a. Proof of structure - Fatigue and damage tolerance / Damage tolerance evaluation
(1) (c)
Fig. 3:
Mfg signification should be explained in the text of Category 1 damage below *"...or allowable manufacturing* (Mfg) *defects."*

Although this acronym is in current use inside composite documents, VID should be precised in the text of Category 2 "*... visible impact damage (VID)*".

Category 1:
To add: "A typical BVID size is an indentation of 1.25 mm after relaxation or the one generated by an impact at a maximum energy of 35 Joules whichever is maximum."

Category 2:
*" ... the level of residual strength retained for inspection interval is **sufficiently** above limit load capability."*
Term *"sufficiently"* is imprecise and has to be clarified.
Position of DA is to request limit load capability for VID.
To add: "A typical VID size is a damage of 12.5 mm diameter or the one generated by an impact at a maximum energy of 80 Joules whichever is maximum."

Category 3:
In the sentence: *" ... Category 3 damage includes demonstration of a reliable and quick detection, while retaining **limit or near limit** load capability."*
term *"near"* is imprecise and has to be clarified.

Furthermore asking for "limit load capability" for this type of damage would lead to avoid detailed search of VID as covered by obvious ones detected during walk-around inspection or during normal course of operations.
Position of Dassault Aviation is, as those damage are obvious and detected within a few flight, to request a lower probability load level i.e. of the order of JAR 25 Change 15 ACJ 25.571 (a) § 2.1.2. *"In the case of damage which is readily detectable within a short period (50 flights, say)..."* b.*"85% of the limit manoeuvre and ground conditions ...and separately 75% of the limit gust velocities..."*.

	Furthermore Category 3 rectangle in Fig. 3: "*Obvious damage requiring repair after it is found within a few flight* ..." is confusing as it can be interpreted as the permission to let fly obvious damage during a few flight. It is preferable to rewrite it in the form *"Obvious damage found within a few flight requiring immediate (or only after a limited agreed supplemental flights) repair "*.
response	*Partially accepted* Although technically correct, The Agency considers that the abbreviation "Mfg", necessary in the limited space available, is adequately common to not require definition. VID is defined in the text of Category 2 For the purposes of document length, specific data and guidance such as the size of VID/BVID is not reported here. This can be found in reference industry standards and guidelines, e.g. CMH-17. Re. Category 3 - The existing wording is considered adequate to allow for detailed substantiation differences between Cat 2 and Cat 3 for various OEMs. Cat 3 is intended to allow for development of large damage capability, which includes some qualitative judgement as described in some industry guidance, see CMH-17 Final part of the comment is accepted. Fig 3 has been amended to avoid any potential confusion.

comment	*104* comment by: *Dassault Aviation* **§ 8. a. Proof of structure - Fatigue and damage tolerance / Damage tolerance evaluation** **(2) (a) and (b)** To be clear, Dassault Aviation suggest to precise that: If a damage is detected during maintenance it should be repaired to restore Ultimate Loads capability. **Fig. 4 Title:** *"... for a too long time."* that is not precise has to be clarified by for example *" ... for more than an inspection interval with the adequate scatter factor."*
response	*Not accepted* 1/ This statement is already included in the last sentence before figure 4. 2/ the term 'too long' is intended to allow for different definitions, dependent upon OEM methodology, damage severity etc. Note text is changed to align with FAA AC 20-107B

comment	*105* comment by: *CAA-NL* Last bullet page 19: We suggest replacing the words 'High loads' into 'Peak loads' as the start of the first sentence. High loads is to our knowledge never defined in the field of fatigue, whereas Peak loads is a well known terminology, further it is in line with the wording used in the FAA AC. a. (1) (c) category 3:

	We understand the differences in behavior of metal and composite structures, and as such the difficulties to prove limit loads with a category 3 damage due to the fact of broken of failed fibers. The need for a little more flexibility is appreciated but we find the terminology 'near limit loads' too unspecific. We suggest that composite expert define a more specific tolerance, for instance in a percentage of the limit loads.
response	*Partially accepted* 1st part Accepted 2nd part - The existing wording is considered adequate to allow for detailed substantiation differences between Cat 2 and Cat 3 for various OEMs. Cat 3 is intended to allow for development of large damage capability, which includes some qualitative judgement as described in some industry guidance, see CMH-17

comment	*132* comment by: *Diamond Aircraft Industries (Austria)* 8.a.(2) A damage slow-growth scenario is identified as the benchmark for periods of time during which residual strength below ultimate is acceptable in a damage no-growth situation. Unless a more specific period of time is provided, which may for example be related to major structural inspection intervals, there is plenty of room for interpretation. What is the maximum damage propagation speed that qualifies as 'slow' growth? How shall one determine slow-growth data when only no-growth is observed?
response	*Not accepted* The inclusion of this option is a development from the rotorcraft AC 29 2C MG8 which is intended to recognise that some damages can grow 'slowly' and safely (often being arrested). If the manufacturer wishes to take advantage of this, then it is their responsibility to show that the damage mode, load, location, growth rate etc is repeatable and can be managed with respect to the inspection process.

comment	*147* comment by: *Gulfstream Aerospace Corp* Para. 8.a.(1)(c) "...the level of residual strength retained for the inspection interval is sufficiently above limit load capability." How much? Provide better definition of required static strength.
response	*Noted* The existing wording is considered adequate to allow for detailed substantiation differences between Cat 2 and Cat 3 for various OEMs. Cat 3 is intended to allow for development of large damage capability, which includes some qualitative judgement as described in some industry guidance, see CMH-17

comment	*148* comment by: *Gulfstream Aerospace Corp* Density of BVID damage is not addressed. BVID density may affect residual strength. Provide guidance on determination of BVID density.
response	*Noted*

For the purposes of document length, such data and guidance is not reported here. This can be found in reference industry standards and guidelines, e.g. CMH-17.

comment *149* comment by: *Gulfstream Aerospace Corp*

Pg 21 Damage Category definitions do not reference energy cutoff levels for impacts that potentially create damage that is not visible. Previous certifications have had energy cutoff s associated with each category. Add wording that recognizes energy cutoff values exist and guidance on determination of these maximum energies associated with category 1& 3 damage.

response *Noted*

For the purposes of document length, such data is not reported here. This can be found in reference industry standards and guidance, e.g. CMH-17.

comment *150* comment by: *Gulfstream Aerospace Corp*

Figure 3 CAT 2 damage not clearly indicated by the schematic. Update schematic diagram

response *Noted*

The Agency believes that, in conjunction with the supporting text, the indication is adequate.

comment *151* comment by: *Gulfstream Aerospace Corp*

Figure 3 Criteria need to be provided for cabin pressure loads that accounts for the factors of 14CFR25.365. Is "ultimate load" proof or burst? Cabin pressure has different definitions of limit and ultimate. Definitions depend on max. cert. altitude. Cover the 1.33 and 1.67 factors of 14CFR25.365 in the criteria for determining ultimate load.

response *Not accepted*

Although differences between metallic and composite behaviour may be of some significance to showing compliance with this requirement, the comment is outside the scope of this AMC. The 1.67 factor is not harmonised with EASA, and is the subject to on-going discussions.

comment *152* comment by: *Gulfstream Aerospace Corp*

Figure 4 These curves do not appear to be based on an actual scenario or comparison of two identical components. It is not apparent that the "slow growth" approach will provide a shorter inspection interval. The residual strength of the "no growth" approach will typically be much closer to ultimate allowable than portrayed. Review of current practice does not support the comparison with "slow growth". Define the residual strength criteria for Category 2 damage in absolute terms instead of using a comparison to "slow growth".
Detail the required residual strength and life (with defects) data necessary to meet the criteria for a given approach.
The criteria should be based on a review of actual details, current material

	systems, and typical aircraft fatigue spectra.
response	*Noted* The purpose of this figure is to explain some basic concepts, which require validation. Use of actual details could also be misleading.

comment	*153* comment by: *Gulfstream Aerospace Corp* Fig 5 How can there be "Slow Growth" at a damage size less than that shown for "No Growth" (Figure 5). No Growth implies smaller defects do not grow either. Revise the curve to show the “slow growth” response that is comparable to the “No Growth” scenario.
response	*Noted* The purpose of this figure is to explain some basic concepts, which require validation. The inclusion of a number of unrelated curves on the same figure was intended to save space.

comment	*154* comment by: *Gulfstream Aerospace Corp* Para. 8.a(4)(a) There is no criteria provided to perform a damage threat analysis or a probabilistic analysis. These analysis points are not defined and their use in determining the required residual strength is not detailed. Develop a criteria that outlines the risks to be considered, the required reliability, and the resulting residual strength
response	*Noted* For the purposes of document length, such data is not reported here. This can be found in reference industry standards and guidance, e.g. CMH-17. There is a need for future standardisation regarding this issue. Future revisions to the AMC may expand upon this subject and/or provide appropriate reference.

comment	*155* comment by: *Gulfstream Aerospace Corp* Para. 8.a(4)(a) Why is cycling prior to residual strength testing required only for the no-growth approach? Residual strength following cycling is required of all approaches. Revise to include all damage tolerance approaches.
response	*Accepted*

comment	*156* comment by: *Gulfstream Aerospace Corp* Para. 8.a(4)(b) The 90/95 statistical value for residual strength analysis is not justified. Metallic structures are not required to be fail-safe nor are they required to show “B” basis for residual strength. A statistical value cannot be required of a single element in the analysis without an assessment of the overall risk. The individual risk associated with each aspect of the analysis (scatter factors on life, load enhancement factors, damage threat, material properties) must be determined in relation to the overall criteria. Use AC25-24 as an example to specify the required reliability of each aspect of the analysis.
response	*Noted* The intent of para. 8a(4)(b), is to repeat the basic expectation that the use of

	composites should not reduce the level of safety provided by metallic structure. The 90/95% allowable example is only quoted as a generic example applicable at the element level and does not attempt to address the overall criteria issue. See also the response to comment 154.

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 9 Proof of structure - flutter a.o. aeroelastic instabilities p. 26-27

comment	*20* comment by: *AIRBUS* Paragraph 9a: The sentence "Control surface clearances may also be an issue that can change with alterations, damage and repair" should be deleted. This sentence does not relate to flutter.
response	*Accepted*

comment	*67* comment by: *Boeing* Page 27; Para 9, first paragraph **Comment** Revise the text to read as follows:: *"... Flutter and other aeroelastic instabilities must be avoided through design, quality control, maintenance and ~~careful attention to the neighboring systems interface~~ **<u>systems interaction</u>**~~.~~"* ***Rationale*** "Systems interaction" is the typically accepted wording in this situation. ***Recommendation*** Page 27; Para 9.a. **Comment** Revise the text to read as follows:: *" ... The evaluation of composite structure needs to account for the effects of repeated loading, environmental exposure and service damage scenarios (e.g., large Category 2, 3 or 4 damage ~~and potential mass increase for sandwich panel water ingression) on critical properties such as stiffness, mass and damping~~. ..."* ***Rationale*** There are many ways to look at flutter when considering control surface damage, such as facesheet disbonding. To avoid misunderstanding, we suggest deleting the indicated text. ***Recommendation*** Change text as indicated.

	Comment Revise the text to read as follows:: *" ... This is particularly important for control surfaces that are ~~relatively fragile and~~ prone to accidental damage and environmental degradation. ..."* ***Rationale*** Sandwich construction is fragile, whether made of composites or aluminum; this is not strictly a composite issue. ***Recommendation*** Change text as indicated.
response	*Partially accepted* 9. - Accepted 9.a - Partially accepted. Text amended as AC 20-107B

comment	*106* comment by: *Dassault Aviation* **§ 9. Proof of structure - Flutter and other aeroelastic instabilities** In place of "*... careful attention to the neighbouring systems interface*": *" ... systems <u>interaction.</u>"* as in AC seams preferable. Typo: § name "a" unusefull without "b" one.
response	*Accepted*

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 10. Continued airworthiness p. 27-29

comment	*21* comment by: *AIRBUS* Paragraph 10a: The third sentence is confusing. Airbus suggests it is revised in line with the wording of AC 20-107B: "The inspection intervals and life-limits for any structural details and levels of damage that preclude repair must be clearly documented <u>in the appropriate continued airworthiness documents</u>." The ALS includes mandatory life limits and inspection intervals, not the levels of damage that preclude repair. This will provide a harmonized text with AC20-107B.
response	*Accepted*

comment	*22* comment by: *AIRBUS* Paragraph 10b(3): The two last sentences address another issue than repair i.e., the need for the reporting of service difficulties to OEM. This should be shifted in a new paragraph 10b(4).
response	*Accepted*

comment	*30* comment by: *Eurocopter* • § 10b: Maintenance Practices - applicable to "appropriate organisations" (AC 20-107B refers) and not only to manufacturers. • § 10b(3): emphasis on documentation and reporting should be put by isolating the information in a specific sub-para (4) as in AC 20-107B.
response	*Accepted*

comment	*55* comment by: *LHT DO* 10 b) (3) Paragraphs 10.b.(3), 10.c and 10.d contain requirements which should be defined (though type certification and by means of the applicable instructions for maintenance) by the design approval holder, yet other organizations (Maintenance Organization, CAMO, etc.) must comply with. We recommend adding to the applicable relevant documents (e.g. Part-145, Part-66, Part-M, EU-OPS1) some reference to AMC 20-29. It should be clearly stated that the Design Organization is not in the position to perform, or control, the related maintenance tasks (e.g. configuration control, maintenance records), but that the obligation is on other organizations 10 c (2) If data can be produced by another Design Organization the original DOA does not have to be consulted. It might be informed accordingly about the major repair for continued airworthiness reasons. Please amend.
response	*Noted* 10 b(3) Not accepted. This section (to be 10 b(4) per AC 20-107B) is intended to require the DO to add the data to the record, i.e. supply it to the 145 organisation, operator, owner etc. It is then the responsibility of those concerned to satisfy the regulations appropriate to them. 10 c(2) Partially accepted. Text to be amended per AC 20-107B.

comment	*68* comment by: *Boeing* Page 27; Para 10, first paragraph **Comment** Clarify the text that states: *"The maintenance and repair of composite aircraft structure **shall** meet all general, design and fabrication ..."* ***Rationale*** Generally, the word "shall" is not used in AMCs. Otherwise, the FAA/EASA normally include a qualifying paragraph that states: *"This material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The Federal Aviation Administration (FAA, we) will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such*

as "should," "shall," "may," and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. …"

We note that there is no similar qualifying paragraph in the proposed AMC, and suggest that one be added for clarity and consistency.

Recommendation
Either replace "shall" with "should," or add a qualifying paragraph as indicated.

Page 27; Para 10.a.

Comment
Clarify the following text:

" .. The inspection intervals and life limits for any structural details and levels of damage that preclude repair must be clearly documented in the airworthiness limitations section of instructions for continued airworthiness. …"

Rationale
Clarification is needed as to where the inspection intervals and limitations should be contained. Multiple documents and manuals are typically involved.

Recommendation
Clarify as appropriate.

Page 28; Para 10.b.(1)(b)

Comment
Revise the text to read as follows:

*"Visual inspection is the predominant damage detection method used in the field ~~and should be performed under prescribed lighting conditions~~. Visual inspection procedures **and probability of detection studies** should account for **lighting conditions,** access, time relaxation in impact damage dent depth, and the color, finish and cleanliness of part surfaces."*

Additionally, add an indication as to whom the paragraph applies.

Rationale
Our suggested textual revision simplifies statement.

As written in the proposed AMC, this paragraph is not clear as to whom it applies: the operator or the manufacturer (OEM)?

Recommendation
Change text as indicated. Clarify the paragraph's intent.

Page 28, Para 10.b.(2)

Comment

Revise text to read as follows:

*"...~~In the case of~~ **Certain** processing defects ~~that~~ cannot be reliably detected ~~following~~ **at** completion of the repair (e.g., weak bonds)**. In such cases**, repair design features and limits ~~that~~ **should** ensure sufficient damage tolerance ~~until the damage can be reliably detected will be needed, as is the case for base composite structures~~. ..."*

Rationale

Our suggested changes provide better clarification of the intent of the paragraph.

Recommendation

Change text as indicated.

Page 28; Para 10.b.(3)

Comment

Revise the text to read as follows:

" ... This information supports future maintenance damage disposition and repair activities performed on the same part. ~~Service difficulties, damage and degradation occurring to composite parts in service should be reported back to the original equipment manufacturer (OEM) to aid in continuous updates of damage threat assessments to support future design detail and process improvements. Such information will also support future design criteria, analysis and test database developments~~."

Rationale

We recommend deleting the indicated text, as it does not seem appropriate for inclusion in an AMC. Currently, there is no specific process that could be followed, and the actions suggested could not be enforced.

Recommendation

Delete text as indicated.

Page 28; Para 10.c.(1)

Comment

Revise the text as follows:

" ... Repairable damage limits (RDL), which outline the details for damage to structural components that may be repaired based on existing data, must be clearly defined and documented. ~~The RDL may be linked with specified levels of repair skills for maintenance personnel and repair conditions in the field. There will be likely differences in the RDL for parts that can be removed from the aircraft for repair and those requiring repair on the aircraft. In some cases, larger RDL may also be substantiated for personnel with additional, special skills to execute the repair~~. ..."

Rationale

We recommend deleting the indicated text, as it does not seem appropriate for inclusion in an AMC. The OEM would not be able to control the situation described.

Recommendation
Delete text as indicated.

Page 28; Para 10.c.(1)

Comment
Revise text to read as follows:

" ... ~~Category 3, 4 and 5 damage types will generally also require special instructions for field repair and the associated quality control.~~ Bonded repair ~~to significant levels of damage~~ is subjected to the same structural bonding considerations as the base design (see paragraph 6.c)."

Rationale
Our suggested changes are for the sake of clarity:

The first sentence of the text is too specific to these categories of damage, as special instructions are required for many situations.

The term "significant" is too restrictive in the second sentence; "bonding considerations" are always required.

Recommendation
Change text as indicated.

Page 29; Para 10.c.(2)

Comment
Revise the text as follows:

*"Operators and maintenance repair organizations (MRO) wishing to complete major repairs, or alterations outside the scope of approved repair documentation should ~~consult the OEM because~~ **be aware of** extensive **analysis**, design, ~~and~~ process, **and test** substantiation ~~is needed~~ **required** to ensure the airworthiness of a **significantly repaired or altered** certificated structure."*

Rationale
The directions to contact the OEM are not appropriate for inclusion in this AC. The OEM is not the only resource available for the described information.

The words "analysis and test substantiation," and "significantly repaired or altered" should be added in order to provide a more thorough description.

Recommendation
Change text as indicated.

Page 29; Para 10.d.(1)

Comment
We recommend deleting subparagraph 10.d.(1) in its entirety.

Rationale
While the paragraph may contain good general information, it does not relate to compliance with regard to this proposed AMC. The deleted information seems better suited for inclusion in AC 145-6 (EASA equivalent), "Repair Stations for Composite and Bonded Aircraft Structure."

Recommendation
Remove paragraph 10.d.(1).

Page 29; Para 10.d.(2)

Comment
We recommend deleting subparagraph 10.d.(2) in its entirety.

Rationale
Competencies and reporting requirements of pilots, ramp maintenance and other operations personnel that service aircraft are defined elsewhere in the regulations. The information in this paragraph appears to be out of the scope of this proposed AMC that pertains to aircraft structure.

Recommendation
Remove paragraph 10.d.(2

response *Partially accepted*

10. - Accepted

10.a - Accepted

10.b.(1)(b) - TBD

10.b.(2) - Partially Accepted in line with AC 20-107B.

10.b.(3) - Partially Accepted. Text is made a recommendation.

10.c.(1) - Accepted

10.c.(2) - Accepted

10.d.(1) & (2) - Not Accepted. This is considered general information applicable to design and is relevant under the Agency's proposals for Operational Suitability Data (OSD).

comment *75* comment by: *KLM EASA DOA 21J.012*

10. Continued Airworthiness.
Par. d. - Damage Detection, Inspection and Repair Competency.

There seems to be a mismatch with Part-66.
On the one side, the NPA indicates that all personnel involved should have the necessary skills, but on the other side no details are given for AMC/GM to Part-66 what should be required for the Certifying Staff in respect with composites.

	Most of composites knowledge is concentrated in the composites repair shop who work 24/7 on composites. By contrast, in general Certifying Staff in Line Maintenance is far less acquainted with composites, however he/she has the ultimate responsibility when releasing for service. It is recommended to involve Part-66 in this NPA.
response	*Noted* The Agency agrees with the points in the comment. However, this AMC is part of a number of activities intended to better link composite certification activities. Regarding Part-66, the Agency plans to revise this to require certifying staff to have at least a minimum level of composite knowledge, e.g. per recently produced SAE AIR 5719.

comment	*93* comment by: *Austro Control GmbH* 10. b. - Comment Complete surface protection inspection should be included in the maintenance practices.
response	*Noted* The Agency considers surface protection inspection to be an implicit part of structural protection, e.g. 25.609, and the inspection process. The subject may be developed in future AMC revisions.

comment	*94* comment by: *Austro Control GmbH* 10. c. (1) – Changed wording Both RDL and ADL must be based on sufficient analysis supported by test data evidence to meet the appropriate structural substantiation requirements and other considerations outlined in this advisory circular.
response	*Not accepted* The Agency considers the wording to be adequate to include the proposed interpretation, which is a normally accepted option per 25.305

B. DRAFT RULES - V Draft Decision AMC-20 - new AMC 20-29 - 11. Additional considerations p. 29-33

comment	*23* comment by: *AIRBUS* Paragraphs 11a(1) to (9), except 11a(6): This part addresses the issue of crashworthiness survivability for a composite airframe design. This is currently not addressed in the CS-25 rules, but through Special Conditions, as established for two current transport airplanes with a composite airframe. To clarify this formal point, Airbus proposes to insert the following sentence, at the beginning of §11a(4): "<u>Special conditions are anticipated for transport category airplanes with composite fuselage structure to address crashworthiness survivability</u>." This will provide a harmonized text with AC20-107B.
response	*Accepted*

comment	*24*	comment by: *AIRBUS*
	Paragraph 11a(3): Due to the second and third sentences (bold text), the two last sentences are unnecessary. They can be deleted, in line with the wording of AC 20-107B. This will provide a harmonized text with AC20-107B.	
response	*Accepted*	

comment	*25*	comment by: *AIRBUS*
	Paragraph 11a(8): The last sentence is redundant with the previous one ("Sensitivity of the structural behaviour to reasonable impact orientation should also be considered") and the reference to CS25.721 contact conditions is not appropriate. Confusion between the intent of Special Conditions issued on crash survivability, and that of CS25.721 should be avoided. SC's address structural behaviour at the limit of crash-survivability considering preponderantly a vertical axis impact, whereas CS25.721 addresses (minor) emergency landing conditions without giving preponderance to one axis. This will provide a harmonized text with AC20-107B.	
response	*Accepted*	

comment	*31*	comment by: *Eurocopter*
	• § 11a(3): Crashworthiness regulations. "The regulations for large aeroplane and rotorcraft address some issues that go beyond those required of small aeroplanes." This statement is the basis for the applicability of the crashworthiness section 11a to rotorcraft. It should be further explained for the sake of clarity.	
response	*Noted* The Agency considers that other paragraphs do make the distinction clearer, e.g. Paragraph 11a(6), regarding differences between fuel tank crash requirements etc. Furthermore, this document is not intended to develop the details for all aircraft types. Note that a Harmonised Crashworthiness Rulemaking activity is planned. This is likely to result in changes to the text in the next AMC revision which may address Eurocopter concerns more directly.	

comment	*32*	comment by: *Eurocopter*
	• § 11a(4): Crashworthiness survivability. Four criteria are considered. The second one, related to emergency egress paths, could be misinterpreted in case of rotorcraft. Rotorcraft certification specifications are not intended to guarantee that the occupants will evacuate the aircraft by their own means in case of a survivable crash landing which is translated in much higher ultimate inertial load factors than for aeroplanes. Rotorcraft emergency exits and	

	doors are indeed not required to remain useable in a crash landing more severe than a minor crash landing (re CS 29.783(d) and CS 29.809(e)). Proposal: in case a criteria related to emergency egress is retained, the criteria should become the last one and should be reworded as follows: "The emergency egress paths must remain following a survivable crash (aeroplanes only)." or "The emergency egress ability must be preserved as specified in the applicable certification specifications identified in the type-certification basis."
response	*Noted* The need to be aware of differences between aircraft types is highlighted in Paragraph 11a(3). Regarding the terminology used '..egress paths must remain…' does not explicitly state that occupants be able to evacuate by there own means and is considered to be adequate to address the minor differences between the CSs regarding evacuation etc. Also see response to comment 31.

comment	*33* comment by: *Eurocopter* • § 11a(8): Structural behaviour. "Sensitivity of the structural behaviour to reasonable impact orientation should be considered for large aeroplane and rotorcraft applications." In the absence of an aircraft level crashworthiness standard, further guidance on what could be "reasonable impact orientation" should be provided for rotorcraft. The rationale for excluding aeroplanes in the normal and commuter categories and including rotorcraft (small and large rotorcraft a priori as they have basically the same crash resistance requirements) should be explained or rotorcraft should be excluded.
response	*Noted* Please note that commuter aircraft are not excluded from the need to show that material change does not lower the level of safety with respect to metal aircraft. This is a basic requirement for all critical structural material change. Note that a Harmonised Crashworthiness Rulemaking activity is planned. This is likely to result in changes to the text in the next AMC revision which may address Eurocopter concerns more directly.

comment	*39* comment by: *Eurocopter* • § 11b Fire Protection. Post-Crash Fire issue. The post-crash fire issue in otherwise survivable impacts does not come up in same terms for rotorcraft and for large aeroplanes. For rotorcraft, the possibility of fire addressed in emergency evacuation requirement CS 29.803 is taken into account through unusable emergency exits in CS-29 Appendix D and a crash resistant fuel system is required to minimise the PCF hazard. This should be made clear in the AMC.
response	*Noted*

	The Agency agrees with the technical point. However, the need to be aware of differences between aircraft types is highlighted in Paragraph 11a(3), the comment providing such an example. Note that a Harmonised Crashworthiness Rulemaking activity is planned. This is likely to result in changes to the text in the next AMC revision which may address Eurocopter concerns more directly.

comment	*43* comment by: *Ludger Duelmer, Extra Flugzeugproduktion* 11. c.: The following might be added: The lightning protection effectiveness for composite structures should be demonstrated by tests, *unless previous experience or test data with similar designs and material system as well as protection system means is available*.
response	*Noted* The Agency agrees with the technical point. However, the AMC is only a MOC and it does allow for credit to be given to previous similar experience at various locations in the text.

comment	*69* comment by: *Boeing* Page 29; Para 11.a.(1) **Comment** Revise the text as follows: *" … With the advent of composite fuselage structure **and/or the use of novel design**, this historical approach may no longer be sufficient to ~~maintain~~ **substantiate** the same level of protection for the passengers as provided by similar metallic designs."* ***Rationale*** "The use of novel design" should be added to the text for precision. We suggest that "substantiate" is a more appropriate word than "maintain" in explaining the intent of this paragraph. ***Recommendation*** Change text as indicated. Page 29; Para 11.a.(2) **Comment** Revise the text as follows: *" … A composite design should account for unique behavior and structural characteristics, including **major** repairs or alterations, …"* ***Rationale*** Revision is necessary to clarify that the repair would have to be "major" to consider its crashworthiness effects. ***Recommendation***

Change text as indicated.

Page 29; Para 11.a.(2)

Comment
Clarify the text that states:

" ... A composite design should account for unique behavior and structural characteristics ***... as compared with conventional metal airframe designs that have been shown to meet current crashworthiness requirements****. ..."*

Rationale
This statement is confusing due to the lack of requirements for past designs. There are no specific requirements; they are spread over multiple sections of the regulations. More clarification is essential in order to understand the intent of the paragraph.

Recommendation
Clarify text as appropriate

Page 29; Para 11.a.(3)

Comment
Revise the text as follows:

~~The crash dynamics of an aircraft and the associated energy absorption are difficult to model and fully define representative tests with respect to structural requirements~~. Each aircraft product type (i.e., transport, small airplane, rotorcraft) has unique regulations governing the crashworthiness of particular aircraft structures. The regulations and guidance associated with each product type should be used accordingly. ~~The regulations for transport airplane and rotorcraft address some issues that go beyond those required of small airplanes. Additionally, any dynamic seat modeling efforts should take into account related guidance for the applicable product type. The aircraft size also distinguishes some of the key issues as related to passenger egress following a survivable crash~~

Rationale
The first sentence does not appear to add anything to increase understanding. We suggest that it be could be deleted without impairing the intent of the paragraph.

The last portion of deleted words is covered in paragraph 11.a.(4).

Recommendation
Change text as indicated.

Page 30; Para 11.a.(4)

Comment

Revise the text as follows:

"The impact response of a composite transport fuselage structure must be evaluated to ensure that ~~survivable crashworthiness characteristics are~~ ***survivability is*** *not significantly different from ~~those~~* ***that*** *of a similar-sized aircraft fabricated from metallic materials. …"*

Rationale
We consider "survivability" a better word in that it summarizes the required final goal more appropriately than "survivable crashworthiness characteristics."

Recommendation
Change text as indicated.

Page 30; Para 11.a.(6)

Comment
Revise the text as follows:

"Existing transport airplane requirements also require that fuel tank structural integrity be addressed during a survivable crash impact event as related to fire safety (also see paragraph 11.b). ~~Again, the benchmark for evaluation of composite structures integral to the fuel tank is the performance of similar-sized airplane structures fabricated from metallic materials.~~ As related to crashworthiness, composite fuel tank structure must not fail or deform to the extent that fire becomes a greater hazard than with metal structure."

Rationale
There are current regulations that can be used for the fuel tank, 5 ft. per second, wheels-up, etc. We suggest that a reference to these regulations be included in lieu of the deleted text.

Recommendation
Change text as indicated and reference existing requirements.

Page 30; Para 11.a.(7)

Comment
Revise the paragraph by <u>deleting</u> the text that states:

" … In addition, care should be taken when altering composite structure to achieve specific mechanical behaviors. (For example, where the change in behavior of a metallic structure with a change in material thickness may be easily predicted, an addition of plies to a composite laminate may significantly alter the failure mode and energy absorption characteristics of a composite element.)"

Rationale
We disagree with the premise that predicting the behavior of composite laminate material is more difficult to predict that that of metallic materials. In fact, slight changes in carbon fiber reinforced plastic (CFRP) are no more difficult to predict that in other materials.

Recommendation
If there is data that could be added in this section to verify the statement, we suggest adding it; otherwise, we suggest deleting the text as indicated

Page 30; Para 11.a.(8)

Comment
Revise text as follows:

~~"Specific composite design and process details~~ ***Representative structure*** *must be included to gain valid test and analysis results. ..."*

Rationale
Our suggested change provides better clarity; it is a more encompassing term.

Recommendation
Change text as indicated.

Page 30; Para 11.a.(8)
Comment
Revise text by adding the following as a last sentence:

" ... ***This can be addressed by analysis supported by test evidence****."*

Rationale
Adding the suggested "compliance statement" will provide better clarity as to the intent of the paragraph.

Recommendation
Add text as indicated.

Page 32; Para 11.b.(6)

Comment
Revise the text by deleting the word "large," as follows:

"...Many composite materials have glass transition temperatures, which mark the onset of ~~large~~ reductions in strength and stiffness that are somewhat lower than the temperatures that can have a similar affect on equivalent metallic structure. ..."

Rationale
Change is suggested for clarification. Many newer resins do not show large drops at these temperatures as in the past older systems.

Recommendation
Change text as indicated

Page 32; Para 11.c., first paragraph

Comment
Revise text as follows:

"...***Current*** carbon fiber composites are approximately one thousand times less electrically conductive than ***standard*** aluminum ***materials***, and composite resins and adhesives are ***traditionally*** non-conductive. ... A lightning strike to composite structures can result in structural failure ***or large area damage***, and induce high lightning current and voltage on metal hydraulic tubes, fuel system tubes, and electrical wiring if proper conductive lightning protection is not provided. ... The lightning protection effectiveness for composite structures should be demonstrated by tests, ***or analysis supported by tests.***

Rationale
Our suggested comments are meant for clarity, and to allow flexibility for future work and advanced materials.

Recommendation
Change text as indicated.

Page 32; Para 11.c.(1)(a)

Comment
Revise the text as follows:

"The composite structural design should incorporate the lightning protection ***when*** *appropriate for the anticipated lightning attachment. The extent of lightning protection features depends on the lightning attachment zone designated for that area of the aircraft.* ~~*Typical*~~ **Traditional** *lightning protection features include,* **but are not limited to,** *adding metal wires or mesh to the outside surface of the composite structure where direct lightning attachment is expected."*

Rationale
Our suggested comments are meant for clarity, and to allow flexibility for future work and advanced materials.

Recommendation
Change text as indicated.

Page 33; Para 11.c.(2)(b)

Comment
Revise the text as follows:

"Large airplane regulations for fuel system ignition prevention in CS 25.981 require lightning protection that is failure tolerant ***or robust and designed to take the specific zone threat****. As a result, redundant* ***or robust*** *lightning protection for composite structure joints and fasteners are needed to*

	ensure proper protection in preventing ignition sources." ***Rationale*** Credit should be given to a robust design. In many cases a robust design may be better than one that is failure tolerant, but not reliable. Our suggested changes would address this issue. ***Recommendation*** Add text as indicated (underlined). Page 33; Para 11.c.(3)(a) **Comment** Revise the text as follows: *"Lightning strike protection of composite structures is needed to avoid inducing high lightning voltages and currents on the electrical and electronic system wiring, ~~with a potential for system~~ **<u>to minimize</u>** upset or damage **<u>to non critical systems, and to prevent damage to or failure of critical systems</u>.** The consequences from a lightning strike ~~of unprotected~~ **<u>on inappropriately designed</u>** composite structures can be catastrophic for …"* ***Rationale*** Our suggested changes are meant to clarify the guidance for critical and non-critical systems. Some structure is left unprotected by design. The main issue here is inappropriately designed composite structures. ***Recommendation*** Change text as indicated.
response	*Partially accepted* 11.a(1) - Accepted 11.a(2) - Accepted 11.a(2) - Partially Accepted. Text per AC 20-107B 11.a(3) - Not Accepted. Provides introductory message to highlight the difficulty in modelling crash dynamics 11.a(4) - Accepted 11.a(6) - Accepted 11.a(7) - Not Accepted Why? 11.a(8) - Accepted 11.b(6) - Accepted 11.c - Accepted 11.c(1)(a) - Partially Accepted. Text aligned with AC 20-107B. 11.c(2)(b) - Partially Accepted. Text aligned with AC 20-107B 11.c(3)(a) - Partially Accepted. Text aligned with AC 20-107B

comment	*95* comment by: *Austro Control GmbH* 11. a. (4) – Comment 11. a. (6) – Comment A comparison of a composite aircraft with a similar-sized metallic aircraft does not seem to be appropriate or practical.
response	*Not accepted* Some form of reference is required considering the need to show an equivalent level of safety with respect to metallic structure. A 'similar-sized' metallic aircraft operating in similar environments with similar operating performance is likely to be exposed to 'similar' basic crash threats, e.g. descent rate etc. This is the approach being taken for large transport aircraft.

comment	*96* comment by: *Austro Control GmbH* 11. b. (5) – Comment Smoke density has not been considered.
response	*Accepted*

comment	*97* comment by: *Austro Control GmbH* 11. c. (1) (a) – Changed wording Typical lightning protection features include adding metal wires, conductive coating or mesh to the outside surface of the composite structure where direct lightning attachment is expected.
response	*Noted* The list provided only identifies 'typical' protection. Other supporting documents should provide a more complete coverage of the issue. 'Conductive coating' may be added to the list in a future revision.

comment	*107* comment by: *Dassault Aviation* **§ 11. Additional Considerations** **a. Crashworthiness** Comments : a methodology to compute dynamic emergency landing (for which, in particular, damping is a first order influencing parameter that is not known) is, on DA point of view, very difficult to put in place on a metallic structure and even more difficult on a composite one. Its validation is in fact of a greater order of difficulty as dynamic composite failure modes have to be identified, characterized and modelled. Furthermore it would necessitate a huge effort of modelling to be able to assess accelerations at the level of items of mass or passengers. Dassault Aviation point on view is the following: - To assess the same emergency load factors than for metallic structures (§25.561 and 25.562). - To define crash pads so that to limit the load introduced in the structure during a prepared emergency landing and show that the structure integrity is conserved.
response	*Noted* The Agency agrees with the comments. The text is reflecting what is

increasingly shown to be possible with modelling methods and increased understanding of composites. Furthermore, management of the crash behaviour is increasingly forming part of the design process, i.e. If EASA understands the comments fully and correctly, the 'crash pad' idea could form part of an 'energy management' system intended to maintain structural integrity and survivability.

comment | *108* | comment by: *Dassault Aviation*

c. Lightning protection
(1) (a)
Dassault Aviation propose to add: "Paint thickness has to be carefully controlled so not to create a dielectric effect resulting in electric loads concentration that possibly can provoke large holes and even explosion due to plasma generation" .

(1) (b)
" ... for movable parts (i.e., ailerons, rudders and elevators)" should be replaced by " ... for movable parts (e.g., ailerons, rudders, elevators, airbrakes, spoilers ...)" to cover all movable surfaces as also flaps and slats.

response | *Partially accepted*

(1) (a) The Agency agrees that some evidence exists regarding this phenomenon which may justify inclusion in future revisions as the understanding of its relevance improves.
(1)(b) The list is only an example. Text amended to replace 'i.e.' with 'e.g'.

comment | *133* | comment by: *Diamond Aircraft Industries (Austria)*

11.a (Crashworthiness): Metallic airframe structures are identified as the benchmark for composite structures. This is not helpful for manufacturers which have not produced metallic airframe structures in the past. The AMC should include specific information which characteristics should be assessed, and which minimum properties are acceptable.

response | *Not accepted*

The comparison argument exists for products which do have other reference points. The Agency recognises that established safe practices exist for other aircraft types which may have no comparison. Note, that this is only an 'acceptable', not the only, means of compliance. Also note that a harmonised 'crashworthiness' rulemaking activity is planned, which may address this concern.

comment | *157* | comment by: *Gulfstream Aerospace Corp*

Para. 11.a Crashworthiness. The requirement for equivalent level of safety to metallic structure is difficult to substantiate. Concerns are clear but advice on means of compliance is too vague Aluminum airframe is accepted based on service history without data. There is no baseline for equivalent level of safety. Provide an acceptable means of compliance.

response | *Noted*

The Agency agrees that substantiating an equivalent level of safety may be difficult and require an extensive 'building block approach', as indicated para.

11(9). Further guidance is available in supporting documents, e.g. CMH-17, and Special Conditions etc. Future revision to the AMC may develop the point further.

comment *158* comment by: *Gulfstream Aerospace Corp*

Para. 11.b Fire Protection, Flammability & Thermal Issues. The requirement for equivalent level of safety to metallic structure is difficult to substantiate. Concerns are clear but advice on means of compliance is too vague. Aluminum airframe is accepted based on service history without data. There is no baseline for equivalent level of safety. Provide an acceptable means of compliance.

response *Noted*

The Agency agrees that substantiating an equivalent level of safety may be difficult and require an extensive 'building block approach', as indicated para. 11(9). Further guidance is available in supporting documents, e.g. CMH-17, and Special Conditions etc. Future revision to the AMC may develop the point further.

B. DRAFT RULES - Appendix 1 - Applicable Regulations and Relevant Guidance p. 34-36

comment *34* comment by: *Eurocopter*

§ 1 Applicable Regulations.

- 11a Crashworthiness:
  - reference to CS-27 §1413 seems useless and could be deleted.
  - reference to §§ 963, 965 and 967 is valid for both CS-27 and CS-29.
  - reference to § 952 could be added for CS-27 and CS-29.
- 11b Fire Protection:
  - reference to § 1194 is valid for CS-27 and CS-29 (not for CS-25).

response *Accepted*

963, 967 added to CS 27 list.
965 added to CS-29 list.
1413 is deleted
1194 column error is corrected

B. DRAFT RULES - Appendix 2 – Definitions p. 37-39

comment *26* comment by: *AIRBUS*

The word "Critical" is a term used in other regulatory context, for example Part 21, paragraph 21A.805.
Airbus proposes to add the following sentence in the definition of "Critical Structure":
"This definition of "Critical Structure" is provided only for the purpose of defining the domain of application of this AMC. It should not be used in other

	regulatory context."
response	*Not accepted* The Agency believes that the inclusion of the definition of 'Critical Structure' for the purposes of the AMC in Appendix 2 is adequate.

comment	*27* comment by: *AIRBUS* Life (or Load) Enhancement Factor: For clarity, Airbus suggests the following change: "an additional load factor and/or test duration applied to <u>structural repeated load</u> test, [...]"
response	*Accepted*

comment	*70* comment by: *Boeing* Page 37; Appendix 2 **Comment** Delete the proposed definition of "Critical Structure," add substitute in its place the definition of a primary structural element (PSE). ***Rationale*** The current EASA definition of PSE is appropriate for defining "critical structure." Adding a new definition will likely create confusion. ***Recommendation*** Revise definition of "critical structure" as suggested. Page 38; Appendix 2 **Comment** Revise the definition of "No-Growth Approach" as follows: *"No-Growth Approach - a method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads without ~~detectable~~ <u>**detrimental**</u> flaw growth for the life of the structure."* ***Rationale*** "Detectable" does not seem an appropriate term in the definition, especially when it is related to how to inspect. "Detrimental" is the more appropriate term with regard to the intent of the paragraph. ***Recommendation*** Change text as indicated. Appendix 2 **Comment** Add a definition of "Manufacturing Defect," and differentiate between flaws <u>within</u> the specification and <u>outside</u> of the specification allowances.

Rationale
A definition of "manufacturing defect" is appropriate, as the term is used in various portions of the proposed AMC. Clarity on this issue is essential to understanding.

Recommendation
Add a definition of "manufacturing defect."

response *Partially accepted*

Text is amended to align with AC 20-107B.

comment *109* comment by: *Dassault Aviation*

Appendix 2 - Definition
Allowables: *The sentence between brackets"... (e.g., A or B base values, with 99% probability and 95% confidence or 90% probability ...respectively)"* should be replaced by, as B values are selected for composites: *" ...(for composites i.e. B base values with 90% probability and 95% confidence).".*

response *Not accepted*

Although 'B' base values are predominantly used for composites, the rapidly extending application of these materials is seeing use of 'A' values.

B. DRAFT RULES - Appendix 3 - Change of Composite Material and/or Process p. 40-43

comment *71* comment by: *Boeing*

Page 40; Appendix 3, Para 5.
Comment
Revise text as follows:

*" ... Furthermore, failure modes may vary from one material and/or process to another, and analytical models are ~~still~~ **sometimes** insufficiently precise to reliably predict failure without sufficient empirical data. Therefore, a step-by-step test verification with more complex specimens ~~is~~ **may be** required."*

Rationale
Analytical models have improved in recent years. We suggest the text be revised to reflect this.

Recommendation
Change text as indicated.

Page 41; Appendix 3, Para 6.d.

Comment
Define the term "equivalency sampling tests" as used in the text that states:

" ... Other minor material changes that fall under Case B may warrant

	equivalency sampling tests *only at lower levels of building block substantiation."* ***Rationale*** A definition of the term "equivalency sampling tests" is needed for clarity and to ensure understanding. ***Recommendation*** Add definition as suggested.
response	*Partially accepted* Text is amended to align with AC 20-107B.

comment	*73* comment by: *Ludger Duelmer, Extra Flugzeugproduktion* Appendix 3: This appendix should as additional guidance provide more change of material and/or process examples per discipline. It should also refer to Part 21 and related AMC & GM (21A.91) addressing the classification of changes (classification criteria for major/minor changes with respect to material and/or process changes).
response	*Not accepted* Appendix 3, Para 1 already provides the link to Part 21 etc. More examples could be added to future revisions of the AMC.

comment	*83* comment by: *Sell GmbH* Comment to 1. last sentence: This sentence is unclear and thus misleading to shift change classification to the level of material and process specifications. To prevent any pre-classification by this AMC replace "... are often major changes in type design" by "... are changes in the type design" as change classification is performed evaluating the effects on product level as required by Part 21A.91.
response	*Not accepted* Appendix 3, Para 1 already provides the link to Part 21. The existing text is considered to be adequately clear in the context of Appendix 3.

comment	*84* comment by: *Sell GmbH* Comment to 3.: The definition of "several batches" is missing and would therefore lead to ambiguous application. A clear specification of the minimum quantity of batches required to justify reproducibility should be added.
response	*Not accepted* The term 'several' is used in its generic sense because the number of batches is a function of the change significance. A less significant change could be addressed by a lower level equivalence process, per statistics in guidance, e.g. NCAMP, STAT17 etc. More significant changes require some 'engineering

	judgement' regarding the impact upon the test pyramid and the number of batches, tests etc required.

comment	*85* comment by: *Sell GmbH* Comment to 6.: The terms "minor changes" and "significant changes" as used for material and/or process changes may lead to misunderstanding with the same terms as used in Part 21 for changes on product level. Therefore there is the need for more explanation and guidance to clearly distinguish between changes on material/process level and changes on product level as per Part 21.
response	*Not accepted* Since the significance of a material/process change is determined by its impact upon product safety, the linkage to Part 21 should be the driving factor. Note that Part 21 is a Rule, this is only AMC guidance. The existing text is considered to be adequately clear in the context of Appendix 3.

comment	*86* comment by: *Sell GmbH* Comment to 7. a. (1) and (2): Replace "procurement specification" by "material specification", as material specifications include respective requirements to ensure that consistent material can be procured.
response	*Not accepted* The use of the term 'procurement specifications' only intended to highlight this aspect of a material specification, not necessarily imply a separate document. See also AC 23-20 in the reference list for guidance. Also note, this AMC is an 'acceptable', but not only, means of compliance.

comment	*110* comment by: *Dassault Aviation* **Appendix 3 - Change of composite material and / or process** **§ b (1) Testing** *"... (see figures in paragraph ~~6~~ 7)..."* (typo already corrected on FAA side).
response	*Accepted*

Appendix A - REVISED TEXT OF AMC 20-29 AFTER CRD

NOTE

- Underlined text is additional text in AMC 20-29 w.r.t. AC 20-107B
- Deleted text is text in AC 20-107B not retained in AMC 20-29

AMC 20-29
Composite Aircraft Structures

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1. PURPOSE

This AMC provides an acceptable means, but not the only means for airworthiness certification of composite aircraft structures, including fibre reinforced materials, e.g. carbon and glass fibre reinforced plastics. Guidance information is also presented on the closely related design, manufacturing and maintenance aspects.

2. OBJECTIVE

AMC 20-29 standardises recognised good design practices common to composite aircraft structures in one document.

For rotorcraft (CS-27 and CS-29), AMC 20-29 complements existing harmonised guidance material contained in AC 27-1B MG8 and AC 29-2C MG8, (as adopted as AMC in Book 2 of CS-27 and CS-29).

3. APPLICABILITY

This AMC provides acceptable means of compliance with the provisions of CS-23, CS-25, CS-27 and CS-29. Many of the concepts included in this AMC may also be applicable in part or in full to other CSs. However when using this AMC as an acceptable means of compliance for these other CSs, appropriate engineering judgement should be exercised and early agreement with the Agency sought.

This AMC applies to: applicants for a type-certificate, restricted type- certificate or supplemental type-certificate; certificate/approval holders; parts manufacturers; material suppliers; and maintenance and repair organisations.

Note: The technical content of this AMC is harmonised with FAA Advisory Circular AC 20-107B, dated 08 September 2009.

4. RELATED REGULATIONS AND GUIDANCE.

The material contained herein applies to aircraft to be certificated under CS-23, CS-25, CS-27, CS-29

a. Applicable paragraphs are listed in Appendix 1.

b. Relevant guidance considered complementary to this AMC is provided in Appendix 1.

5. GENERAL.

a. The procedures outlined in this AMC provide acceptable means of compliance and guidance material for composite structures, particularly those that are essential in maintaining the overall flight safety of the aircraft ("critical structure" as defined in Appendix 2). This AMC is published to aid in the evaluation of certification programmes for composite applications and to reflect the current status of composite technology. It is expected that this AMC will be modified periodically to reflect the continued evolution of composite technology and the data collected from service experience and expanding applications.

b. There are factors unique to the specific composite materials and processes used for a given application. For example, the environmental sensitivity, anisotropic properties, and heterogeneous nature of composites can make the determination of structural failure loads, modes, and locations difficult. The reliability of such evaluation depends on repeatable structural details created by scaled manufacturing or repair processes. The extent of testing and/or analysis may differ for a structure depending upon the criticality to flight safety, expected service usage, the material and processes selected, the design margins, the failure criteria, the database and experience with similar structures, and on other factors affecting a particular structure. It is expected that these factors will be considered when interpreting this AMC for use on a specific application.

c. Definitions of terms used in this AMC can be found in Appendix 2.

6. MATERIAL AND FABRICATION DEVELOPMENT.

All composite materials and processes used in structures are qualified through enough fabrication trials and tests to demonstrate a reproducible and reliable design. One of the important features of composite construction is the degree of care needed in the procurement and processing of composite materials. The final mechanical behaviour of a given composite material may vary greatly depending on the processing methods employed to fabricate production parts. Special care needs to be taken in controlling both the materials being procured and how the material is processed once delivered to the fabrication facility. Regulatory requirements in the CSs (namely paragraphs 2x.603 and 2x.605) specify the need to procure and process materials under approved material and process specifications that control the key parameters governing performance. These paragraphs outline a need to protect structures against the degradation possible in service. They also require that the design account for any changes in performance (e.g., environmental and variability effects) permitted by material and process specifications.

a. Material and Process Control.

(1) Specifications covering material, material processing, and fabrication procedures are established to ensure a basis for fabricating reproducible and reliable structure. Material specifications are required to ensure consistent material can be procured, and batch acceptance testing or statistical process controls are used to ensure material properties do not drift over time. Specifications covering processing procedures should be developed to ensure that repeatable and reliable structure can be manufactured. The means of processing qualification and acceptance tests defined in each material specification should be representative of the expected applicable manufacturing process. The process parameters for fabricating test specimens should match the process parameters to be used in manufacturing actual production parts as closely as possible. Both test and production parts must conform to material and process specifications.

(2) Once the fabrication processes have been established, changes should undergo additional qualification, including testing of differences, before being implemented, (refer to Appendix 3). It is important to establish processing tolerances; material handling and storage limits; and key characteristics, which can be measured and tracked to judge part quality.

(3) Material requirements identified in procurement specifications should be based on the qualification test results for samples produced using the related process specifications. Qualification data must cover all properties important to the control of materials (composites and adhesives) and processes to be used for production of composite structure. Carefully selected physical, chemical, and mechanical qualification tests are used to demonstrate the formulation, stiffness, strength, durability, and reliability of materials and processes for aircraft applications. It is recommended that airframe designers and manufacturers work closely with material suppliers to properly define material requirements.

(4) To provide an adequate design database, environmental effects on critical properties of the material systems and associated processes should be established. In addition to testing in an ambient environment, variables should include extreme service temperature and moisture content conditions and effects of long-term durability. Qualification tests for environmental effects and long-term durability are particularly important when evaluating the materials, processes, and interface issues associated with structural bonding (refer to paragraph 6.c for related guidance).

(5) Key characteristics and processing parameters should be specified and monitored for in-process quality control. The overall quality control plan required by the certifying agency should involve all relevant disciplines, i.e., engineering, manufacturing, and quality control. A reliable quality control system should be in place to address special engineering requirements that arise in individual parts or areas as a result of potential failure modes, damage tolerance and flaw growth requirements, loadings, inspectability, and local sensitivities to manufacture and assembly.

(6) Tolerances permitted by the material and process specifications should be substantiated by analysis supported by test evidence, or tests at the coupon, element or sub-component level. For new production methods, repeatable processes should be demonstrated at sufficient structural scale in a way shown to be consistent with the material and process qualification tests and development of the associated specifications. This will require integration of the technical issues associated with product design and manufacturing details prior to a large investment in structural tests and analysis correlation. It will also ensure the relevance of quality control procedures defined to control materials and processes as related to the product structural details.

(7) Note that the Agency does not certify materials and processes. However, materials and processes specifications are part of the type-design subject to type-certification. Appropriate certification credit may be given to products and organisations using the same materials and processes in similar applications subject to substantiation and applicability. In some cases, material and processing information may become part of accepted shared databases used throughout the industry. New users of shared qualification databases must control the associated materials and processes through proper use of the related specifications and demonstrate their understanding by performing equivalency sampling tests for key properties. Note that materials and processes used in European technical standard order (ETSO) articles or authorisations must also be qualified and controlled.

b. Design Considerations for Manufacturing Implementation.

(1) Process specifications and manufacturing documentation are needed to control composite fabrication and assembly. The environment and cleanliness of facilities are controlled to a level validated by qualification and proof of structure testing. Raw and ancillary materials are controlled to specification requirements that are consistent with material and process qualifications. Parts fabricated should meet design drawing tolerances obtained from the production tolerances validated in qualification, design data development, and proof of structure tests. Some key fabrication process considerations requiring such control include: (i) material handling and storage, (ii) laminate layup and bagging (or other alternate process steps for non-laminated material forms and advanced processes), (iii) mating part dimensional tolerance control, (iv) part cure (thermal management), (v) machining and assembly, (vi) cured part inspection and handling procedures, and (vii) technician training for specific material, processes, tooling and equipment.

(2) Substantiating data is needed for design to justify all known defects, damage and anomalies allowed to remain in service without rework or repair. Adequate manufacturing records support the identification and substantiation of known defects, damage and anomalies.

(3) Additional substantiating design data is needed from new suppliers of parts previously certificated. This may be supported by manufacturing trials and quality assessments to ensure equivalent production and repeatability. Some destructive inspection of critical structural details is needed for manufacturing flaws that are not end item inspectable and require process controls to ensure reliable fabrication.

c. Structural Bonding Bonded structures include multiple interfaces (e.g., composite-to-composite, composite-to-metal, or metal-to-metal), where at least one of the interfaces requires additional surface preparation prior to bonding. The general nature of technical parameters that govern different types of bonded structures are similar. A qualified bonding process is documented after demonstrating repeatable and reliable processing steps such as surface preparation. It entails understanding the sensitivity of structural performance based upon expected variation permitted per the process. Characterisation outside the process limits is recommended to ensure process robustness. In the case of bonding composite interfaces, a qualified surface preparation of all previously cured substrates is needed to activate their surface for chemical adhesion. For all bonding interfaces, regardless if on metallic or previously cured composite substrates, a qualified surface preparation is needed to activate their surface for chemical adhesion. Many technical issues for bonding require cross-functional teams for successful applications. Applications require stringent process control and a thorough substantiation of structural integrity.

(1) Many bond failures and problems in service have been traced to invalid qualifications or insufficient quality control of production processes. Physical and chemical tests may be used to control surface preparation, adhesive mixing, viscosity, and cure properties (e.g., density, degree of cure, glass transition temperature). Lap shear stiffness and strength are common mechanical tests for adhesive and bond process qualification. Shear tests do not provide a reliable measure of long-term durability and environmental degradation associated with poor bonding processes (i.e., lack of adhesion). Some type of peel test has proven more reliable for evaluating proper adhesion. Without chemical bonding, the so-called condition of a “weak bond” exists when the bonded joint is either loaded by peel forces or exposed to the environment over a long period of time, or both. Adhesion failures, which indicate the lack of chemical bonding between substrate and adhesive materials, are considered an unacceptable failure mode in all test types. Material or bond process problems that lead to adhesion failures are solved before proceeding with qualification tests.

(2) Process specifications are needed to control adhesive bonding in manufacturing and repair. A “process control mentality”, which includes a combination of in-process inspections and tests, has proven to be the most reliable means of ensuring the quality of adhesive bonds. The environment and cleanliness of facilities used for bonding processes are controlled to a level validated by qualification and proof of structure testing. Adhesives and substrate materials are controlled to specification requirements that are consistent with material and bond process qualifications. The bonding processes used for production and repair meet tolerances validated in qualification, design data development, and proof of structure tests. Some key bond fabrication process considerations requiring such control include: (i) material handling and storage, (ii) bond surface preparation, (iii) mating part dimensional tolerance control, (iv) adhesive application and clamp-up pressure, (v) bond line thickness control, (vi) bonded part cure (thermal management), (vii) cured part inspection and handling procedures, and (vii) bond technician training for specific material, processes, tooling and equipment. Bond surface preparation and subsequent handling controls leading up to the bond assembly and cure must be closely controlled in time and exposure to environment and contamination.

(3) CS 23.573(a) sets the certification specification for primary composite airframe structures, including considerations for damage tolerance, fatigue, and bonded joints. Although this is a small aeroplane rule, the same performance standards are normally expected for large aeroplanes and rotorcraft (via special conditions and CRIs).

(a) For bonded joints, CS 23.573(a)(5) states:

"*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) 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

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

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

(b) These options do not supersede the need for a qualified bonding process and rigorous quality controls for bonded structures. For example, fail safety implied by the first option is not intended to provide adequate safety for the systematic problem of a bad bonding process applied to a fleet of aircraft structures. Instead, it gives fail safety against bonding problems that may occasionally occur over local areas (e.g., insufficient local bond contact pressure or contamination). Performing static proof tests to limit load, which is the second option, may not detect weak bonds requiring environmental exposure and time to degrade bonded joint strength. This issue should be covered by adequately demonstrating that qualified bonding materials and processes have long-term environmental durability. Finally, the third option is open for future advancement and validation of non-destructive inspection (NDI) technology to detect weak bonds, which degrade over time and lead to adhesion failures. Such technology has not been reliably demonstrated at a production scale to date.

(4) Adhesion failures are an unacceptable failure mode for bonded structure that require immediate action by the responsible engineers to identify the specific cause and isolate all affected parts and assemblies for directed inspection and repair. Depending on the suspected severity of the bonding problem, an airworthiness directive may be required to restore the affected aircraft to an airworthy condition. Any design, manufacturing or repair details linked to the bonding problem should also be permanently corrected.

d. Environmental Considerations. Environmental design criteria should be developed that identify the critical environmental exposures, including humidity and temperature, to which the material in the application under evaluation may be exposed. Service data (e.g., moisture content as a function of time in service) can be used to ensure such criteria are realistic. In addition, the peak temperatures for composite structure installed in close proximity to aircraft systems that generate thermal energy need to be identified for worst-case normal operation and system failure cases. Environmental design criteria are not required where existing data demonstrate that no significant environmental effects, including the effects of temperature and moisture, exist for the material system and construction details, within the bounds of environmental exposure being considered.

(1) Experimental evidence should be provided to demonstrate that the material design values or allowables are attained with a high degree of confidence in the appropriate critical environmental exposures to be expected in service. It should be realized that the worst case environment may not be the same for all structural details (e.g., hot wet conditions can be critical for some failure modes, while cold dry conditions may be worse for others). The effect of the service environment on static strength, fatigue and stiffness properties and design values should be determined for the material system through tests; e.g., accelerated environmental tests, or from applicable service data. The maximum moisture content considered is related to that possible during the service life, which may be a function of a given part thickness, moisture diffusion properties and realistic environmental exposures. The effects of environmental cycling (i.e., moisture and temperature) should be evaluated when the application involves fluctuations or unique design details not covered in the past. Existing test data may be used where it can be shown to be directly applicable to the material system, design details, and environmental cycling conditions characteristic of the application. All accelerated test methods should be representative of real-time environmental and load exposure. Any factors used for acceleration that chemically alter the material (e.g., high temperatures that cause post-cure) should be avoided to ensure behaviour representative of real environmental exposures.

(2) Depending on the design configuration, local structural details, and selected processes, the effects of residual stresses that depend on environment should be addressed (e.g., differential thermal expansion of attached parts).

e. Protection of Structure. Weathering, abrasion, erosion, ultraviolet radiation, and chemical environment (glycol, hydraulic fluid, fuel, cleaning agents, etc.) may cause deterioration in a composite structure. Suitable protection against and/or consideration of degradation in material properties should be provided for conditions expected in service and demonstrated by test and/or appropriate validated experience. Where necessary, provide provisions for ventilation and drainage. Isolation layers are needed at the interfaces between some composite and metal materials to avoid corrosion (e.g., glass plies are used to isolate carbon composite layers from aluminium). In addition, qualification of the special fasteners and installation procedures used for parts made from composite materials need to address the galvanic corrosion issues, as well as the potential for damaging the composite (delamination and fibre breakage) in forming the fastener.

f. Design Values. Data used to derive design values must be obtained from stable and repeatable material that conforms to mature material and representative production process specifications. This will ensure that the permitted variability of the production materials is captured in the statistical analysis used to derive the design values. Design values derived too early in the material's development stage, before raw material and composite part production processes have matured, may not satisfy the intent of the associated rules. Laminated material system design values should be established on the laminate level by either test of the laminate or by test of the lamina in conjunction with a test validated analytical method. Similarly, design values for non-laminated material forms and advanced composite processes must be established at the scale that best represents the material as it appears in the part or by tests of material substructure in conjunction with a test validated analytical method.

g. Structural Details. For a specific structural configuration of an individual component (point design), design values may be established which include the effects of appropriate design features (holes, joints, etc.). Specific metrics that quantify the severity of composite structural damage states caused by foreign impact damage threats are needed to perform analysis (i.e., the equivalent of a metallic crack length). As a result, testing will often be needed to characterise residual strength, including the structural effects of critical damage location and combined loads. Different levels of impact damage are generally accommodated by limiting the design strain levels for ultimate and limit combined load design criteria. In this manner, rational analyses supported by tests can be established to characterise residual strength for point design details.

7. PROOF OF STRUCTURE – STATIC.

The structural static strength substantiation of a composite design should consider all critical load cases and associated failure modes. It should also include effects of environment (including residual stresses induced during the fabrication process), material and process variability, non-detectable defects or any defects that are allowed by the quality control, manufacturing acceptance criteria, and service damage allowed in maintenance documents of the end product. The static strength of the composite design should be demonstrated through a programme of component ultimate load tests in the appropriate environment, unless experience with similar designs, material systems, and loadings is available to demonstrate the adequacy of the analysis supported by sub-component, element and coupon tests, or component tests to accepted lower load levels. The necessary experience to validate an analysis should include previous component ultimate load tests with similar designs, material systems, and load cases.

a. The effects of repeated loading and environmental exposure which may result in material property degradation should be addressed in the static strength evaluation. This can be shown by analysis supported by test evidence, by tests at the coupon, element or sub-component level, as appropriate, or alternatively by relevant existing data. Earlier discussions in this AMC address the effects of environment on material properties (paragraph 6.d) and protection of structure (paragraph 6.e). For critical loading conditions, three approaches exist to account for prior repeated loading and/or environmental exposure in the full scale static test.

(1) In the first approach, the full scale static test should be conducted on structure with prior repeated loading and conditioned to simulate the critical environmental exposure and then tested in that environment.

(2) The second approach relies upon coupon, element, and sub-component test data to determine the effect of repeated loading and environmental exposure on static strength. The degradation characterised by these tests should then be accounted for in the full scale static strength demonstration test (e.g., overload factors), or in analysis of these results (e.g., showing a positive margin of safety with design values that include the degrading effects of environment and repeated load).

(3) In practice, aspects of the first two approaches may be combined to obtain the desired result (e.g., a full scale static test may be performed at critical operating temperature with a load factor to account for moisture absorbed over the aircraft structure's life). Alternate means to account for environment using validated tests and analyses (e.g., an equivalent temperature enhancement to account for the effect of moisture without chemically altering the material), may be proposed by the applicant.

b. The strength of the composite structure should be reliably established, incrementally, through a programme of analysis and a series of tests conducted using specimens of varying levels of complexity. Often referred to in industry as the "building block" approach, these tests and analyses at the coupon, element, details, and sub-component levels can be used to address the issues of variability, environment, structural discontinuity (e.g., joints, cut-outs or other stress risers), damage, manufacturing defects, and design or process-specific details. Typically, testing progresses from simple specimens to more complex elements and details over time. This approach allows the data collected for sufficient analysis correlation and the necessary replicates to quantify variations occurring at the larger structural scales to be economically obtained. The lessons learned from initial tests also help avoid early failures in more complex full scale tests, which are more costly to conduct and often occur later in a certification programme schedule.

(1) Figures 1 and 2 provide a conceptual schematic of tests typically included in the building block approach for a fixed wing and tail rotor blade structures, respectively. The large quantity of tests needed to provide a statistical basis comes from the lowest levels (coupons and elements) and the performance of structural details are validated in a lesser number of sub-component and component tests. Detail and subcomponent tests may be used to validate the ability of analysis methods to predict local strains and failure modes. Additional statistical considerations (e.g., repetitive point design testing and/or component overload factors to cover material and process variability) will be needed when analysis validation is not achieved. The static strength substantiation programme should also consider all critical loading conditions for all Critical Structure. This includes an assessment of residual strength and stiffness requirements after a predetermined length of service, which takes into account damage and other degradation due to the service period.

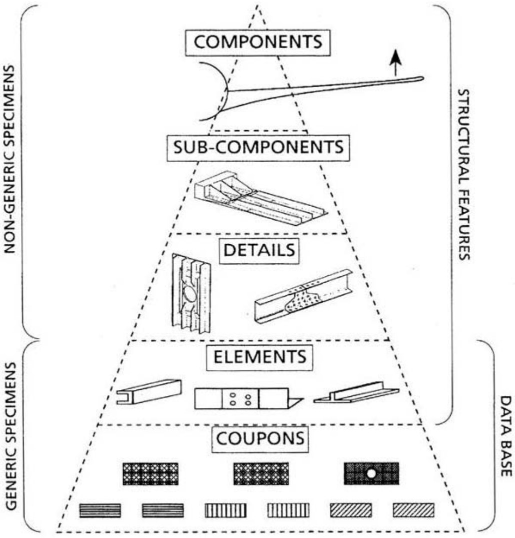

Figure 1 - Schematic diagram of building block tests for a fixed wing.

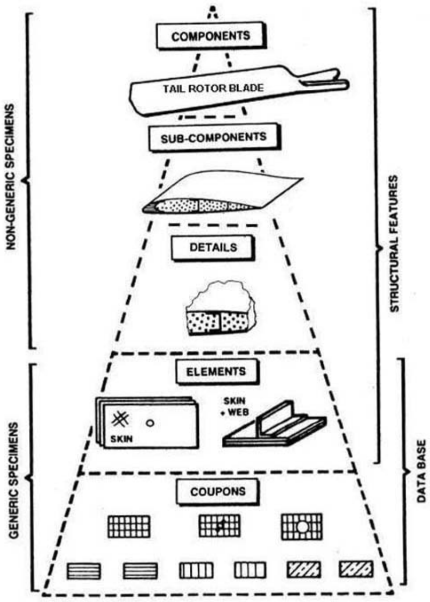

Figure 2 - Schematic diagram of building block tests for a tail rotor blade.

(2) Successful static strength substantiation of composite structures has traditionally depended on proper consideration of stress concentrations (e.g., notch sensitivity of details and impact damage), competing failure modes and out-of-plane loads. A complete building block approach to composite structural substantiation addresses most critical structural issues in test articles with increasing levels of complexity such that many areas of reliable performance can be demonstrated prior to the component tests. The details and sub-component testing should establish failure criteria and account for impact damage in assembled composite structures. Component tests are needed to provide the final validation accounting for combined loads and complex load paths, which include some out-of-plane effects. When using the building block approach, the critical load cases and associated failure modes would be identified for component tests using the analytical methods, which are supported by test validation.

c. The component static test may be performed in an ambient atmosphere if the effects of the environment are reliably predicted by building block tests and are accounted for in the static test or in the analysis of the results of the static test.

d. The static test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structure including defects consistent with the limits established by manufacturing acceptance criteria.

e. The material and processing variability of the composite structure should be considered in the static strength substantiation. This is primarily achieved by establishing sufficient process and quality controls to manufacture structure and reliably substantiate the required strength by test and analysis. The scatter in strength properties due to variability in materials and processes are characterised by proper allowables or design values, which are derived in compliance with CS 2x.613. When the detail, sub-component and component tests show that local strains are adequately predicted and positive margins of safety exist using a validated analysis everywhere on the structure, then proof of static strength is said to be substantiated using analysis supported by test evidence. Alternatively, in the absence of sufficient building block test data and analysis validation, overloads are needed in the component test to gain proof of static strength for the structure using an approach referred to as substantiated by tests. The overload factors applied in this case need to be substantiated either through tests or past experience and must account for the expected material and process variation.

f. It should be shown that impact damage that can be expected from manufacturing and service, but not more than the established threshold of detectability for the selected inspection procedure, will not reduce the structural strength below ultimate load capability. This can be shown by analysis supported by test evidence, or by a combination of tests at the coupon, element, sub-component and component levels. The realistic test assessment of impact damage requires proper consideration of the structural details and boundary conditions. When using a visual inspection procedure, the likely impact damage at the threshold of reliable detection has been called barely visible impact damage (BVID). Selection of impact sites for static strength substantiation should consider the criticality of the local structural detail, and the ability to inspect a location. The size and shape of impactors used for static strength substantiation should be consistent with likely impact damage scenarios that may go undetected for the life of an aircraft. Note that it is possible for some designs to have detectable impact damage and still meet static strength loads and other requirements without repair (refer to allowable damage discussions in paragraph 10.c.(1)).

g. Major material and process changes on existing certified structure require additional static strength substantiation (e.g., refer to Appendix 3).

8. PROOF OF STRUCTURE – FATIGUE AND DAMAGE TOLERANCE.

The evaluation of composite structure should be based on the applicable certification specifications identified in the type-certification basis. Such evaluation must show that catastrophic failure due to fatigue, environmental effects, manufacturing defects, or accidental damage will be avoided throughout the operational life of the aircraft. The nature and extent of analysis or tests on complete structures and/or portions of the primary structure will depend upon applicable previous fatigue/damage tolerant designs, construction, tests, and service experience on similar structures. In the absence of experience with similar designs, Agency-approved structural development tests of components, sub-components, and elements should be performed (following the same principles discussed in paragraph 7.b and Appendix 3). The following considerations are unique to the use of composite material systems and provide guidance for the method of substantiation selected by the applicant. When establishing details for the damage tolerance and fatigue evaluation, attention should be given to a thorough damage threat assessment, geometry, inspectability, good design practice, and the types of damage/degradation of the structure under consideration.

- Composite damage tolerance and fatigue performance is strongly dependent on structural design details (e.g., skin laminate stacking sequence, stringer or frame spacing, stiffening element attachment details, damage arrestment features, and structural redundancy).
- Composite damage tolerance and fatigue evaluations require substantiation in component tests unless experience with similar designs, material systems, and loadings is available to demonstrate the adequacy of the analysis supported by coupons, elements, and sub-component tests.
- Final static strength, fatigue, and damage tolerance substantiation may be gained in testing a single component test article if sufficient building block test evidence exists to ensure that the selected sequence of repeated and static loading yield results representative of that possible in service or provide a conservative evaluation.
- Peak repeated loads are needed to practically demonstrate the fatigue and damage tolerance of composite aircraft structure in a limited number of component tests. As a result, metal structures present in the test article generally require additional consideration and testing. The information contained in AMC 25.571 provides fatigue and damage tolerance guidance for metallic structures.

a. Damage Tolerance Evaluation.

(1) Damage tolerance evaluation starts with identification of structure whose failure would reduce the structural integrity of the aircraft. A damage threat assessment must be performed for the structure to determine possible locations, types, and sizes of damage considering fatigue, environmental effects, intrinsic flaws, and foreign object impact or other accidental damage (including discrete source) that may occur during manufacture, operation or maintenance.

(a) There currently are very few industry standards that outline the critical damage threats for particular composite structural applications with enough detail to establish the necessary design criteria or test and analysis protocol for complete damage tolerance evaluation. In the absence of standards, it is the responsibility of individual applicants to perform the necessary development tasks to establish such data in support of product substantiation. Some factors to consider in development of a damage threat assessment for a particular composite structure include part function, location on the aircraft, past service data, accidental damage threats, environmental exposure, impact damage resistance, durability of assembled structural details (e.g., long-term durability of bolted and bonded joints), adjacent system interface (e.g., potential overheating or other threats associated with system failure), and anomalous service or maintenance handling events that can overload or damage the part. As related to the damage threat assessment and maintenance procedures for a given structure, the damage tolerance capability and ability to inspect for known damage threats should be developed.

(b) Foreign object impact is a concern for most composite structures, requiring attention in the damage threat assessment. This is needed to identify impact damage severity and detectability for design and maintenance. It should include any available damage data collected from service plus an impact survey. An impact survey consists of impact tests performed with representative structure, which is subjected to boundary conditions characteristic of the real structure. Many different impact scenarios and locations should be considered in the survey, which has a goal of identifying the most critical impacts possible (i.e., those causing the most serious damage but are least detectable). When simulating accidental impact damage at representative energy levels, blunt or sharp impactors of different sizes and shapes should be selected to cause the most critical and least detectable damage, according to the load conditions (e.g., tension, compression or shear). Until sufficient service experience exists to make good engineering judgments on energy and impactor variables, impact surveys should consider a wide range of conceivable impacts, including runway or ground debris, hail, tool drops, and vehicle collisions. This consideration is important to the assumptions needed for use of probabilistic damage threat assessments in defining design criteria, inspection methods, and repeat inspection intervals for maintenance. Service data collected over time can better define impact surveys and design criteria for subsequent products, as well as establish more rational inspection intervals and maintenance practice. In review of such information, it should be realized that the most severe and critical impact damages, which are still possible, may not be part of the service database.

(c) Once a damage threat assessment is completed, various damage types can be classified into five categories of damage as described below (refer to figure 3). These categories of damage are used for communication purposes in this AMC. Other categories of damage, which help outline a specific path to fatigue and damage tolerance substantiation, may be used by applicants in agreement with the regulatory authorities.

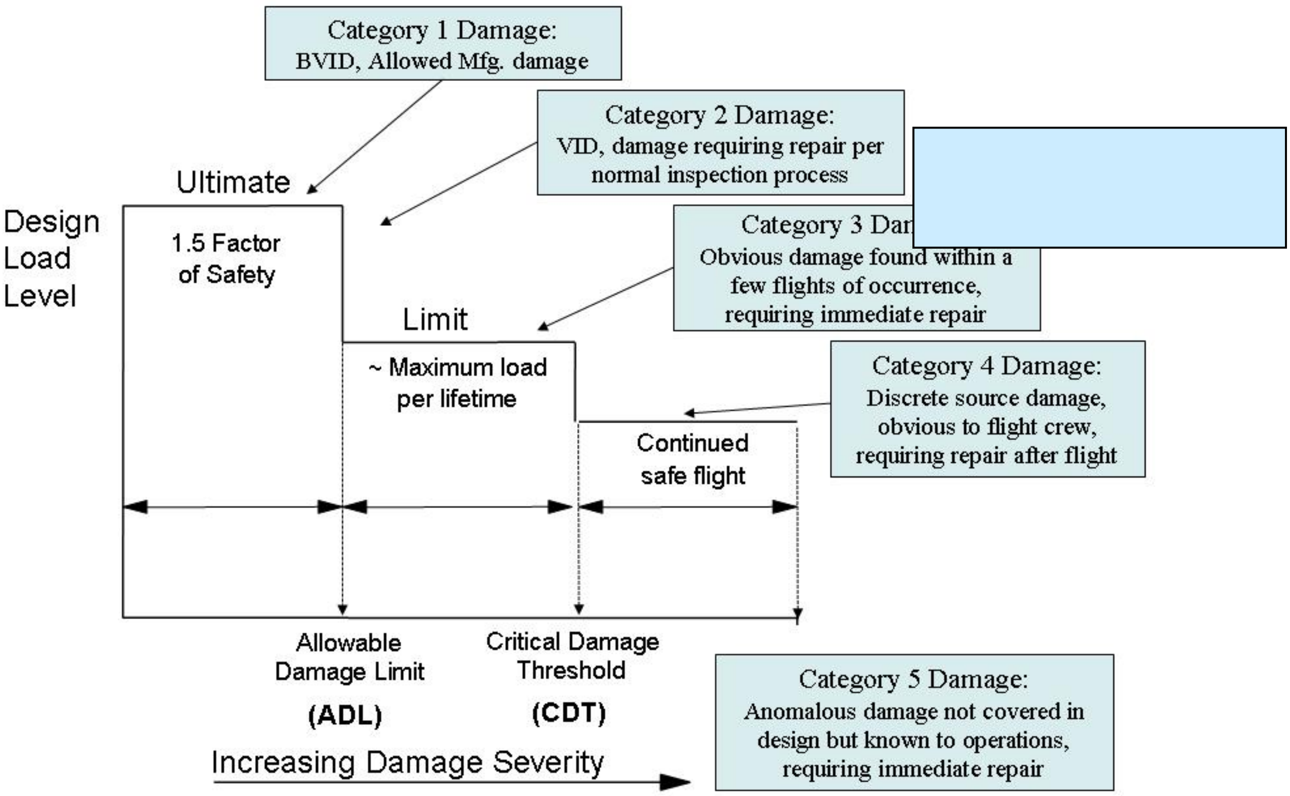

Figure 3 - Schematic diagram showing design load levels versus categories of damage severity.

Category 1: Allowable damage that may go undetected by scheduled or directed field inspection and allowable manufacturing defects. Structural substantiation for Category 1 damage includes demonstration of a reliable service life, while retaining ultimate load capability. By definition, such damage is subjected to the requirements and guidance associated with paragraph 7 of this AMC. Some examples of Category 1 damage include BVID and allowable defects caused in manufacturing or service (e.g., small delamination, porosity, small scratches, gouges, and minor environmental damage) that have substantiation data showing ultimate load is retained for the life of an aircraft structure.

Category 2: Damage that can be reliably detected by scheduled or directed field inspections performed at specified intervals. Structural substantiation for Category 2 damage includes demonstration of a reliable inspection method and interval while retaining loads above limit load capability. The residual strength for a given Category 2 damage may depend on the chosen inspection interval and method of inspection. Some examples of Category 2 damage include visible impact damage (VID), VID (ranging in size from small to large), deep gouges or scratches, manufacturing mistakes not evident in the factory, detectable delamination or debonding, and major local heat or environmental degradation that will sustain sufficient residual strength until found. This type of damage should not grow or, if slow or arrested growth occurs, the level of residual strength retained for the inspection interval is sufficiently above limit load capability.

Category 3: Damage that can be reliably detected within a few flights of occurrence by operations or ramp maintenance personnel without special skills in composite inspection. Such damage must be in a location such that it is obvious by clearly visible evidence or cause other indications of potential damage that becomes obvious in a short time interval because of loss of the part form, fit or function. Both indications of significant damage warrant an expanded inspection to identify the full extent of damage to the part and surrounding structural areas. In practice, structural design features may be needed to provide sufficient large damage capability to ensure limit or near limit load is maintained with easily detectable, Category 3 damage. Structural substantiation for Category 3 damage includes demonstration of a reliable and quick detection, while retaining limit or near limit load capability. The primary difference between Category 2 and 3 damages are the demonstration of large damage capability at limit or near limit load for the latter after a regular interval of time, which is much shorter than the former. The residual strength demonstration for Category 3 damage may be dependent on the reliable short time detection interval. Some examples of Category 3 damage include large VID or other obvious damage that will be caught during walk-around inspection or during the normal course of operations (e.g., fuel leaks, system malfunctions or cabin noise).

Category 4: Discrete source damage from a known incident such that flight manoeuvres are limited. Structural substantiation for Category 4 damage includes a demonstration of residual strength for loads specified in the regulations. It should be noted that pressurized structure will generally have Category 4 residual strength requirements at a level higher than shown in figure 3. Some examples of Category 4 damage include rotor burst, bird strikes (as specified in the regulations), tyre bursts, and severe in-flight hail.

Category 5: Severe damage created by anomalous ground or flight events, which is not covered by design criteria or structural substantiation procedures. This damage is in the current guidance to ensure the engineers responsible for composite aircraft structure design and the Agency work with maintenance organisations in making operations personnel aware of possible damage from Category 5 events and the essential need for immediate reporting to responsible maintenance personnel. It is also the responsibility of structural engineers to design-in sufficient damage resistance such that Category 5 events are self-evident to the operations personnel involved. An interface is needed with engineering to properly define a suitable conditional inspection based on available information from the anomalous event. Such action will facilitate the damage characterization needed prior to repair. Some examples of Category 5 damage include severe service vehicle collisions with aircraft, anomalous flight overload conditions, abnormally hard landings, maintenance jacking errors, and loss of aircraft parts in flight, including possible subsequent high-energy, wide-area (blunt) impact with adjacent structure. Some Category 5 damage scenarios will not have clearly visual indications of damage, particularly in composite structures. However, there should be knowledge of other evidence from the related events that ensure safety is protected, starting with a complete report of possible damage by operations.

(d) The five categories of damage will be used as examples in subsequent discussion in this paragraph and in paragraphs 9 and 10. Note that Category 2, 3, 4 and 5 damages all have associated repair scenarios.

(2) Structure details, elements, and sub-components of Critical Structure should be tested under repeated loads to define the sensitivity of the structure to damage growth. This testing can form the basis for validating a no-growth approach to the damage tolerance requirements. The testing should assess the effect of the environment on the flaw and damage growth characteristics and the no-growth validation. The environment used should be appropriate to the expected service usage. Residual stresses will develop at the interfaces between composite and metal structural elements in a design due to differences in thermal expansion. This component of stress will depend on the service temperature during repeated load cycling and is considered in the damage tolerance evaluation. Inspection intervals should be established, considering both the likelihood of a particular damage and the residual strength capability associated with this damage. The intent of this is to assure that structure is not exposed to an excessive period of time with residual strength less than ultimate, providing a lower safety level than in the typical slow growth situation, as illustrated in Figure 4. Conservative assumptions for capability with large damage sizes that would be detected within a few flights may be needed when probabilistic data on the likelihood of given damage sizes does not exist. Once the damage is detected, the component is either repaired to restore ultimate load capability or replaced.

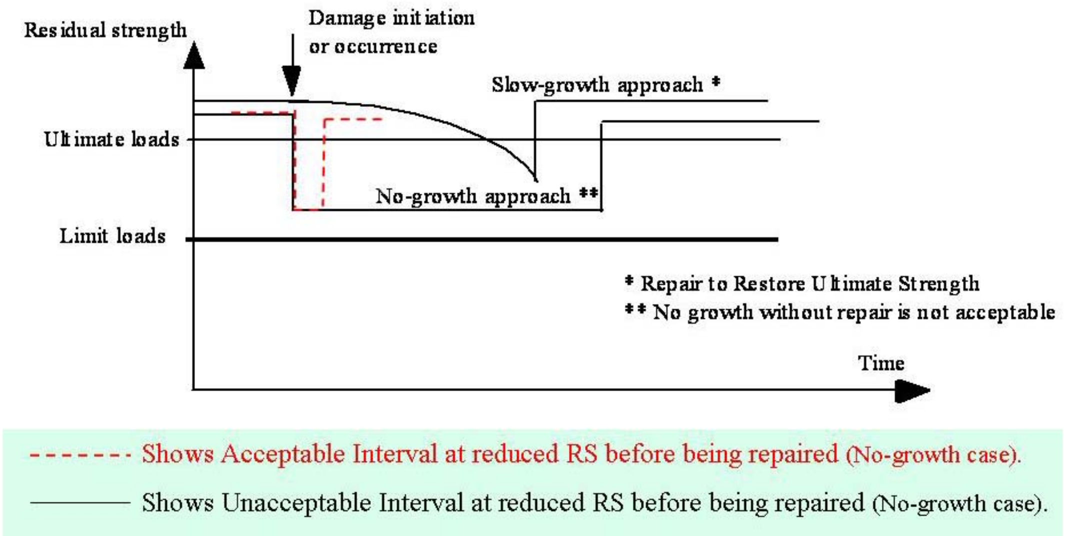

Figure 4 - Schematic diagram of residual strength illustrating that significant accidental damage with "no-growth" should not be left in the structure without repair for a long time.

(a) The traditional slow growth approach may be appropriate for certain damage types found in composites if the growth rate can be shown to be slow, stable and predictable. Slow growth characterization should yield conservative and reliable results. As part of the slow growth approach, an inspection programme should be developed consisting of the frequency, extent, and methods of inspection for inclusion in the maintenance plan. Inspection intervals should be established such that the damage will have a very high probability of detection between the time it becomes initially detectable and the time at which the extent of the damage reduces the residual static strength to limit load (considered as ultimate), including the effects of environment. For any detected damage size that reduces the load capability below ultimate, the component is either repaired to restore ultimate load capability or replaced. Should functional impairment (such as unacceptable loss of stiffness) occur before the damage becomes otherwise critical, part repair or replacement will also be necessary.

(b) Another approach involving growth may be appropriate for certain damage types and design features adopted for composites if the growth can reliably be shown to be predictable and arrested before it becomes critical. Figure 5 shows schematic diagrams for all three damage growth approaches applied to composite structure. The arrested growth method is applicable when the damage growth is mechanically arrested or terminated before becoming critical (residual static strength reduced to limit load), as illustrated in Figure 5. Arrested growth may occur due to design features such as a geometry change, reinforcement, thickness change, or a structural joint. This approach is appropriate for damage growth that is detectable and found to be reliably arrested, including all appropriate dynamic effects. Structural details, elements, and sub-components of Critical Structure, components or full-scale structures, should be tested under repeated loads for validating an Arrested Growth Approach. As was the case for a "no-growth" approach to damage tolerance, inspection intervals should be established, considering the residual strength capability associated with the arrested growth damage size (refer to the dashed lines added to Figure 5 to conceptually show inspection intervals consistent with the slow growth basis). Again, this is intended to ensure that the structure does not remain in a damaged condition with residual strength capability close to limit load for long periods of time before repair. For any damage size that reduces load capability below ultimate, the component is either repaired to restore ultimate load capability or replaced.

(c) The repeated loading should be representative of anticipated service usage. The repeated load testing should include damage levels (including impact damage) typical of those that may occur during fabrication, assembly, and in-service, consistent with the inspection techniques employed. The damage tolerance test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structure.

(3) The extent of initially detectable damage should be established and be consistent with the inspection techniques employed during manufacture and in service. This information will naturally establish the transition between Category 1 and 2 damage types (i.e., inspection methods used by trained inspectors in scheduled maintenance). For damage that is clearly detectable to an extent that it will likely be found before scheduled maintenance (i.e., allowing classification as Category 3 damage), detection over shorter intervals and by untrained personnel may be permitted. Flaw/damage growth data should be obtained by repeated load cycling of intrinsic flaws or mechanically introduced damage. The number of cycles applied to validate both growth and no-growth concepts should be statistically significant, and may be determined by load and/or life considerations and a function of damage size. The growth or no growth evaluation should be performed by analysis supported by test evidence or by tests at the coupon, element, or sub-component level.

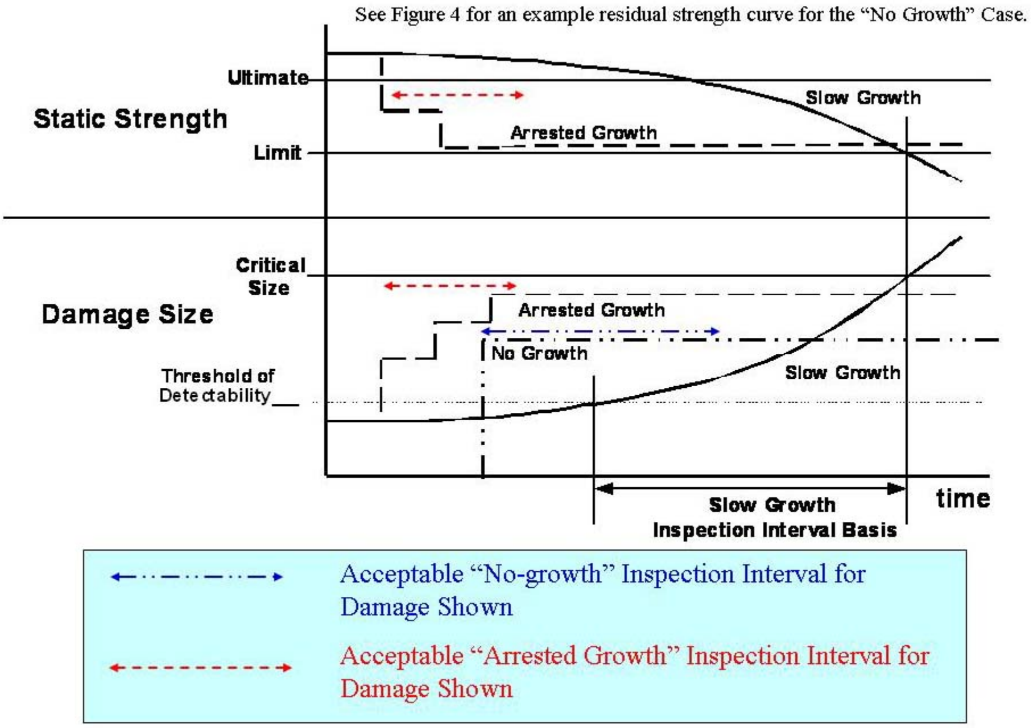

Figure 5 - Illustrations of residual strength and damage size relationships for three different approaches to composite structural damage tolerance substantiation.

(4) The extent of damage for residual strength assessments should be established, including considerations for the probability of detection using selected field inspection procedures. The first four categories of damage should be considered based on the damage threat assessment. In addition, Category 3 damage should be detected in a walk-around inspection or through the normal course of operations. Residual strength evaluation by component or sub-component testing or by analysis supported by test evidence should be performed considering that damage. The evaluation should demonstrate that the residual strength of the structure will reliably be equal to or greater than the strength required for the specified design loads (considered as ultimate), including environmental effects. The statistical significance of reliable sub-component and detail residual strength assessments may include conservative methods and engineering judgment. It should be shown that stiffness properties have not changed beyond acceptable levels.

(a) For the no-growth, slow growth, arrested growth approaches, residual strength testing should be performed after repeated load cycling. All probabilistic analyses applied for residual strength assessments should properly account for the complex nature of damage defined from a thorough damage threat assessment. Conservative damage metrics are permitted in such analyses assuming sufficient test data on repeated load and environmental exposure exists.

(b) Composite designs should afford the same level of fail-safe, multiple load path structure assurance as conventional metals design. Such is also the expectation in justifying the use of static strength allowables with a statistical basis of 90 percent probability with 95 percent confidence.

(c) Some special residual strength considerations for bonded structure are given in paragraph 6.c.(3).

(5) The repeated load spectrum developed for fatigue testing and analysis purposes should be representative of the anticipated service usage. Low amplitude load levels that can be shown not to contribute to damage growth may be omitted. Reducing maximum load levels is generally not accepted. Variability in repeated load behaviour should be covered by appropriate load enhancement or life scatter factors and these factors should take into account the number of specimens tested. The use of such factors to demonstrate reliability in component tests should be consistent with the fatigue and damage tolerance behaviour characterised for the materials, processes and other design details of the structure in building block tests.

(6) An inspection programme should be developed consisting of frequency, extent, and methods of inspection for inclusion in the maintenance plan. Inspection intervals should be established such that the damage will be reliably detected between the time it initially becomes detectable and the time at which the extent of damage reaches the limits for required residual strength capability. The potential for missed inspections should be considered.

(a) For the case of no-growth design concept, inspection intervals should be established as part of the maintenance programme. In selecting such intervals, the residual strength level associated with the assumed damages should be considered. This point was illustrated in Figures 4 and 5. Note that an acceptable inspection interval for the larger damages shown for the “no-growth” and “arrested growth” options in Figures 4 and 5 was conceptually shown as related to an acceptable slow growth basis in terms of the residual strength and time below ultimate load before damage was detected and repaired. Data on the probability of occurrence for different damage sizes also helps define an inspection interval.

(b) A thorough composite damage threat assessment and the separation of different damage sizes into categories, each with associated detection methods, supports programmes using a rigorous damage tolerance assessment to avoid conservative design criteria with very large damage assumptions. In such cases, Category 2 damage types will require the structural substantiation of well specified and reliable inspection methods applied by trained inspectors at scheduled maintenance intervals (by default, Category 1 damage is at the threshold of this evaluation). Those damages classified as Category 3 may take advantage of shorter service time intervals provided sufficient structural substantiation exists with demonstrated proof that there will be early detection by untrained ramp maintenance or operations personnel. By definition, Category 4 damage will require residual strength substantiation to levels that complete a flight with limited manoeuvres based on the associated regulatory loads. Due to the nature of service events leading to Category 4 damage, suitable inspections will need to be defined to evaluate the full extent of damage, prior to subsequent aircraft repair and return to service. By definition, Category 5 damages do not have associated damage tolerance design criteria or related structural substantiation tasks. Category 5 damage will require suitable inspections based on engineering assessment of the anomalous service event, and appropriate structural repair and/or part replacement, prior to the aircraft re-entering service.

(7) The structure should be able to withstand static loads (considered as ultimate loads) which are reasonably expected during a completion of the flight on which damage resulting from obvious discrete sources occur (i.e., uncontained engine failures, etc.). The extent of damage should be based on a rational assessment of service mission and potential damage relating to each discrete source. Structural substantiation will be needed for the most critical Category 4 damage as related to the associated load cases. Some Category 4 damage may have high margins but will likely still require suitable inspections because their detectability may not be consistent with the substantiations validated for Category 2 damage types.

(8) The effects of temperature, humidity, and other environmental or time-related aging factors which may result in material property degradation should be addressed in the damage tolerance evaluation. Unless tested in the environment, appropriate environmental factors should be derived and applied in the evaluation.

b. Fatigue Evaluation. Fatigue substantiation should be accomplished by component fatigue tests or by analysis supported by test evidence, accounting for the effects of the appropriate environment. The test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structures. Sufficient component, sub-component, element or coupon tests should be performed to establish the fatigue scatter and the environmental effects. Component, sub-component, and/or element tests may be used to evaluate the fatigue response of structure with impact damage levels typical of those that may occur during fabrication, assembly, and in service, consistent with the inspection procedures employed. Other allowed manufacturing and service defects, which would exist for the life of the structure, should also be included in fatigue testing. It should be demonstrated during the fatigue tests that the stiffness properties have not changed beyond acceptable levels. Replacement lives should be established based on the test results. By definition, Category 1 damage is subjected to fatigue evaluation and expected to retain ultimate load capability for the life of the aircraft structure.

c. Combined Damage Tolerance and Fatigue Evaluation. Generally, it is appropriate for a given structure to establish both an inspection programme and demonstrate a service life to cover all detectable and non-detectable damage, respectively, which is anticipated for the intended aircraft usage. Extensions in service life should include evidence from component repeated load testing, fleet leader programmes (including NDI and destructive tear-down inspections), and appropriate statistical assessments of accidental damage and environmental service data considerations.

9. PROOF OF STRUCTURE – FLUTTER AND OTHER AEROELASTIC INSTABILITIES.

The aeroelastic evaluations including flutter, control reversal, divergence, and any undue loss of stability and control as a result of structural loading and resulting deformation, are required. Flutter and other aeroelastic instabilities must be avoided through design, quality control, maintenance, and systems interaction.

a. The evaluation of composite structure needs to account for the effects of repeated loading, environmental exposure, and service damage scenarios (e.g., large Category 2, 3 or 4 damage) on critical properties such as stiffness, mass and damping. Some control surfaces exposed to large damage retain adequate residual strength margins, but the potential loss of stiffness or mass increase (e.g., sandwich panel disbond and/or water ingression) may adversely affect flutter and other aeroelastic characteristics. This is particularly important for control surfaces that are prone to accidental damage and environmental degradation. Other factors such as the weight or stiffness changes due to repair, manufacturing flaws, and multiple layers of paint need to be evaluated. There may also be issues associated with the proximity of high temperature heat sources near structural components (e.g., empennage structure in the path of jet engine exhaust streams or engine bleed air pneumatics system ducting). These effects may be determined by analysis supported by test evidence, or by tests at the coupon, element or sub-component level.

10. CONTINUED AIRWORTHINESS.

The maintenance and repair of composite aircraft structure should meet all general, design and fabrication, static strength, fatigue/damage tolerance, flutter, and other considerations covered by this AMC as appropriate for the particular type of structure and its application.

a. Design for Maintenance. Composite aircraft structure should be designed for inspection and repair access in a field maintenance environment. The inspection and repair methods applied for structural details should recognize the special documentation and training needed for critical damage types that are difficult to detect, characterise and repair. The inspection intervals and life limits for any structural details and levels of damage that preclude repair must be clearly documented in the appropriate continued airworthiness documents.

b. Maintenance Practices. Maintenance manuals, developed by the appropriate organisations, should include appropriate inspection, maintenance, and repair procedures for composite structures, including jacking, disassembly, handling, part drying methods, and repainting instructions (including restrictions for paint colours that increase structural temperatures). Special equipment, repair materials, ancillary materials, tooling, processing procedures, and other information needed for inspection or repair of a given part should be identified since standard field practices, which have been substantiated for different aircraft types and models, are not common.

(1) Damage Detection.

(a) Procedures used for damage detection must be shown to be reliable and capable of detecting degradation in structural integrity below ultimate load capability. These procedures must be documented in the appropriate sections of the instructions for continued airworthiness. This should be substantiated in static strength, environmental resistance, fatigue, and damage tolerance efforts as outlined in paragraphs 6, 7 and 8. Substantiated detection procedures will be needed for all damage types identified by the threat assessment, including a wide range of foreign object impact threats, manufacturing defects, and degradation caused by overheating. Degradation in surface layers (e.g., paints and coatings) that provide structural protection against ultraviolet exposure must be detected. Any degradation to the lightning strike protection system that affects structural integrity, fuel tank safety, and electrical systems must also be detected.

(b) Visual inspection is the predominant damage detection method used in the field and should be performed under prescribed lighting conditions. Visual inspection procedures should account for access, time relaxation in impact damage dent depth, and the colour, finish and cleanliness of part surfaces.

(2) Inspection. Visual indications of damage, which are often used for composite damage detection, provide limited details on the hidden parts of damage that require further investigation. As a result, additional inspection procedures used for complete composite damage characterization will generally be different than those used for initial damage detection and need to be well documented. Non-destructive inspection performed prior to repair and destructive processing steps performed during repair must be shown to locate and determine the full extent of the damage. In-process controls of repair quality and post-repair inspection methods must be shown to be reliable and capable of providing engineers with the data to determine degradation in structural integrity below ultimate load capability caused by the process itself. Certain processing defects cannot be reliably detected at completion of the repair (e.g., weak bonds). In such cases, the damage threat assessment, repair design features and limits should ensure sufficient damage tolerance.

(3) Repair. All bolted and bonded repair design and processing procedures applied for a given structure shall be substantiated to meet the appropriate requirements. Of particular safety concern are the issues associated with bond material compatibilities, bond surface preparation (including drying, cleaning, and chemical activation), cure thermal management, composite machining, special composite fasteners, and installation techniques, and the associated in-process control procedures. The surface layers (e.g., paints and coatings) that provide structural protection against ultraviolet exposure, structural temperatures, and the lightning strike protection system must also be properly repaired.

(4) Documentation and Reporting. Documentation on all repairs must be added to the maintenance records for the specific part number. This information supports future maintenance damage disposition and repair activities performed on the same part. It is recommended that service difficulties, damage, and degradation occurring to composite parts in service should be reported back to the design approval holder to aid in continuous updates of damage threat assessments to support future design detail and process improvements. Such information will also support future design criteria, analysis, and test database development.

c. Substantiation of Repair.

(1) When repair procedures are provided in Agency approved documents or the maintenance manual, it should be demonstrated by analysis and/or test that the method and techniques of repair will restore the structure to an airworthy condition. Repairable damage limits (RDL), which outline the details for damage to structural components that may be repaired based on existing data, must be clearly defined and documented. Allowable damage limits (ADL), which do not require repair, must also be clearly defined and documented. Both RDL and ADL must be based on sufficient analysis and test data to meet the appropriate structural substantiation requirements and other considerations outlined in this AMC. Additional substantiation data will generally be needed for damage types and sizes not previously considered in design development. Some damage types may require special instructions for field repair and the associated quality control. Bonded repair is subjected to the same structural bonding considerations as the base design (refer to paragraph 6.c).

(2) Operators and maintenance repair organisations (MRO) wishing to complete major repairs or alterations outside the scope of approved repair documentation should be aware of the extensive analysis, design, process, and test substantiation required to ensure the airworthiness of a certificated structure. Documented records and the certification approval of this substantiation should be retained in accordance with regulations to support any subsequent maintenance activities.

d. Damage Detection, Inspection and Repair Competency.

(1) All technicians, inspectors and engineers involved in damage disposition and repair should have the necessary skills to perform their supporting maintenance tasks on a specific composite structural part. The continuous demonstration of acquired skills goes beyond initial training (e.g., similar to a welder qualification). The repair design, inspection methods, and repair procedures used will require approved structural substantiation data for the particular composite part. Society of Automotive Engineers International (SAE) Aerospace Information Report (AIR) 5719 outlines training for an awareness of the safety issues for composite maintenance and repair. Additional training for specific skill-building will be needed to execute particular engineering, inspection and repair tasks.

(2) Pilots, ramp maintenance, and other operations personnel that service aircraft should be trained to immediately report anomalous ramp incidents and flight events that may potentially cause serious damage to composite aircraft structures. In particular, immediate reporting is needed for those service events that are outside the scope of the damage tolerance substantiation and standard maintenance practices for a given structure. The immediate detection of Category 4 and 5 damages are dependent on the proper reaction of personnel that operate and service the aircraft.

11. ADDITIONAL CONSIDERATIONS.

a. Crashworthiness

(1) The crashworthiness of the aircraft is dominated by the impact response characteristics of the fuselage. Regulations, in general, evolve based on either experience gained through incidents and accidents of existing aircraft or in anticipation of safety issues raised by new designs. In the case of crashworthiness, regulations have evolved as experience has been gained during actual aircraft operations. For example, emergency load factors and passenger seat loads have been established to reflect dynamic conditions observed from fleet experience and from controlled FAA and industry research. Fleet experience has not demonstrated a need to have an aircraft level crashworthiness standard. As a result, the regulations reflect the capabilities of traditional aluminium aircraft structure under survivable crash conditions. This approach was satisfactory as aircraft have continued to be designed using traditional construction methods. With the advent of composite fuselage structure and/or the use of novel design, this historical approach may no longer be sufficient to substantiate the same level of protection for the passengers as provided by similar metallic designs.

(2) Airframe design should assure that occupants have every reasonable chance of escaping serious injury under realistic and survivable crash impact conditions. A composite design should account for unique behaviour and structural characteristics, including major repairs or alterations, as compared with conventional metal airframe designs. Structural evaluation may be done by test or analysis supported by test evidence. Service experience may also support substantiation.

(3) The crash dynamics of an aircraft and the associated energy absorption are difficult to model and fully define representative tests with respect to structural requirements. Each aircraft product type (i.e., large aeroplane, small aeroplane, and rotorcraft) has unique regulations governing the crashworthiness of particular aircraft structures. The regulations and guidance associated with each product type should be used accordingly. The regulations for large aeroplane and rotorcraft address some issues that go beyond those required of small aeroplanes.

(4) Special conditions are anticipated for large aeroplanes with composite fuselage structure to address crashworthiness survivability. The impact response of a composite fuselage structure must be evaluated to ensure the survivability is not significantly different from that of a similar-sized aircraft fabricated from metallic materials. Impact loads and resultant structural deformation of the supporting airframe and floor structures must be evaluated. Four main criteria areas should be considered in making such an evaluation.

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

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

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

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

(5) The criticality of each of these four criteria will depend on the particular crash conditions. For example, the loads and accelerations experienced by passengers may be higher at lower impact velocities where structural failures have not started to occur. As a result, validated analyses may be needed to practically cover all the crashworthiness criteria for a fuselage.

(6) Existing large aeroplane requirements also require that fuel tank structural integrity be addressed during a survivable crash impact event as related to fire safety (also refer to paragraph 11.b). As related to crashworthiness, composite fuel tank structure must not fail or deform to the extent that fire becomes a greater hazard than with metal structure.

(7) Physics and mechanics of the crashworthiness for composite structures involve several issues. The local strength, energy absorbing characteristics, and multiple competing failure modes need to be addressed for composite structure subjected to a survivable crash. This is not simply achieved for airframe structures made from anisotropic, quasi-brittle, composite materials. As a result, the accelerations and load histories experienced by passengers and equipment on a composite aircraft may differ significantly from that seen on a similar metallic aircraft unless specific considerations are designed into the composite structure. In addition, care should be taken when altering composite structure to achieve specific mechanical behaviours. (For example, where the change in behaviour of a metallic structure with a change in material thickness may be easily predicted, an addition or deletion of plies to a composite laminate may also require data for the effects of laminate stacking sequence on the failure mode and energy absorption characteristics of a composite element).

(8) Representative structure must be included to gain valid test and analysis results. Depending on aircraft loading (requiring investigation of various aircraft passenger and cargo configurations), structural dynamic considerations, and progressive failures, local strain rates and loading conditions may differ throughout the structure. Sensitivity of the structural behaviour to reasonable impact orientation should also be considered for large aeroplane and rotorcraft applications. This can be addressed by analysis supported by test evidence.

(9) Considering a need for comparative assessments with metal structure and a range of crash conditions, analysis with sufficient structural test evidence is often needed for large aeroplane and rotorcraft applications. Analysis requires extensive investigation of model sensitivity to modelling parameters (e.g., mesh optimization, representation of joints, element material input stress-strain data). Test also requires investigation of test equipment sensitivity appropriate to composites (e.g., filter frequencies with respect to expected pulse characteristics in the structure). Model validation may be achieved using a building block approach, culminating in an adequately complex test (e.g., a drop test with sufficient structural details to properly evaluate the crashworthiness criteria).

b. Fire Protection, Flammability and Thermal Issues.

(1) Fire and exposure to temperatures that exceed maximum operating conditions require special considerations for composite airframe structure. (Refer to note below). Requirements for flammability and fire protection of aircraft structure attempt to minimize the hazard to occupants in the event that flammable materials, fluids, or vapours ignite. ***The regulations associated with each aircraft product type (i.e., transport, small airplane, rotorcraft) should be used accordingly.*** Compliance may be shown by tests or analysis supported by test evidence. A composite design, including repair and alterations, should not decrease the existing level of safety relative to metallic structure. In addition, maintenance procedures should be available to evaluate the structural integrity of any composite aircraft structures exposed to fire and temperatures above the maximum operating conditions substantiated during design.

Note: Aircraft cabin interiors and baggage compartments have been areas of flammability concerns in protecting passenger safety. This revision of the AMC does not address composite materials used in aircraft interiors and baggage compartments. Please consult other guidance material for acceptable means of compliance with flammability rules for interiors.

(2) Fire protection and flammability has traditionally been considered for engine mount structure, firewalls, and other powerplant structures that include composite elements. Additional issues critical to passenger safety have come with the expanded use of composites in wing and fuselage structures for large aeroplanes. Existing regulations do not address the potential for the airframe structure itself to be flammable. Wing and fuselage applications should consider the effects of composite design and construction on the resulting passenger safety in the event of in-flight fires or emergency landing conditions, which combine with subsequent egress when a fuel-fed fire is possible.

(3) The results of fire protection and flammability testing with structural composite parts indicate dependence upon overall design and process details, as well as the origin of the fire and its extent. For example, the overall effects of composite fuselage structures exposed to fire may be significantly different when the fire originates within the cabin, where it can be controlled by limiting the structure's contribution to spreading the fire, than when the fire occurs exterior to the fuselage after a crash landing, where fuel is likely to be the primary source for maintaining and spreading the fire. The threat in each case is different, and the approach to mitigation may also be different. In-flight fire safety addresses a fire originating within the aircraft due to some fault, whereas post-crash fire safety addresses a fuel fed pool fire external to the aircraft. Special conditions are anticipated for large aeroplanes with fuselage structure subjected to both in-flight and post-crash fire conditions. Large aeroplane wing structure will need to have special conditions for post-crash fire conditions.

(4) For an in-flight fire in large aeroplanes, it is critical that the fire not propagate or generate hazardous quantities of toxic by-products. In-flight fires have been catastrophic when they can grow in inaccessible areas. Composite fuselage structure could play a role different than traditional metal structure if the issue is not addressed.

(5) Metallic large aeroplane fuselage and wing structures have established a benchmark in fire protection that can be used to evaluate specific composite wing and fuselage structural details. Exterior fire protection issues associated with composite structure must include the effects of an exterior pool fire following a survivable crash landing. Fuselage structure should provide sufficient time for passenger egress, without fire penetration or the release of gasses and/or materials that are either toxic to escaping passengers or reduce visibility (smoke density) or could increase the fire severity. Furthermore, these considerations must be extended to wing and fuel tank structure, which must also be prevented from collapse and release of fuel (including consideration of the influence of fuel load upon the structural behaviour. For large aeroplanes, the standards of CS 25.856(b) provide the benchmark to establish the required level of safety.

(6) The exposure of composite structures to high temperatures needs to extend beyond the direct flammability and fire protection issues to other thermal issues. Many composite materials have glass transition temperatures, which mark the onset of reductions in strength and stiffness that are somewhat lower than the temperatures that can have a similar affect on equivalent metallic structure. The glass transition temperature of most composite materials is further reduced by moisture absorption. The reduced strength or stiffness of composites from high temperature exposures must be understood per the requirements of particular applications (e.g., engine or other system failures). After a system failure and/or known fire, it may be difficult to detect the full extent of irreversible heat damage to an exposed composite structure. As a result, composite structures exposed to high temperatures may require special inspections, tests, and analysis for proper disposition of heat damage. All appropriate damage threats and degradation mechanisms need to be identified and integrated into the damage tolerance and maintenance evaluation accordingly. Reliable inspections and test measurements of the extent of damage that exists in a part exposed to unknown levels of high temperatures should be documented. Particular attention should be given to defining the maximum damages that likely could remain undetected by the selected inspection procedures.

c. **Lightning Protection.** Lightning protection design features are needed for composite aircraft structures. Current Carbon fibre composites are approximately 1,000 times less electrically conductive than standard aluminium materials, and composite resins and adhesives are traditionally non-conductive. Glass and aramid fibre composites are non-conductive. A lightning strike to composite structures can result in structural failure or large area damage, and it can induce high lightning current and voltage on metal hydraulic tubes, fuel system tubes, and electrical wiring if proper conductive lightning protection is not provided. Aircraft lightning protection design guidance can be found in the FAA Technical Report "Aircraft Lightning Protection Handbook" (DOT/FAA/CT-89/22). The lightning protection effectiveness for composite structures should be demonstrated by tests or analysis supported by tests. Such tests are typically performed on panels, coupons, subassemblies, or coupons representative of the aircraft structure, or tests on full aircraft. The lightning test waveforms and lightning attachment zones are defined in EUROCAE ED-84 and ED-91. Any structural damage observed in standard lightning tests should be limited to Category 1, 2 or 3, depending on the level of detection. This damage is characterised and integrated into damage tolerance analyses and tests as appropriate. Small simple aeroplanes certified under CS-23 for VFR use only may be certified based on engineering assessment, according to AC 23-15A. The effects of composite structural repairs and maintenance on the lightning protection system should be evaluated. Repairs should be designed to maintain lightning protection.

(1) Lightning Protection for Structural Integrity.

(a) The composite structural design should incorporate the lightning protection when appropriate for the anticipated lightning attachment. The extent of lightning protection features depends on the lightning attachment zone designated for that area of the aircraft. Lightning protection features may include, but are not limited to, metal wires or mesh added to the outside surface of the composite structure where direct lightning attachment is expected.

(b) When lightning strikes an aircraft, very high currents flow through the airframe. Proper electrical bonding must be incorporated between structural parts. This is difficult to achieve for moveable parts (e.g., ailerons, rudders and elevators). The electrical bonding features must be sized to conduct the lightning currents or they can vaporize, sending the high currents through unintended paths such as control cables, control rods, or hydraulic tubes. Guidance for certification of lightning protection of aircraft structures can be found in EUROCAE ED-113.

(2) Lightning Protection for Fuel Systems.

(a) Special consideration must be given to the fuel system lightning protection for an aircraft with integral fuel tanks in a composite structure. Composite structure with integral fuel systems must incorporate specific lightning protection features on the external composite surfaces, on joints, on fasteners, and for structural supports for fuel system plumbing and components to eliminate structural penetration, arcing, sparks or other ignition sources. AC 20-53B provides certification guidance for aircraft fuel system lightning protection.

(b) Large aeroplane regulations for fuel system ignition prevention in CS 25.981 require lightning protection that is failure tolerant. As a result, redundant and robust lightning protection for composite structure joints and fasteners in fuel tank structure is needed to ensure proper protection in preventing ignition sources.

(3) Lightning Protection for Electrical and Electronic Systems.

(a) Lightning strike protection of composite structures is needed to avoid inducing high lightning voltages and currents on the wiring for electrical and electronic systems whose upset or damage could affect safe aircraft operation. The consequences from a lightning strike of unprotected composite structures can be catastrophic for electrical and electronic systems that perform highly critical functions, such as fly-by-wire flight controls or engine controls.

(b) Electrical shields over system wiring and robust circuit design of electrical and electronic equipment both provide some protection against system upset or damage due to lightning. Since most composite materials provide poor shielding, at best, metal foil or mesh is typically added to the composite structure to provide additional shielding for wiring and equipment. Electrical bonding between composite structure parts and panels should be provided for the shielding to be effective. EUROCAE ED-81 and ED-107 provide certification guidance for aircraft electrical and electronic system lightning protection.

Appendix 1 - Applicable CSs and Relevant Guidance

1. Applicable CSs. A list of applicable CS paragraphs is provided for subjects covered in this AMC (see notes). In most cases, these CS paragraphs apply regardless of the type of materials used in aircraft structures.

AMC Paragraphs	CS-23	CS-25	CS-27	CS-29
1. Purpose of this AMC	--------Not Applicable-----------------			
2. To Whom this AMC Applies	--------Not Applicable-----------------			
3. Cancellation	--------Not Applicable-----------------			
4. Related Regulations and Guidance	--------Not Applicable-----------------			
5. General	--------Not Applicable-----------------			
6. Material and Fabrication Development				
	603	603	603	603
	605	605	605	605
	609	609	609	609
	613	613	613	613
	619	619	619	619
7. Proof of Structure – Static	305	305	305	305
	307	307	307	307
8. Proof of Structure – Fatigue and Damage Tolerance				
	573	571	571	571
9. Proof of Structure – Flutter				
	629	629	629	629
10. Continued Airworthiness	1529	1529	1529	1529
	App. G	App. H	App. A	App. A
11. Additional Considerations				
a. Crashworthiness (including impact dynamics)				
	561	561	561	561
	562	562	562	562
	601	601	601	601
		631		631
	721	721		
	783	783	783	783
	785	785	785	785
	787	787	787	787
		789		
		801	801	801
				803
	807		807	

		809		809
		963	963	963
	965		965	965
	967	967	967	967
		981		
b. Fire Protection, Flammability and Thermal Issues				
	609	609	609	609
	853	853	853	853
	855	855	855	855
	859	859	859	859
			861	861
	863	863	863	863
	865	865		
	867			
	903	903		903
	1121	1121	1121	1121
	1181	1181		1181
	1182	1182		
	1183	1183	1183	1183
		1185	1185	1185
			1187	1187
	1189	1189	1189	1189
	1191	1191	1191	1191
	1193	1193	1193	1193
			1194	1194
	1359			
	1365			
c. Lightning Protection * see AMC 25.899 para.6				
		581*		
	609	609	609	609
			610	610
	867			
		899*		
	954	954*	954	954
		981		
	1309		1309	1309
	1316			

Notes:

(1) This list may not be all inclusive and there may be differences between certification agencies (e.g. FAA and the Agency).

(2) Special conditions may be issued in accordance with Part 21 21A.16B for novel and unusual design features (e.g., new composite materials systems).

2. Guidance.

FAA issues guidance providing supportive information of showing compliance with regulatory requirements. Guidance may include the advisory circulars (AC) and policy statements (PS). In general, an AC presents information concerning acceptable means, but not the only means, of complying with regulations. The guidance listed below is deemed supportive to the purposes of this AMC. These FAA documents can be located via website: http://www.faa.gov/regulations_policies/. In addition, EUROCAE have developed industry standards that are recognised by the Agency.

Note: Many of the FAA documents are harmonised with EASA. Applicants should confirm with the Agency if in doubt regarding the status and acceptance of any such documents by the Agency.

a. FAA Advisory Circulars/ EUROCAE guidance documents

- AC 20-53B "Protection of Airplane Fuel Systems Against Fuel Vapor Ignition Due to Lightning" [6/06]
- AC 20-135 "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria" [2/90]
- AC 21-26 "Quality Control for the Manufacture of Composite Structures" [6/89]
- AC 21-31 "Quality Control for the Manufacture of Non-Metallic Compartment Interior Components" [11/91]
- AC 23-15A "Small Airplane Certification Compliance Program" [12/03]
- AC 23-20 "Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems" [9/03]
- AC 25.571-1C "Damage Tolerance and Fatigue Evaluation of Structure" [4/98]
- AC 29 MG 8 "Substantiation of Composite Rotorcraft Structure" [4/06]
- AC 35.37-1A "Guidance Material for Fatigue Limit Tests and Composite Blade Fatigue Substantiation" [9/01]
- AC 145-6 "Repair Stations for Composite and Bonded Aircraft Structure" [11/96]
- RTCA DO-160 / EUROCAE ED-14
- EUROCAE ED-81 "Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning"
- EUROCAE ED-84 "Aircraft Lightning Environment and Related Test Waveforms"
- EUROCAE ED-91 "Aircraft Lightning Zoning"
- EUROCAE ED-107 "Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF)"
- EUROCAE ED-113 Aircraft Lightning Direct Effects Certification
- EUROCAE ED-14E Environmental Conditions and Test Procedures for Airborne Equipment

b. FAA Policy Statements

- "Static Strength Substantiation of Composite Airplane Structure" [PS-ACE100-2001-006, December 2001]
- "Final Policy for Flammability Testing per 14 CFR Part 23, Sections 23.853, 23.855 and 23.1359" [PS-ACE100-2001-002, January 2002]
- "Material Qualification and Equivalency for Polymer Matrix Composite Material Systems" [PS-ACE100-2002-006, September 2003]
- "Bonded Joints and Structures - Technical Issues and Certification Considerations" [PS-ACE100-2005-10038, September 2005]

Appendix 2 – Definitions

The following definitions are applicable to AMC 20-29 and relevant CS paragraphs only.

Allowables: Material values that are determined from test data at the laminate or lamina level on a probability basis (e.g., A or B basis values, with 99% probability and 95% confidence, or 90% probability and 95% confidence, respectively). The amount of data required to derive these values is governed by the statistical significance (or basis) needed.

Anisotropic: Not isotropic; having mechanical and/or physical properties which vary with direction relative to natural reference axes inherent in the material.

Arrested Growth Approach: A method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads with flaw growth which is either mechanically arrested or terminated before becoming critical (residual static strength reduced to limit load). This is to be associated with appropriate inspection intervals and damage detectability.

Category of Damage: One of five categories of damage based on residual strength capability, required load level, detectability, inspection interval, damage threat and whether (or not) the event creating damage is self evident. (See Section 8(a)(1)(c))

Component: A major section of the airframe structure (e.g., wing, body, fin, horizontal stabilizer) which can be tested as a complete unit to qualify the structure.

Coupon: A small test specimen (e.g., usually a flat laminate) for evaluation of basic lamina or laminate properties or properties of generic structural features (e.g., bonded or mechanically fastened joints).

Critical Structure: A load bearing structure/element whose integrity is essential in maintaining the overall flight safety of the aircraft. This definition was adopted for this AMC because there are differences in the definitions of primary structure, secondary structure, and principle structural elements (PSE) when considering the different categories of aircraft. For example, PSE are critical structures for Large Aeroplanes.

Damage: A structural anomaly caused by manufacturing (processing, fabrication, assembly or handling) or service usage.

Debond: Same as Disbond.

Degradation: The alteration of material properties (e.g., strength, modulus, coefficient of expansion) which may result from deviations in manufacturing or from repeated loading and/or environmental exposure.

Delamination: The separation of the layers of material in a laminate. This may be local or may cover a large area of the laminate. It may occur at any time in the cure or subsequent life of the laminate and may arise from a wide variety of causes.

Design Values: Material, structural elements, and structural detail properties that have been determined from test data and chosen to assure a high degree of confidence in the integrity of the completed structure. These values are most often based on allowables adjusted to account for actual structural conditions, and used in analysis to compute margins-of-safety.

Detail: A non-generic structural element of a more complex structural member (e.g., specific design configured joints, splices, stringers, stringer runouts, or major access holes).

Disbond: An area within a bonded interface between two adherends in which an adhesion failure or separation has occurred. It may occur at any time during the life of the substructure and may arise from a wide variety of causes. Also, colloquially, an area of separation between two laminae in the finished laminate (in this case the term “delamination” is normally preferred).

Discrepancy: A manufacturing anomaly allowed and detected by the planned inspection procedure. They can be created by processing, fabrication or assembly procedures.

Element: A generic part of a more complex structural member (e.g., skin, stringers, shear panels, sandwich panels, joints, or splices).

Environment: External, non-accidental conditions (excluding mechanical loading), separately or in combination, that can be expected in service and which may affect the structure (e.g., temperature, moisture, UV radiation, and fuel).

Factor(s):

- **Life (or Load) Enhancement Factor:** An additional load factor and/or test duration applied to structural repeated load tests, relative to the intended design load and life values, used to account for material variability. It is used to develop the required level of confidence in data.
- **Life Scatter Factor:** Same as Life/Load Enhancement Factor.
- **Overload Factor:** A load factor applied to a specific structure test which is used to address parameters (e.g., environment, a short test pyramid, etc.) not directly addressed in that test. This factor is usually developed from lower pyramid testing addressing such parameters.

Heterogeneous: Descriptive term for a material consisting of dissimilar constituents separately identifiable; a medium consisting of regions of unlike properties separated by internal boundaries.

Intrinsic Flaw: Defect inherent in the composite material or resulting from the production process.

Manufacturing Defect: An anomaly or flaw occurring during manufacturing that can cause varying levels of degradation in structural strength, stiffness and dimensional stability. Those manufacturing defects (or permissible manufacturing variability) allowed by the quality control, manufacturing acceptance criteria are expected to meet appropriate structural requirements for the life of the aircraft part. Other manufacturing defects that escape detection in manufacturing quality control should be included in a damage threat assessment and must meet damage tolerance requirements until detected and repaired.

No-Growth Approach: A method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads without detrimental flaw growth for the life of the structure.

Primary Structure: The structure which carries flight, ground, or pressurization loads, and whose failure would reduce the structural integrity of the aircraft.

Point Design: An element or detail of a specific design which is not considered generically applicable to other structure for the purpose of substantiation, e.g., lugs and major joints. Such a design element or detail can be qualified by test or by a combination of test and analysis.

Slow Growth Approach: A method that requires demonstration that the structure, with defined flaws present, is able to withstand appropriate repeated loads with slow, stable, and predictable flaw growth for the life of the structure, or beyond appropriate inspection intervals associated with appropriate damage detectability.

Structural Bonding: A structural joint created by the process of adhesive bonding, comprising of one or more previously-cured composite or metal parts (referred to as adherends).

Sub-component: A major three-dimensional structure which can provide completed structural representation of a section of the full structure (e.g., stub-box, section of a spar, wing panel, body panel with frames).

Weak Bond: A bond line with mechanical properties lower than expected, but without any possibility to detect that by normal NDI procedures. Such situation is mainly due to a poor chemical bonding.

Appendix 3 - Change of Composite Material and/or Process

1. It is necessary to re-certify composite structures, which during production, incorporate substitutions of, or changes to, the materials and/or processes from those originally substantiated at the time of initial certification. For example, the original material supplier may either change its product, or cease production. Manufacturers may also find it necessary to modify their production processes to improve efficiency or correct product deficiencies. In either case, care must be taken to ensure that modifications and/or changes are adequately investigated to ensure the continued adequacy of already certificated composite structure. This appendix covers such material and/or process changes, but does not address other changes to design (e.g., geometry, loading). The definition of the materials and processes used is required in the specifications by Part 21A.31. Changes to the material and process specifications are often major changes in type design and must be addressed as such under Part-21, subpart D or E as applicable.

2. The qualification and structural substantiation of new or modified materials and/or processes used to produce parts of a previously certified aircraft product requires:

- **a.** The identification of the key material and/or process parameters governing performances;
- **b.** The definition of the appropriate tests able to measure these parameters; and
- **c.** The definition of pass/fail criteria for these tests.

3. 'Qualification' procedures developed by every manufacturer include specifications covering:

- **a.** Physical and chemical properties,
- **b.** Mechanical properties (coupon level), and
- **c.** Reproducibility (by testing several batches).

4. Specifications and manufacturing quality procedures are designed to control specific materials and processes to achieve stable and repeatable structure for that combination of materials and processes. However, the interchangeability of alternate materials and processes for a structural application can not be assumed if one only considers the properties outlined in those specifications (as it could be for materials that are much less process dependent, e.g., some metallic material forms). A structure fabricated using new or modified materials and/or processes, which meet the 'qualification' tests required for the original material and process specifications, does not necessarily produce components that meet all the original engineering requirements for the previously certified structure.

5. Until improvements in identifying the complex relations between key material parameters that govern composite processing occurs, there will be a need for extensive and diverse testing that directly interrogates material performance using a range of representative specimens of increasing complexity in building block tests. Furthermore, failure modes may vary from one material and/or process to another, and analytical models are sometimes insufficiently precise to reliably predict failure without sufficient empirical data. Therefore, a step-by-step test verification with more complex specimens may be required.

6. Classification of Material or Process Change.

Material and/or process changes require appropriate classification in order to aid the determination of the extent of investigation necessary. Some minor changes may only require material equivalency sampling tests to be completed at the base of the test pyramid, whilst more significant changes will require more extensive investigations, including possibly a new structural substantiation.

a. Any of the following situations requires further investigation of possible changes to a given composite structure:

(1) Case A: A change in one or both of the basic constituents, resin, or fibre (including sizing or surface treatment alone) would yield an alternate material. Other changes that result in an alternate material include changes in fabric weave style, fibre aerial weight and resin content.

(2) Case B: Same basic constituents, but any change of the resin impregnation method. Such changes include: (i) prepregging process (e.g., solvent bath to hot melt coating), (ii) tow size (3k, 6k, 12k) for tape material forms with the same fibre areal weight, (iii) prepregging machine at the same suppliers, (iv) supplier change for a same material (licensed supplier).

(3) Case C: Same material, but modification of the processing route (if the modification to the processing route governs eventual composite mechanical properties). Example process changes of significance include: (i) curing cycle, (ii) bond surface preparation, (iii) changes in the resin transfer moulding process used in fabricating parts from dry fibre forms, (iv) tooling, (v) lay-up method, (vi) environmental parameters of the material lay-up room, and (vii) major assembly procedures.

b. For each of the above cases, a distinction should be made between those changes intended to be a replica of the former material/process combination (Case B and some of Case C) and those which are "truly new material" (Case A and some of Case C). So, two classes are proposed:

(1) "Identical materials/processes" in cases intended to create a replica structure.

(2) "Alternative materials/processes" in cases intended to create truly new structure.

c. Within the "identical materials/processes" class, a sub-classification can be made between a change of the prepregging machine alone at the supplier and licensed production elsewhere. For the time being, a change to a new fibre produced under a licensed process and reputed to be a replica of the former one, will be dealt with as an "alternative material/process".

d. Some minor changes within the class representing identical materials/processes may not interact with structural performances (e.g., prepreg release papers, some bagging materials, etc.) and should not be submitted to the Agency as part of the change. However, the manufacturers (or the supplier) should develop a proper system for screening those changes, with adequate proficiency at all relevant decision levels. Other minor material changes that fall under Case B may warrant sampling tests to show equivalency only at lower levels of building block substantiation.

e. Case C changes that may yield major changes in material and structural performance need to be evaluated at all appropriate levels of the building block tests to determine whether the manufacturing process change yields identical or alternate materials. Engineering judgment will be needed in determining the extent of testing based on the proposed manufacturing change.

f. Case A (alternative material) should always be considered as an important change, which requires structural substantiation. It is not recommended to try a sub-classification according to the basic constituents being changed, as material behaviour (e.g., sensitivity to stress concentrations) may be governed by interfacial properties, which may be affected either by a fibre or a resin change.

7. Substantiation Method. Only the technical aspects of substantiation are addressed below.

a. Compliance Philosophy. Substantiation should be based on a comparability study between the structural performances of the material accepted for type certification, and the second material. Whatever the modification proposed for a certificated item, the revised margins of safety should remain adequate. Any reduction in the previously demonstrated margin should be investigated in detail.

(1) Alternative Material/Process: New design values for all relevant properties should be determined for any alternate material/process combination. Analytical models initially used to certify structure, including failure prediction models, should be reviewed and, if necessary, substantiated by tests. The procurement specification should be modified (or a new specification suited to the selected material should be defined) to ensure key quality variations are adequately controlled and new acceptance criteria defined. For example, changing from first to second generation of carbon fibres may improve tensile strength properties by more than 20% and a new acceptability threshold will be needed in the specification of the alternate material to ensure the detection of quality variations.

(2) Identical Material: Data should be provided that demonstrates that the original design values (whatever the level of investigation, material or design) remain valid. Statistical methods need to be employed for data to ensure that key design properties come from the same populations as the original material/process combination. Calculation models including failure prediction should remain the same. The technical content of the procurement specification (Case B) should not need to be changed to properly control quality.

b. Testing.

(1) The extent of testing needed to substantiate a material change should address the inherent structural behaviour of the composite and will be a function of the airworthiness significance of the part and the material change definition. For example, the investigation level might be restricted to the generic specimens at the test pyramid base (refer to figures in paragraph 7) for an identical material, but non-generic test articles from higher up the pyramid should be included for an alternative material. Care needs to be taken to ensure that the test methods used yield data compatible with data used to determine properties of the original structure.

(2) The testing that may be required for a range of possible material and/or process changes should consider all levels of structural substantiation that may be affected. In some instances (e.g., a minor cure cycle change), possible consequences can be assessed by tests on generic specimens only. For other changes, like those involving tooling (e.g., from a full bag process to thermo-expansive cores), the assessment should include an evaluation of the component itself (sometimes called the “tool proof test”). In this case, an expanded NDI procedure should be required for the first items to be produced. This should be supplemented – if deemed necessary – by “cut up” specimens from a representative component, for physical or mechanical investigations.

c. Number of Batches.

(1) The purpose for testing a number of batches is the demonstration of an acceptable reproducibility of material characteristics. The number of batches required should take into account: material classification (identical or alternative), the investigation level (non-generic or generic specimen) the source of supply, and the property under investigation. Care should be taken to investigate the variation of both basic material and the manufacturing process.

(2) Existing references (e.g., The Composite Materials Handbook (CMH-17) Volumes 1 and 3, FAA Technical Report DOT/ FAA/AR-03/19), addressing composite qualification and equivalence and the building block approach, provide more detailed guidance regarding batch and test numbers and the appropriate statistical analysis up to laminate level. Changes at higher pyramid levels, or those associated with other material forms, e.g., braided VARTM (Vacuum-Assisted Resin Transfer Moulding) structure, may require use of other statistical procedures or engineering methods.

d. **Pass/Fail Criteria.** Target pass/fail criteria should be established as part of the test programme. For strength considerations for instance, a statistical analysis of test data should demonstrate that new design values derived for the second material provide an adequate margin of safety. Therefore, provision should be made for a sufficient number of test specimens to allow for such analysis. At the non-generic level, when only one test article is used to assess a structural feature, the pass criteria should be a result acceptable with respect to design ultimate loads. In the cases where test results show lower margins of safety, certification documentation will need to be revised.

e. **Other Considerations.** For characteristics other than static strength (all those listed in AMC 20-29, paragraphs 8, 9, 10 and 11), the substantiation should also ensure an equivalent level of safety.