European Union Aviation Safety Agency

PART 21 WORKSHOP CERTIFICATION CONFERENCE

SIDE MEETING

EASA CM-S-008 ‘Additive Manufacturing’
- Revision Progress

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PART 21 WORKSHOP

November 26th 2024

Your safety is our mission.

An Agency of the European Union

Material and Process… importance in the Regulations

- ➢ EC No 216/2008 annex 1.a.**Structures and materials**: the **integrity of the structure must be ensured throughout, and sufficiently beyond, the operational envelope for the aircraft,** including its **propulsion system**, and maintained for the **operational life** of the aircraft.

Basic Regulation

(EU) 2018/1139

EU Parliament
EU Council

Binding

Implementing rules

Initial Airworthiness

For the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations.

Implementing rules

Continued Airworthiness

On the continuing airworthiness of aircraft … parts and … pproval of … involved in

EU
Commission

- ➢ **21A.31 Type design …** consists of:
  - ➢ 2. Information on **materials and processes … methods of manufacture and assembly…**

- ➢ **21A.147(a) Changes to approved production organisation. GM 21.A.147(a) – Significant Changes 1… significant changes to production methods**

AMC 20-29
Composite
Aircraft
Structure

Part 21

- Acceptable means of compliance (AMC)
- Guidance material (GM)

Certification specifications

- Airworthiness codes

Acceptable means of compliance (AMC)
Guidance Material (GM)

- Part M – Continuing Airworthiness
- Part-145 – Maintenance Organisations Approvals
- Part-66 – Certifying staff
- Part-147 – Training organisations requirements

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Non-Binding

- ➢ **e.g. CS25 Certification Specifications: Limited 'Material and Process'**

CS 25.603: Materials… 'suitability and durability … based upon experience/test… conform to specifications… consider environment

CS 25.613: Mechanical Strength Properties and Design Values Materials. (a) … design values based upon a statistical basis

Note: CS
binding once
in Type
Design

EASA

Other regulatory activities of relevance…

Performance Based Regulation* (PBR): 'A regulatory approach that focuses on desired, measurable outcomes'

***https://www.easa.europa.eu/sites/default/files/dfu/Report%20A%20Harmonised%20European%20Approach%20to%20a%20Performance%20Based%20Environment.pdf**

Level of Involvement (LoI): 21.B.100: Certification proportionality:

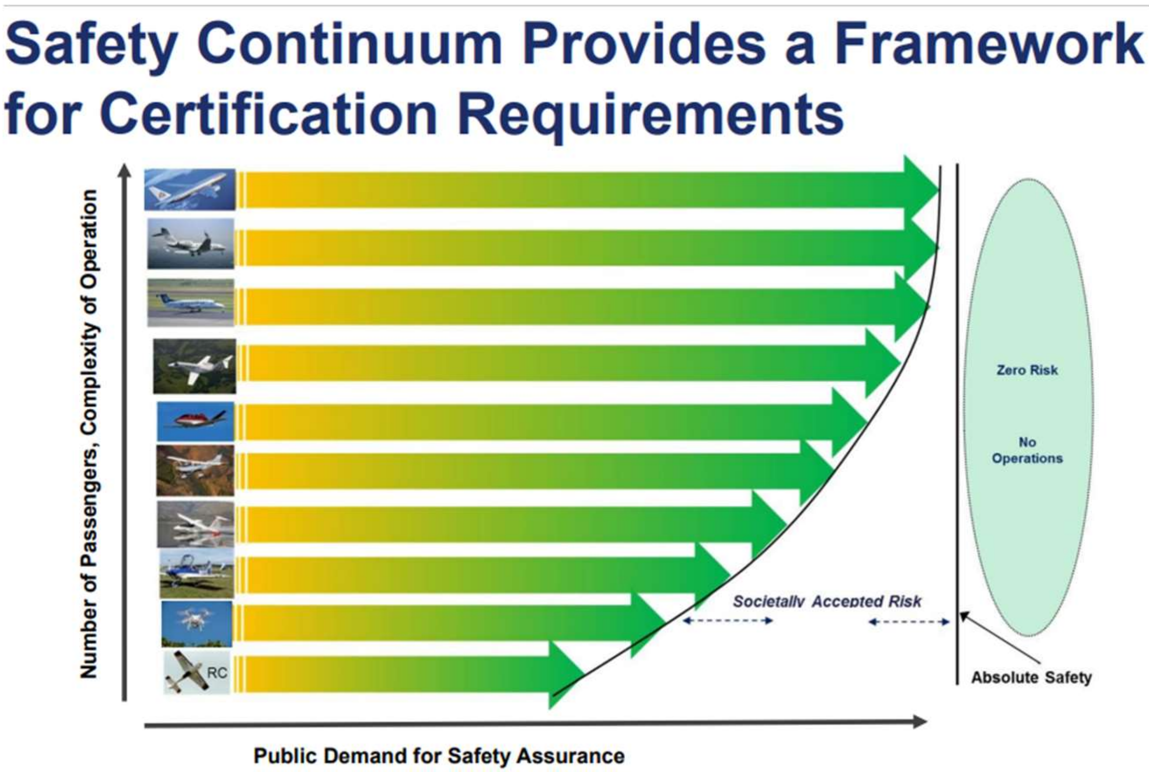
> ***1.… the <u>novel or unusual features</u> of the certification project, including operational, organisational and <u>knowledge management</u> aspect***

novel or unusual to **applicant** and/or **industry** and/or **regulator**

> ***3.… the <u>criticality of the design or technology</u> and the related safety and environmental risks, including those identified on similar designs***

…AM suggests need for development of more prescriptive industry guidance, e.g. supported by standards bodies etc… yet engineering properties are typically product specific!

Reminder: certification being proportionate to risk criticality… example/thoughts:



- For example, do we require the same for a Class A part (as defined in ASTM F3572-22 for AM parts) on
  - a transport category commercial aircraft or,
  - on a two-seat general aviation aircraft?
- Are there any differences in means of compliance between Class C or Class D parts based on operation?

Note: Slide taken from CMH-17 Composite Cert Tutorial.

Changes to structure etc… baseline structure, modifications, repairs etc

CS 25.605* (CS25 amdt 27): Fabrication Methods

(a) The fabrication methods used (i.e. the manufacturing and assembly methods, including consideration of the materials and material processes) must produce the strength and other properties necessary to ensure a consistently safe part. If a fabrication method includes processes that require close control to reach this objective, then those processes must be performed under representative approved fabrication process specifications, supported by appropriately approved material specifications (including considering the raw/feedstock/unfinished material specifications) with appropriate controls for the design data.

(b) Each new fabrication method must be substantiated by a test programme that is representative of the application.

* Intent applies to all products

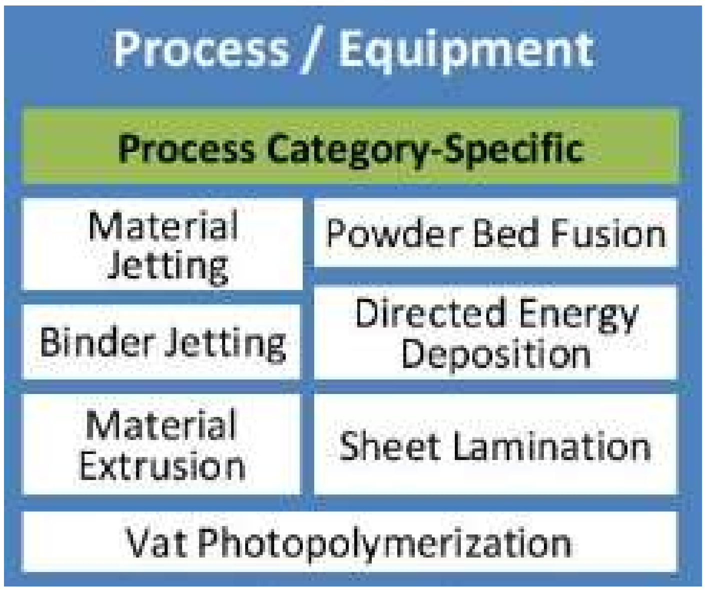
Changes to structure etc… baseline structure, modifications, repairs etc

CS 25.571: Damage tolerance & fatigue evaluation of structure

(a) General. An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, manufacturing defects, environmental deterioration, or accidental damage will be avoided throughout the operational life of the aeroplane

(3)…..inspections or other procedures must be established as necessary to prevent catastrophic failure, and must be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by CS 25.1529'

Multiple processes and methods

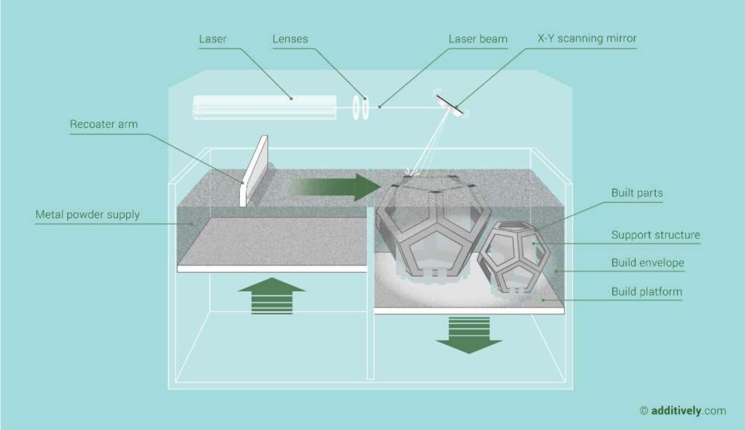


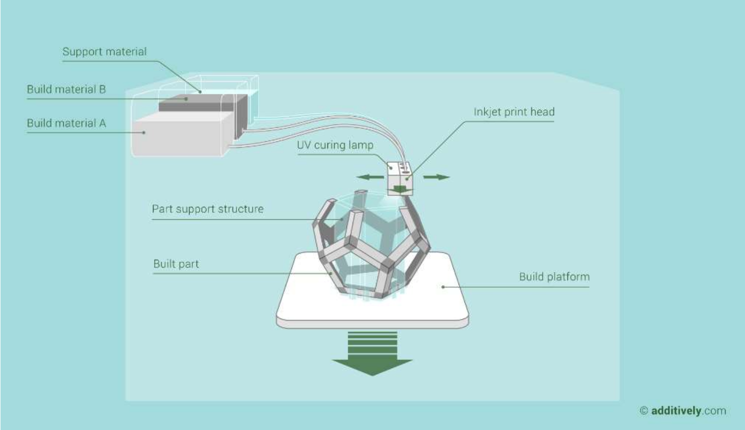
- metallic/non-metallic
- single material, multi-material, + fillers,
- hybrid processes, e.g. icw conventional methods
- **significant potential commercial benefits**, e.g. rapid prototype evolution, reduced part count, weight reduction, ‘optimised’ design, etc.

AM

Additive Manufacturing – many methods, and definitions:

'... make objects...layer upon layer...'





Illustrations courtesy of additively
>>> your access to 3D printing

- metallic/non-metallic
- single material, multi-material, + fillers,
- hybrid processes, e.g. icw convention methods

- **significant potential commercial benefits**, e.g. rapid prototype evolution, reduced part count, weight reduction, 'optimised' design etc

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Engineering properties

AM ‘Engineering Properties’ are defined:

- by the ‘material/process/fabrication method’
- during consolidation of the complex part or repair

challenges:

- ‘complex parts’ – base pyramid coupon data may not represent the complex part properties (although stable simple base pyramid data is important…otherwise, how can the higher pyramid work be trusted?)
- ‘sensitive processes’ – a major challenge if completing production activities in a more challenging maintenance environment

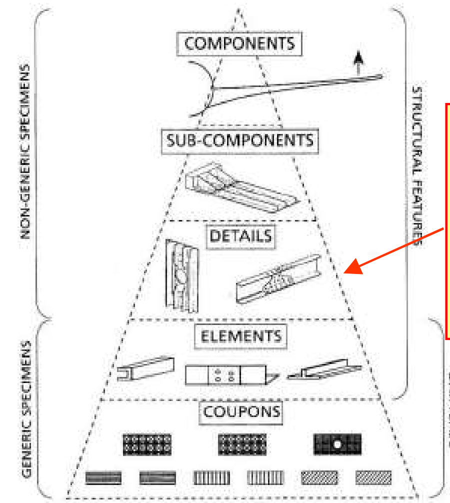
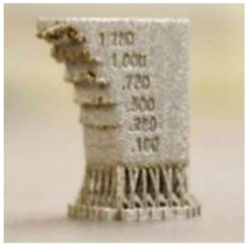


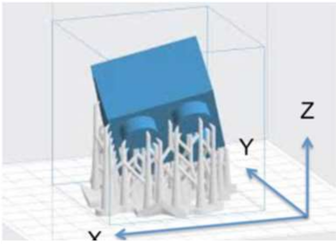
Figure 1 - Schematic diagram of building block tests for a fixed wing.

Where are the ‘engineering properties’ developed in the pyramid?

e.g. AM, composites, bonded joints, advanced alloys



e.g. no access to free edges – fatigue issue?



e.g. support structure on the build platform

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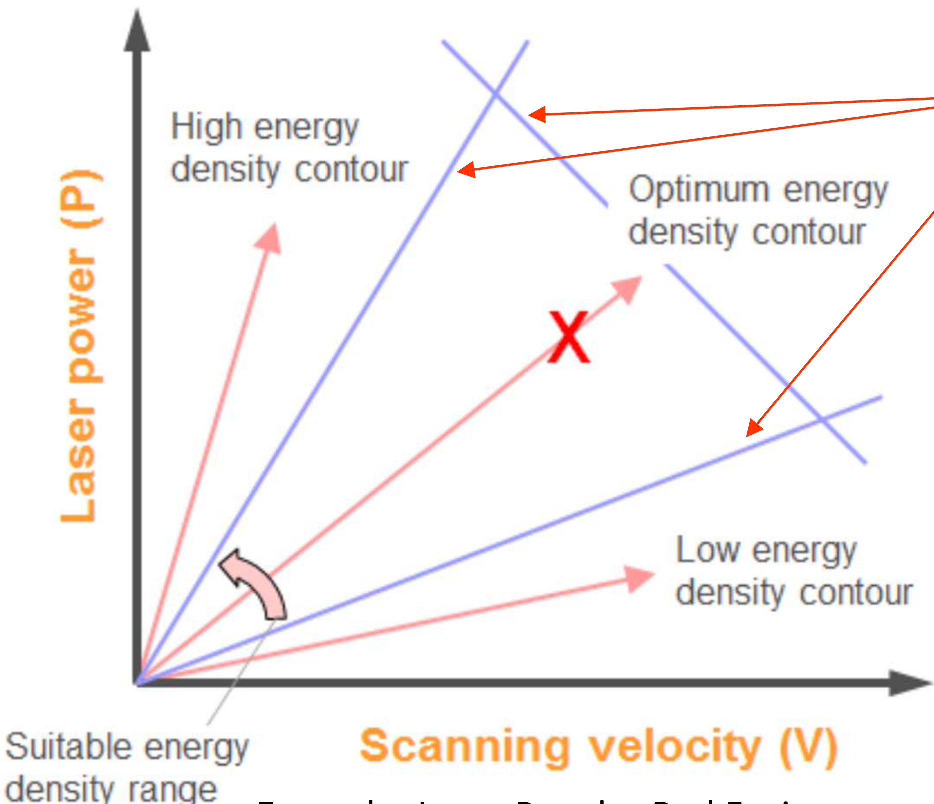
Influence of parameters

what is to be understood?



Example: Laser Powder Bed Fusion

- 100+ control parameters
  20, 30, 40….'KPPs'?

Metallic/non-metallic and many processes generalisation:

Boundary definitions:

- **Key Process Parameter (KPPs)** definition?
- **Competing defect/damage modes**?
  - e.g. Lack of Fusion? Key holes?
- **Statistical credentials** (A, B-Basis, or C, D-Basis)?
- **Sensitivity** (% change in '**engineering properties**' wrt **KPPs**?)

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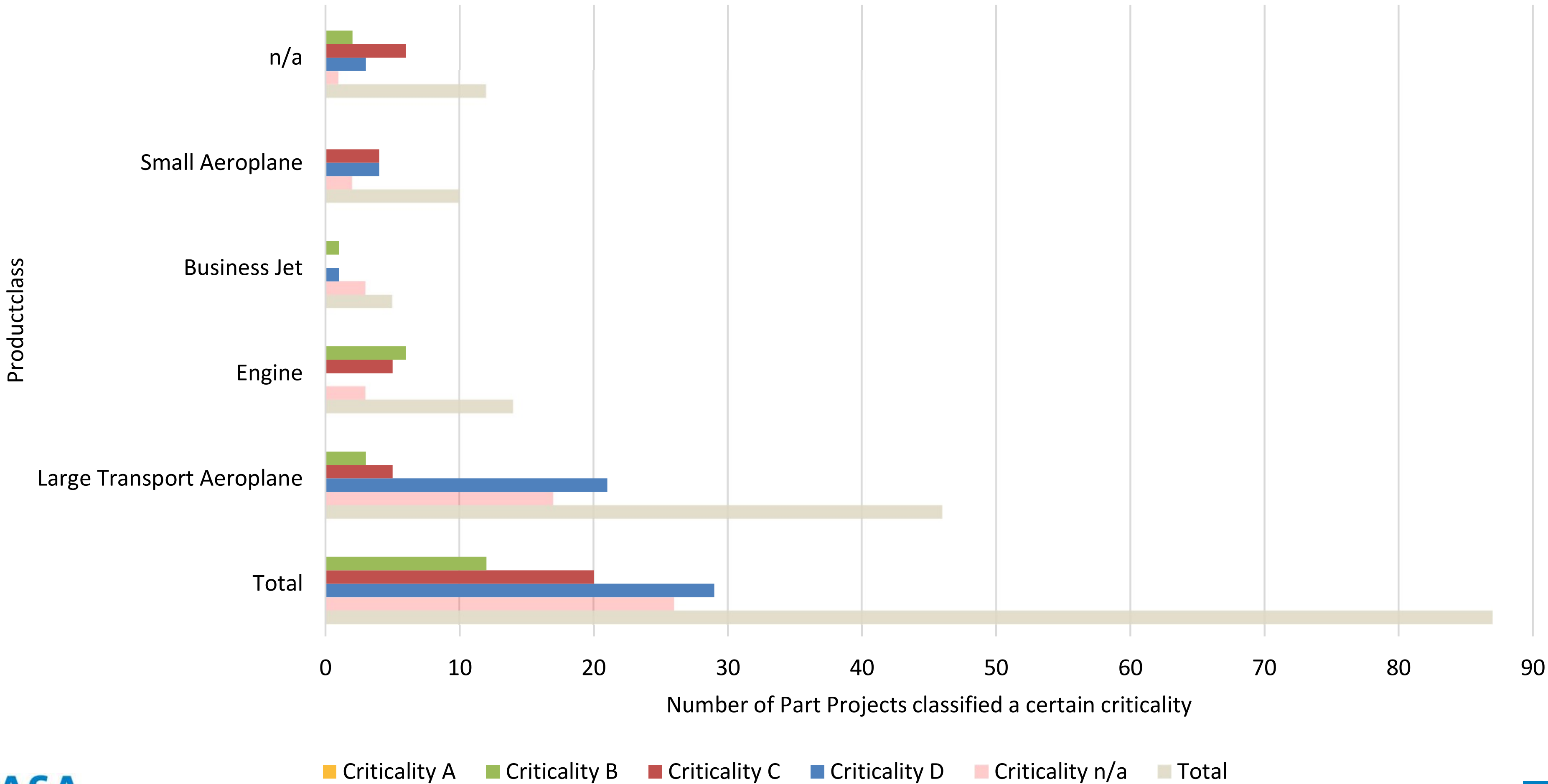
AM **projects** per product class & classification



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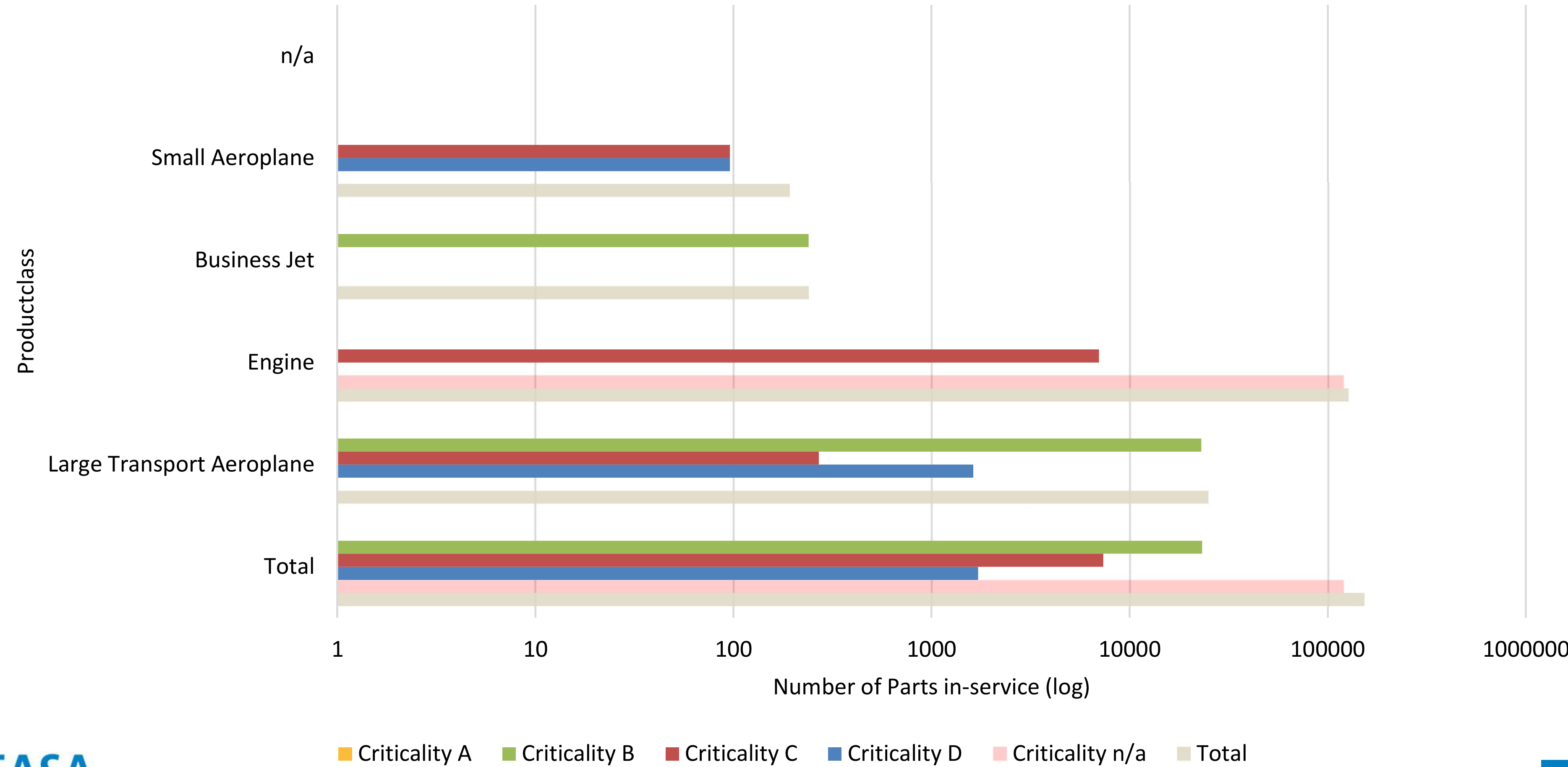
AM **parts** in service (**log scale**)



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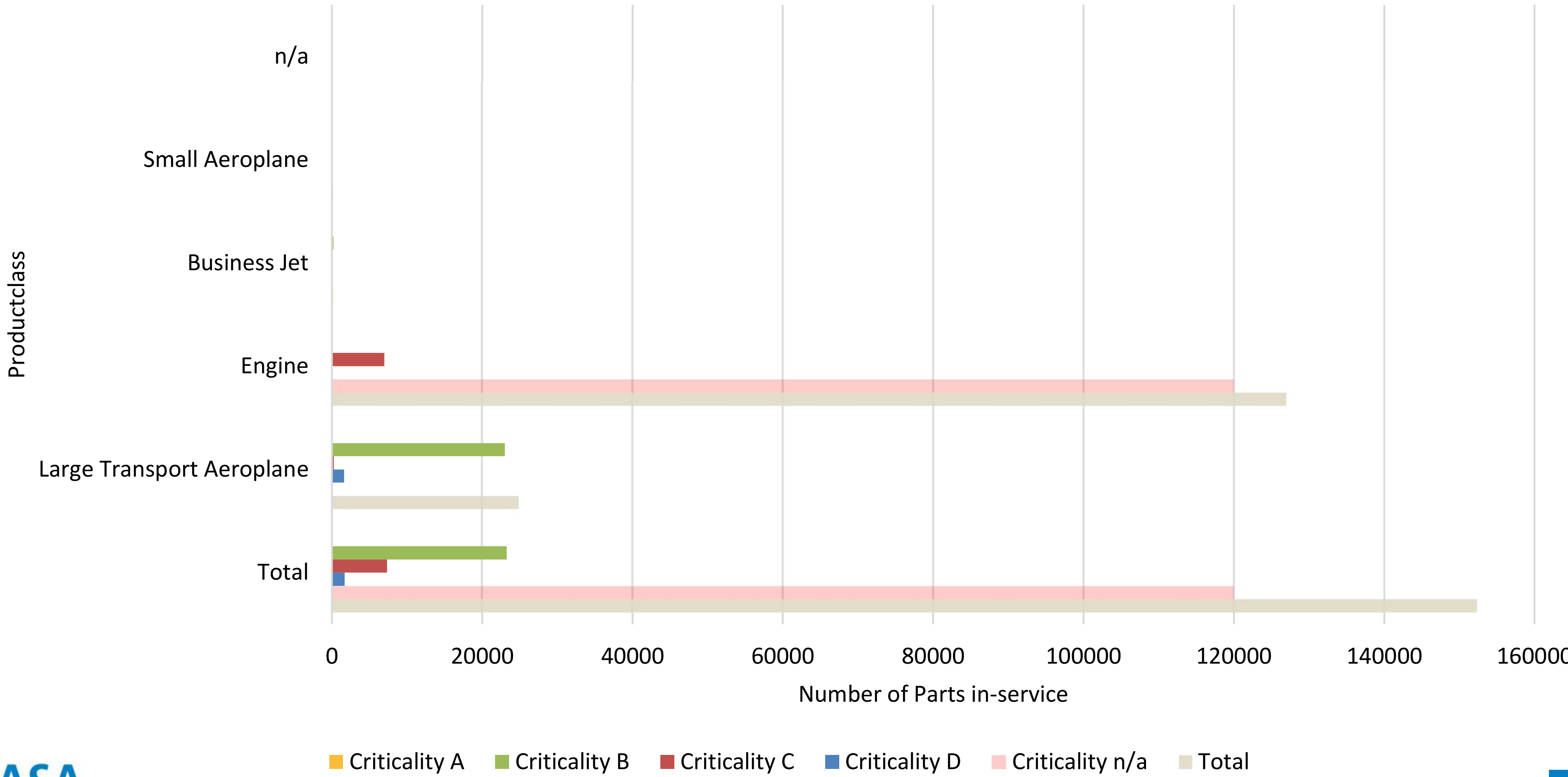
AM **parts** in service (**NOT** Log Scale)



CM-S-008

Content and Development

CM Purpose

Notification of a Proposal to issue a [delete for final]
Certification Memorandum

[Title]

EASA CM No.: [Proposed] CM–XXX-XXX Issue XX issued DD Month YYYY

Regulatory requirement(s): [List regulatory requirement(s) the CM relates to]

EASA Certification Memoranda clarify the European Union Aviation Safety Agency's general position on specific initial airworthiness, validation, continuing airworthiness or organisational items. They are intended to provide guidance on a particular subject and may provide complementary information for compliance demonstration, similar to AMC/GM even if not formally adopted through an ED Decision. Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements.

CM development history

- Issue 1 released 2017
- Issue 4 draft released for comment in April 2024
- Issue 4 development based on:
  - Response to industry questions
  - Step by step approach regarding criticality
  - EAAMIRG discussions
  - Comment Response Document (CRD) input (ref. April 2024 CM revision)
- Participation
  - 13 organisations (industry & regulators)
  - ~ 60 comments

Certification Memorandum

Additive Manufacturing

EASA CM No.: CM–S-008 Issue 04 issued 30 April 2024

Regulatory references:
Primarily impacted product CSs:
CS2x.305, CS2x.307, CS 2X.571, CS 2X.603, CS 2X.605, CS 2X.613, CS 2X.853, CS23.2260, CS E.70, CS E.100 (a), CS P.170, CS P.240, CS APU.60, CS-ETSO (see ~~Section 2 Tables, and~~ Appendix 1 for more detailed CS listing)
Other potentially impacted references:
21.A.15, AMC 21.A.15(b), 21.A.31, GM 21.A.91, 21.A.101, 21.A.131, 21.A.133, 21.A.147, 21.A.247, 21.A.307(b), 21.A.433, GM 21.A.435(a), , 21.B.100, 21L, 145.A.42(b), CAO.A.020, M.A.603(c)

CM revision process

Reminder: EASA AM CM-S-008 ‘Additive Manufacturing’ revision process

Issue 3 released 30th April 2021

Revision process since issue 3 included many open shared industry/regulator meetings including evolving draft text:

- Industry – Regulator AM Events* (EASA – FAA 2021, 2022, 2023, 2024)
- Supported by Working Groups
    - e.g. WG1 ‘Qualification of Additive Manufacturing (AM) Parts of No, or Low, Criticality (for use in Certified products))’
- European Aviation AM Industry Regulator Group (EAAMIRG)
- EASA (Advanced Materials and Processes)AMPs WG
- EASA Structures Staff
- SDOs like SAE and ASTM

*https://www.easa.europa.eu/en/newsroom-and-events/events/joint-easa-faa-additive-manufacturing-workshop-2023
https://www.easa.europa.eu/en/newsroom-and-events/events/joint-faa-easa-additive-manufacturing-workshop-2024
(proceedings yet to be published)

CM revision changes in Issue 4

Revision developed for **issue 4** included changes relating to:

- **'criticality classification'**
    - **'no and low' criticality applications**
    - **- typically new parts, or 'repair by replacement' (no 'build up' repairs, yet!)**
    - particularly important for non-TCH applications using segmented supply chains (see Working Group 1 activities)
- **early engagement with EASA – initial information expected**
- '**initial certification demonstration effort being proportionate to criticality**' (developing discussion)
    - criticality classification actions v MOC and supporting actions?
- increased emphasis upon '**Safety Assessments**', 'top down' and 'bottom up', e.g. FHAs, FMECA
- addition of AM parts of 'no or low' criticality '**Examples**'
- updates references

Reminder: 'Step by Step' approach relative to application criticality

EASA

CM content overview

Note: main points, considered CM section by section, in following slides. See current CM revision file for ‘wordsmithing’ discussion.

Section 2
‘background/discussion/ context/future development potential

NOT POLICY

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Section 3
POLICY

- initial application information expectations
- ‘no and low’ criticality applications only at this CM revision (supported by Appendix 2,3,and 5)

CM - purpose and scope

IMPORTANT REMINDER: AM is a rapidly developing technology supported by many developing industry guideline documents, but lacking regulatory guidance in any detail. Therefore, this CM revision process attempts to periodically document and share progress relative to EASA regulatory expectations and does not represent a complete or final EASA position. EASA is of the opinion that this approach is preferable, i.e preferable to not doing so, for the purposes of visibility and progressing development and the safe use of AM in certified parts.

Section 2 content ONLY provides background and context for the developing Policy, NOT Policy, unless specifically and directly referenced from Section 3.

Section 3 content provides Policy. This revision addresses early engagement with EASA regarding AM and also applications of no or low criticality (Class C and D), see appendix 2 and 3.

Policy focused on no and low criticality
(see also Appendix 2 and 3)

CM – Criticality

2. Background – increasing development of AM use in aviation and the EASA regulations

Design certification 'Criticality' and proportionate certification effort demonstration:

'The word '**criticality**' is used extensively throughout the regulations and in industry in various contexts which may impact product and/or passenger safety, e.g. part criticality, manufacturing criticality, and procedural/administrative criticality.

For the purposes of this CM, **part criticality** is a measure of the significance of a part to the overall safety of a product or its occupants.

Manufacturing criticality is a measure of the significance of sensitivity of AM engineering properties to M&P and manufacturing method process variability. This may, or may not, have safety implications, depending upon the part criticality.

Procedural/administrative criticality may also impact product and/or passenger safety, e.g. inappropriate use of certification processes, such as LoI, may adversely impact effective and safe certification.

Initial paragraphs re-written in an attempt to better clarify the various understandings of the meaning of 'criticality'

Criticality and proportionate certification effort demonstration:

Based on ASTM F3572-22

Focus of current draft revision:
Class C and D
(No / Low Criticality)

ASTM F3572-22 Classification	Consequence of Failure	General Description	Application for engine products (CS-E 510), propellers (CS-P 150) and APU (CS-APU 210)	Application for aircraft products (CS-25.1309, CS-23, CS-27, CS-29, CS-22, CS-VLA)
A	High	Part whose failure can directly affect continued safe flight and landing Part whose failure can result in serious or fatal injury to passengers or cabin crews or maintenance personnel Part whose failure can result in excessive workload of flight crew	**HAZ** engine/propeller/APU Effects	**CAT/HAZ** aircraft effects
B	Medium	Part whose failure can indirectly affect continued safe flight and landing Part whose failure can result in minor injury to passengers or cabin crews or maintenance personnel Part whose failure can result in significant increase in workload of flight crew	**MAJ** engine/propeller/APU Effects	**MAJ** aircraft effects
C	Low	Part whose failure has no effect on continued safe flight and landing Part whose failure has no effect on passenger or cabin crew or maintenance personnel safety Part whose failure can result in slight reduction in operational/functional capabilities Part whose failure can result in slight increase in workload of flight crew	**MIN** engine/propeller/APU Effects	**MIN** aircraft effects
D	Negligible or No Effect	Part not covered above Part whose failure would pose no risk of damage to other equipment or personnel Parts not affecting operational/functional capabilities	No effect	No effect

CM Chapter 3

EASA Certification Policy and Guidance for DOA, ADOA and POA Holders

3.1 Design Certification – early engagement with EASA

Reminder: the intent of all appropriate regulations should be met!

Applicants to:

- identify, and demonstrate understanding of, the ‘**part criticality**’
  - supported by Design Safety Assessment, both ‘top down’ and ‘bottom up’, e.g. FHAs, FMECA
  - **initial** demonstration of meeting requirements to be proportionate to novelty (to applicant and/or industry, and/or regulator – Level of Involvement (LOI) process)

  Reminder: Regulator retains right to request further information to establish that all requirements are satisfied

- identification of **Key Variables** and **Key Process Parameters (KPPs*)**
  - including demonstration of understanding of ‘engineering properties’ to KPPs

- statistical coverage of engineering properties
  - considering variability, competing damage and failure modes
  - appropriate use of ‘**Point Design**’* strategy (testing details, not coupons)

*not yet standardised by industry

3.1 Design Certification – early engagement with EASA

- appropriate and substantiated use of standards

- use supporting information from FAA documents ‘Applicant Specific Guidance Memorandum (ASGM)’

- appropriate transfer of knowledge and control between stakeholders, as necessary to ensure the development of complete and achievable specifications which allow consistent production of **safe certified parts** (e.g. DO/PO Arrangement)

3.2 Certification Programmes and MoCs

- communicate project
  - ideally using ‘end to end*’ format, e.g. CS27/29.602 ‘Critical Parts’, CS-E 515 Critical Engine Parts
  - <u>content/information adapted and proportionate to criticality</u>

*including design, production, in-service, raw material, equipment suppliers (e.g. AM Machine Manufactures, Suppliers)

Note: supply chain/stakeholder interfaces, and interfaces between disciplines, e.g. airframe - propulsion are often weak (based upon ‘conventional’ M&P experience – use ‘lessons learned’!)

3.3 Design Certification - Changes and Repairs

- established regulations and practices apply

- use of AM in repairs and design changes may be classified Major based upon the level of substantiation required*, ref. GM 21.A.435(a), being also a function of criticality, novelty (i.e. novel to the applicant and/or industry and/or regulator), and complexity.
- Design Organisations are advised to consult the Agency when introducing AM in repairs, including cases where they hold a privilege for repair design approval.

* see Appendices 2, 3, and 5 for ‘no and low’ criticality applications, the scope of this revision to the CM

3.4 Impact of AM on design organisations

- established regulations and practices apply
- involve the Agency at the earliest opportunity during the development and implementation of AM
- use of AM will initially lead to a higher level of EASA involvement in compliance verification
- introduction of additive manufacturing may, depending upon circumstances, represent a significant change to the Design Assurance System of the DOA Holder* according to point 21.A.247

* see Appendices 2,3, and 5 for ‘no and low’ criticality applications, the scope of this revision to the CM

3.5 Impact of AM on production organisations

- established regulations and practices apply
- involve the Agency at the earliest opportunity during the development and implementation of AM
- use of AM will initially lead to a higher level of EASA involvement in compliance verification
- It is ultimately the responsibility of the design approval holder to ensure that the production methods (e.g. processes, fabrication technologies etc.), or any changes, are appropriately addressed. Therefore, a robust communication process between the POA holder and the DOA holder should be demonstrated, supported by appropriate **DO-PO** agreements (21.133), which include appropriate engagement with the material supplier and other impacted subcontractors. Production Organisations are therefore reminded of the published design data requirements in point 21.A.31
- implementation of an AM process that is new for the POA holder is a change to the approved production organisation typically identified as a significant change in accordance with point 21.A.147. However, depending on circumstances, such a change may not necessarily be a significant change*

* see Appendices 2,3, and 5 for 'no and low' criticality applications, the scope of this revision to the CM

Transfer of knowledge and training:

- applicants are required to demonstrate that staff have appropriate levels of competence **throughout design, manufacture, and in service activities** in accordance with Safety Management System (SMS) principles, e.g. point 21.A.145(d)(1), point 21.A.239(c)(5)(i) etc. This also applies to the regulatory authorities, ref. PART 21.B.25(a)(3) and GM*.

*Note: In order to improve certification efficiency, it is important for industry to familiarise competent authorities with new technology applications because this should improve the potential to quickly agree upon appropriate means of showing compliance with the requirements.

1. Whom this Certification Memorandum affects

- certification of Products, Parts and Appliances, Design Changes to Products, Parts and Repairs to Products in compliance with the material, process, and fabrication related specifications, CSs, SCs, ETSO, all other regulatory material.

- It is also relevant to DOA and POA Applicants/Holders and their competent authorities, as well as other organisations declaring their capabilities under Part 21L and Part 21F organisations.

Note: The content of this CM may also be of relevance to Part 145, Part CAO, and Part M Subpart F organisations for awareness purposes. These organisations, and supporting DOAs not directly supported by TCHs, wishing to fabricate parts per Point145.A.42(b)(iii) , CAO.A.20(c) or M.A. 603(c) are reminded of the associated criteria requiring the use of appropriately approved data, design support, and approval.

support interpretation for ‘repair by replacement’

Appendix 2. Design Certification for AM parts of no or low criticality (Class C and D only)

- For parts of no or low criticality classifications (**C and D, see also ASTM F3572-22 Table 1**), i.e. being of no, or minimal, safety concern, either at aircraft or passenger level, and considering the potential for initially demonstrated 'Certification Effort Proportionality to Part Criticality' tables and 'footnotes', see Section 2 and Appendix 4 in this CM, the applicant will be required to demonstrate, at least:

- part criticality has been correctly assessed, supported by an appropriate Threat Assessment and Design Safety Assessments including both 'top down' and 'bottom up' processes, see Appendix 3… allowing for all likely defect, damage and failure modes including consideration of potential **non-conformities*** etc . Note: This should support a conservative criticality assessment.

- appropriate scope and capability regarding the AM technology to be used (including appropriate stakeholder and supply chain management).

- representative development work in support of a first application for any new material and/or process… work is likely to be beyond that expected for a similar application of no or low, criticality using 'conventional' technologies, see 'Examples' Appendix 5

*EASA CM 21.A-K-001 'Installation of new parts and appliances without an EASA Form 1'

Appendix 2. Design Certification for AM parts of no or low criticality (Class C and D only)

- conservative design practices have been used, including consideration of attachments to surrounding structure, including impact on baseline structure

- an appropriate use of standards. Subject to clear demonstration of no or low criticality classification (Class D only), appropriate use of some test standards not specific to aviation could be demonstrated to support the certification process, e.g. ISO/ASTM DIS 52927:2022

- for parts for which strength properties are important to maintaining fit, form, and function, e.g. maintaining shape, supporting its own weight or negligible/low loads, that a minimal set of representative coupon test data is presented showing that the material properties can be produced which consistently meet the application design requirements , e.g. in tension, shear, and compression, as applicable, e.g. S-basis

- S-basis data per MMPDS or CMH-17 values may be used to support proportionate MoCs for Class C and D, noting that such data is coupon based and would require consideration of additional influencing factors in order to provide design values representative of a more complex configuration.

Appendix 2. Design Certification for AM parts of no or low criticality (Class C and D only)

- direct part testing (certification by 'Point Design' or 'Detail' testing supporting CS2x.305, CS2x.307
    - not standardised!
    - test numbers?
    - load cases?
    - Boundary Condition challenges, e.g. feeding loads into small complex part

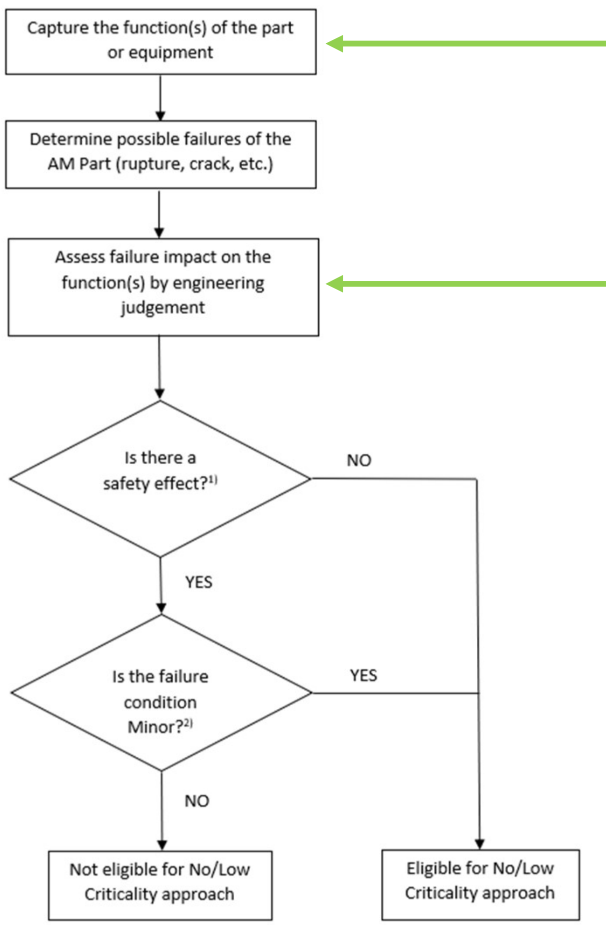
- appropriate performance when subjected to vibration loads, which may result in failure modes, extents, and variabilities significantly different to those resulting from static loads… which may impact safety outcomes, e.g. different debris size, shape, hardness, part departing aircraft, system jam/engine ingestion
    - although Class D should be, by definition, of no consequence to safety, repeated failures should be avoided
    - should be of minimal impact to applicants… such consideration is likely to have formed part of any commercially driven material and process selection decision, so should also (at least) be available to the regulators as part of any safety related assessment.

Appendix 2. Design Certification for AM parts of no or low criticality (Class C and D only)

Reminder: Aligned with the intent of CMs (see cover sheet), this CM is not intended to 'introduce new certification requirements, or to modify existing certification requirements'. However, for the purposes of pursuing proportionate regulation effort relative to criticality, the intent is for parts manufactured using AM considered to be of **no or low criticality** (**in accordance with the guidance above**) to be addressed under a **minor change approval**, even upon **initial use of AM for "D" parts, provided all other aspects of the change meet the requirements for minor classification** in accordance with established EASA processes based upon the amount of work required for approval (as indicated in PART 21). **Design organisations** (including holders of, or applicants for, ETSO authorization(s)) are **expected to inform EASA, and POA Holders are expected to inform their respective Competent Authority**, of intent to use AM (and the intended applications, criticalities, etc..) and to provide an impact assessment for the introduction of AM process based on a gap analysis, although EASA/the respective POA Competent Authority retains the right to change the assessment in accordance with established EASA/respective POA Competent Authority processes.

Appendix 3. Design safety assessment for AM parts of no or low criticality (Class C and D)

Intended to support 'top down' and 'bottom up' Safety Assessments



Consider any potential for interaction between functions/disciplines - Airframe, Systems, Propulsion, Interiors (including seats) etc

Also consider potential for any new failure modes (relative to conventional technologies and applications) to change the Safety outcome beyond direct functionality of the part to include other potential threats, e.g. debris, PDA impact, propulsion system ingestion, flammability, introduction of sharp interior edges etc

1) **No Safety Effect (Cat.D)** Part the failure of which would pose no risk of damage to other equipment, personnel, or reduce operational/functional capabilities

2) **Minor (Cat.C):** Part the failure of which has no affect on continued safe flight and landing, no affect on pax or cabin crews, but can result in a slight reduction in operational/functional capabilities or a slight increase in workload for the flight crew

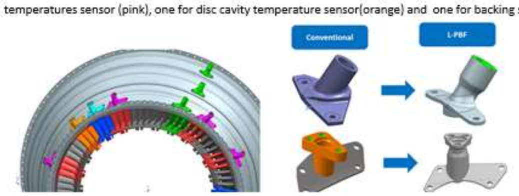
Appenix 5 Early AM applications in certified parts of no or low criticality

- examples of early AM applications in certified parts (or parts close to being certified at the time of this CM revision) and are provided for broader industry awareness/standardisation purposes

Examples - Propulsion:

Propulsion Example 1:(ITP): Low Pressure Turbine casing bosses.

Parts installed on the Low pressure turbine, 3 of the them for boroscopic inspection (green); 4 for flow path temperatures sensor (pink), one for disc cavity temperature sensor(orange) and one for backing sensor (blue).



Design Driver: Interference, mechanical and thermal loads.

Extent of Safety Assessment, FHA, FMECA~~, RAS~~, completed: FMECA as part of the casing assy.

Material and Process: In718, Laser Powder Bed Fusion

Material and Process Control

- Internal ITP Aero specifications for powder manufacturing process, powder characteristics, powder management and L-PBF process, material and applied post-processing
- L-PBF process/machine qualified in XY and height of the build chamber under internal ITP Aero specification (tensile, metallography, chemistry, dimensional and surface roughness).
- L-PBF part qualified under internal ITP Aero specification (tensile, metallography, chemistry, dimensional and surface roughness)
- Part Non destructive controls: Visual, FPI + dimensional and surface roughness.
- Periodic destructive tests (tensile, metallography and chemistry) are performed to control the manufacturing process.
- Control supported by Statistical Process Control (SPC), Process Control Document (PCD), and other broader supplier documented processes.
-

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Examples – Interiors (Including Seats): Non-Metallic

Interiors Example 1 (SAFRAN): Large Aircraft CS25: *Bumper Mounted on Seat Surrounding Furniture assembly.*

Note: Bumper mounted on the aisle side of the seat surrounding furniture and remains within the geometrical requirements of the original component.

Design Driver: Tooling, Retention and Impact loads.

Extent of Safety Assessment, FHA, FMECA~~, RAS~~, completed: This is not located in the passenger interaction area, and therefore does not require occupant safety assessment (i.e. Cat B). However, it is located on the aisle egress pathway and needs to be evaluated from egress perspective.

Material and Process: Ultem 9085 Fused Deposition Modeling (FDM)

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Airframe Example 4: (Liebherr-Aerospace Lindenberg GmbH): A350XWB NLG Lock Stay Bracket:

The AM sensor bracket is part of the locking stay assembly of the A350XWB nose landing gear. A steel target is mounted to the bracket, which indicates if the landing gear is in its down and locked position. Out of redundancy reasons, the AM bracket is one of three brackets located all around the locking stay apex. Only one sensor bracket is 3D printed, the others are conventionally machined.

Design Driver: Static Strength, vibrations and operational shock

Extent of Safety Assessment, FHA, FMECA~~, RAS~~ completed: In addition to the functional analysis and possible damage during use, a more comprehensive safety assessment was carried out. Not only the individual component was considered, but also the effects on the complete system and its environment if all AM components fail. All results have been compared with the original configuration and evaluated.

Material and Process: Ti-6Al-4V, Laser Powder Bed Fusion

Material and Process Control:

- Internal Liebherr specifications for powder, powder management, L-PBF process, subsequent post processing steps and printed Ti6Al4V material
- L-PBF process and machine qualified according to internal Liebherr specification
- Periodic control of relevant machine parameters and process condition monitoring
- Part Non destructive controls: Visual, FPI, dimensional and X-ray inspection
- Periodic destructive tests (tensile and metallography) are performed to control the manufacturing process.

Machines/Locations: The approved manufacturing process is only valid for one specific AM printer. Hence the type and serial number (S/N) is specified.

Post Processing: HIP and chemical milling process performed. Part interfaces machined in accordance to part specification drawing.

Design Values: Design values are determined by material qualification tests program. The qualification program included multiple builds with a few hundred test samples (static and dynamic properties, porosity, microstructure and chemistry).

Static Strength: FE analysis. Accompanying test specimens for tensile strength are tested for each build job.

Flammability (and/or other considerations): N/A

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EASA AMP Group

Please use the following initial EASA contacts for the product or discipline of interest:

Materials	S. Waite	simon.waite@easa.europa.eu
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*original EASA contact addressing theme

EASA
European Union Aviation Safety Agency

PART 21 WORKSHOP CERTIFICATION CONFERENCE

Thank you for your attention.

Questions?

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NDT

Question: Does the CS demand NDT for non-critical components?

Comment:

NDT is not a requirement of the CS or AM requirements.

- NDTs might be accepted as part of the Type Design
- EASA accepts NDT via “special procedures” and supported by EN4179

NDT can, however, be utilised for flaw characterisation in support of developing confidence in AM technology.

The general effort should be proportionate to the criticality of the part.

Change Management

Question: Change management not yet regulated/standardized. What are the guidelines on the amount and volume of test scopes after changes to to a frozen process?

Comment:

- Change management is generally addressed in Part 21 and implied in reqs. like 25.605. Usually generalised and not M&P specific. The exception is AMC 20-29 Appendix 3 on composite changes.
- Change management and qualification is highly discussed in AM
- EASA is aware of it not being standardised on the specific M&P level
- Providing information at this point is senseless due to changes in the future

Training Requirements

Question: What training is required for DOA designers, without AM experience, for no/low critical parts?

Comment:

- No specific training identified, generic needs indicated in CM-S-008
- Non exhaustive list:
  - DO/PO Interface (e.g. proper transfer of information to PO and understanding of the meta data an AM file can transport)
  - Technological understanding of the process to be used
  - Technological understanding of the characteristics of the machine model to be used (e.g. laser type, laser interactions if multiple lasers, etc.)
  - Use of material specs.

DOA involvement in AM

Question: 3-4% of DOA involvement in AM in 2019. How about now?

Comment:

- Currently no further data
- Survey for DOA, MOA and POA to be published
  - Goal: to receive an updated picture of AM activities across the industry

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Support Slides

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EASA - AM

Appendix 4: Certification effort proportionality to part criticality – Draft Tables:

			Material and Process control	Design Values	Static Strength	Fatigue / Damage Tolerance	Powerplant	Systems
Requirements for Structures, Equipment and Installations	Large Aeroplanes		CS 25.603 Materials CS 25.605 Fabrication methods	CS 25.613 Material strength properties and Material Design Values	CS 25.305 Strength and deformation CS 25.307a Proof of structure	CS 25.571 Damage tolerance and fatigue evaluation of structure	CS25.901c and 25.903c Sustained Engine Imbalance (windmilling)	CS 25.1309 Equipment, systems and installations CS25.1435 Hydraulic systems
Part Classification (see new ASTM-F42 standard)	A	(CAT)	X	X (3)	X (4)	X	As required (6)	As required (8)
		(HAZ)	X	X (3)	X (4)	TBD(9)	As required (6)	As required (7)
	B	(MAJ)	X	X (3)	X (4)	TBD(9)	As required (6)	As required (7)
	C	(MIN)	S (2)	S(5)	S (4)	TBD(9)	TBD(1)	As required (7)
	D	(NSE)	N (1)	N(1)	N(1)	N(1)	N(1)	N(1)

Table 2a: CERTIFICATION EFFORT PROPORTIONALITY TO PART CRITICALITY – Large Aeroplanes (table key above)

Large Aeroplanes – Footnotes:

NOT POLICY!

Appendix 4 included for visibility/awareness purposes - evolving discussion with future higher criticality applications in mind:
e.g. **N (Class D only) suggests no MoC. However, a convincing 'top down' and 'bottom up' Safety Assessment is required to support classification. Above Class D, TBD (To Be Determined) indicates that debate continues regarding the interpretation of, and distinguishing between, actions necessary to support criticality classification relative to the actions necessary to demonstrate the showing of the means of compliance being proportionate to criticality**

EASA - AM

Appendix 4: Certification effort proportionality to part criticality – Draft Tables:

Example Footnote:

(9) **effective and safe use of this table relies significantly upon the correct classification of criticality**. No need for application of CS25.571 is possible based upon demonstration of appropriate assessment of criticality as Class A Haz or Class B Major, as agreed with the regulator. **Although 25.571(a) only requires assessment for *'each part of the structure that could contribute to a catastrophic failure'*, the identification of such parts relies initially and significantly upon demonstrating understanding of failure modes, loads, locations etc, which may be challenging for new M&P, new configurations, reduced part count/load paths (made possible by AM) etc. Therefore, for less than full CS25.571 MoC to be accepted for any specific part and application, similarity and applicability will need to be demonstrated relative to established practices, including substantiated demonstration of understanding of part performance relative to anomalies, flaws, and potential defects. Such an approach would typically be associated with established TCHs.**

EASA Composite Materials Safety Strategy

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

Do not reduce the 'existing Level of Safety'

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

Change of material, process, and application changes the reference points

applies to baseline structures, **changes, and repairs**

EASA Composite Materials Safety Strategy

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

Maintain robust 'aircraft level' design concept

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

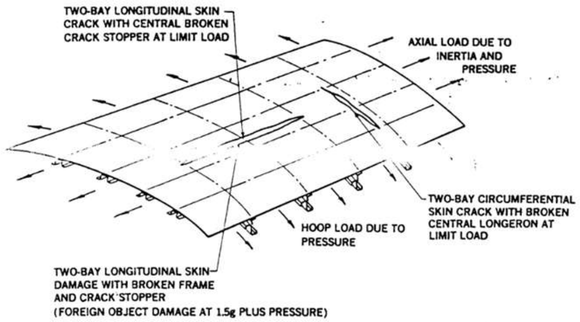
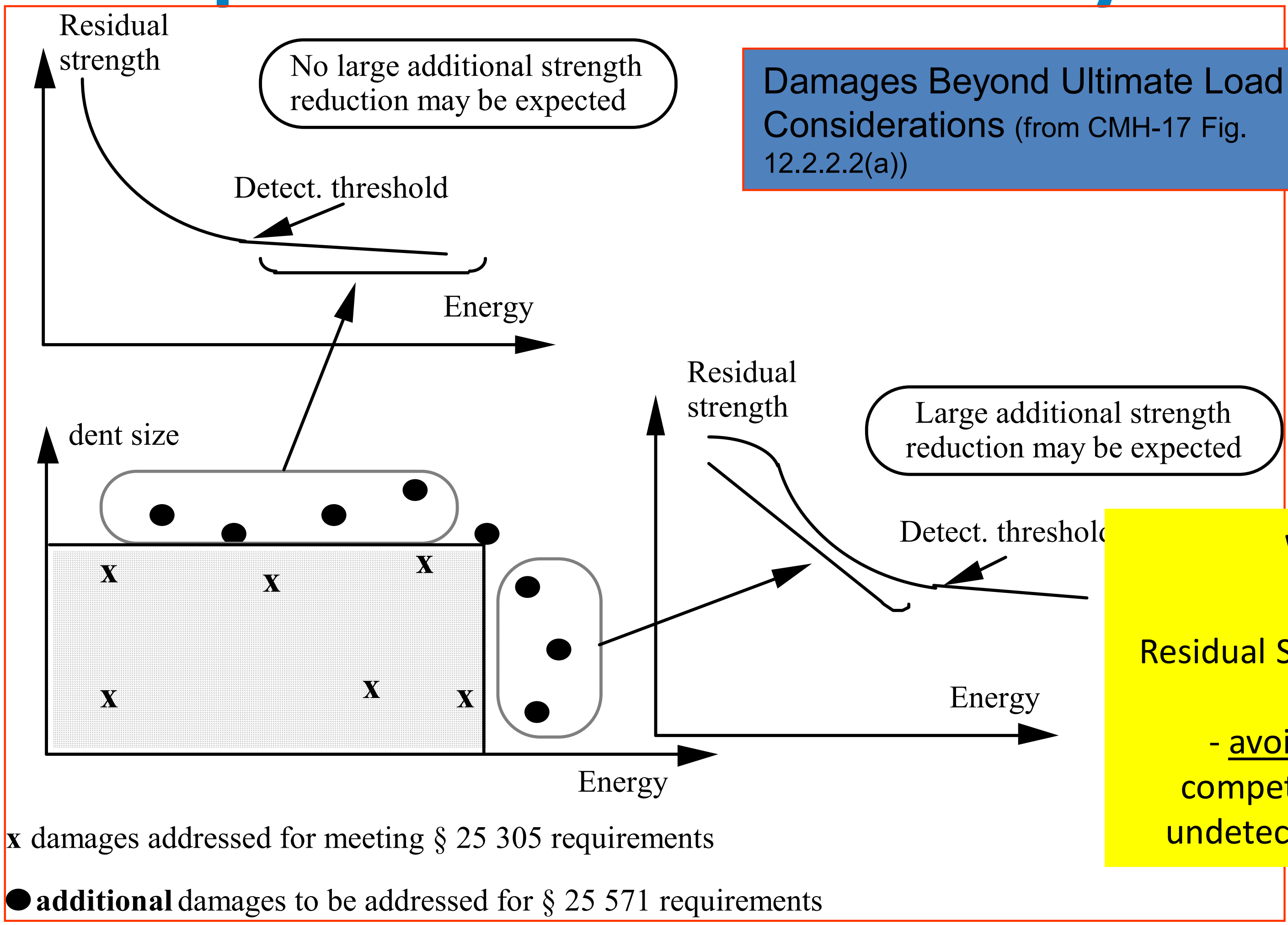


FIGURE 2. FUSELAGE DAMAGE TOLERANCE SIZES FOR STRUCTURAL DESIGN

e.g. Design for Redundant Structures ...Tom Swift
For conventional metals, a cracked frame and 2 cracked frame bay skins

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

EASA Composite Materials Safety Strategy



Damages Beyond Ultimate Load Considerations (from CMH-17 Fig. 12.2.2.2(a))

Warning!

Residual Strength (RS) sensitivity

- avoid steep RS curves, competing damage modes, undetectable damage modes

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EASA – AM WG1

Qualification of Additive Manufacturing (AM) Parts of No, or Low, Criticality (for use in Certified products) – Introduction and Scope:

WG1 Scope: metallic and **non-metallic AM parts** (of no/low criticality), AM repairs (including repair by replacement), as applicable to a **range of products** (airframe, systems, cabin safety, propulsion etc)

Who is this for? - Decision makers, typically in the supply chain beyond Type Cert Holder:

Reminder: Decision makers/designers exist in a diverse range of organisations with a broad range of capabilities and experience supporting a broad range of approvals… impact upon safety may not be clear to some of these organisations

- Supplemental Type Cert Holders
- Design Organisation Approval (DOA) Holders supporting MROs etc, e.g. under minor change approval, provided all aspects of the change meet the requirements for minor classification.
- ETSO/TSOs
- PART 145 organisations interpreting PART 145 etc (for information - allows repair by replacement)
- Stakeholders new to aviation, e.g. AM Machine Manufacturers.
- Regulators (in order to help define a 'level playing field' for industry)

no/low criticality – broader generic concept, not only of interest to AM

EASA