Certification Memorandum

Additive Manufacturing

EASA CM No.: CM–S-008 Issue 04 issued 06 May 2024

Regulatory references:
Primarily impacted product CSs:
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.A.447~~, 21.B.100, 21L, 145.A.42(b), CAO.A.020, M.A.603(c)

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.

Log of issues

Issue	Issue date	Change description
01	04.04.2017	First issue.
02	03.11.2020	Issue 2 included new supporting text for the existing basic CS materials requirements and guidance regarding the use of AM in non-critical parts. Issue 2 also emphasised the importance of the appropriate transfer of knowledge and training.
03	30.04.2021	Issue 3 included all changes introduced based on the comments received during the public consultation of Issue 2 from 3rd to 24th November 2020.
04	30.04.2024	Issue 4 includes revisions following various industry - regulator AM activities, e.g. annual industry – regulator AM Events 2021/2022/2023, supporting Working Group and SDO activities etc., addressing: - criticality classification - emphasis upon completing an appropriate design safety assessment - certification effort being proportionate to criticality - AM parts of no or low criticality (including examples) - reference updates - text re-organisation

Table of Content

1. Introduction

1.1. Purpose and scope

The purpose of this Certification Memorandum is to provide guidance regarding EASA certification effort expectations of industry associated with the introduction and use of Additive Manufacturing (AM) technologies (metallic and non-metallic) across a broad range of Products, Parts, and Appliances subject to showing compliance with CS-22, CS-VLA, CS-23, CS-25, CS-VLR, CS-27, CS-29, CS-E, CS-P, CS-APU, CS-ETSO, as well as other emerging product Certification Specifications (CSs) and Special Conditions (SCs), e.g. those addressing eVTOL etc.

This CM has been developed in conjunction with tasks, priorities, and objectives identified in various industry-regulator AM related activities, e.g EAAMIRG Actions.

EAAMIRG Action Item 1: Part Classification and Authority Engagement
EAAMIRG Action Item 2: Standardisation: understanding and use of 'standards'

Issue 3 of this CM was raised following rapid development in the planned use of AM since the initial release of the CM and also following considerable dialogue between industry and the regulators (in accordance with the intent of this CM at issue 1). Issue 3 included new guidance intended to support the existing certification specifications (see Appendix 1 of this CM), some of which have been superseded by revision to AMC 25.603, 605, and 613, for CS25 at amdt.27 (intended to address materials, processes, and fabrication methods, including Advanced Manufacturing methods, such as AM). Issue 3 also included some guidance associated with the use of AM in non-critical applications and emphasised the importance of appropriate knowledge transfer and training.

Issue 4 builds upon subsequent industry-regulator AM activities, including the annual industry – regulator AM Event 2021, 2022, and 2023 Working Group activities, and progress made in other various working groups, e.g. EAAMIRG, AIA, MMPDS, and Standards Development Organisations (SDOs). Amendments include reference to standardisation of understanding and awareness of criticality and new emphasis upon the importance of developing appropriate thorough design safety assessment processes, e.g. FHAs, FMECAs, RASs etc., particularly for non-Type Certificate Holder (TCH) organisations repairing or altering baseline structures and systems. Issue 4 also develops the intent for certification effort to be proportionate to criticality and provides further guidance regarding the use of AM in no or low-criticality applications, including the addition of a new 'examples' Appendix 4. At the time of this CM revision, AM has been used for new parts or parts produced for the purpose of 'repair by replacement'. Therefore, the scope for this CM Policy revision (Section 3) is limited to new parts or 'repair by replacement' for parts of no and low criticality. Further revision to this CM will be required for repairs involving material build up on baseline structure damaged (and prepared) surfaces.

Note: AM is a term used to cover a broad range of new and emerging manufacturing processes (also known as 3D printing) that involve sequential-layer material addition (metallic and/or non-metallic) throughout a 3D work envelope (i.e. 'build space', 'build volume') under automated control. This CM does not address established and approved methods which may demonstrate similarities with the evolving definitions of AM, e.g. repetitive weld build-up repair processes accepted prior to the issue of this CM.

Note: This CM does not attempt to catalogue the use of, or repeat detail from, the many evolving industry guidance documents related to AM materials, processes, fabrication methods, or applications. The use of such guidance, e.g. as developed by standardisation bodies, industry-regulator groups etc., may be accepted based upon demonstration of appropriate applicability and substantiation, as agreed with the competent authority.

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 of the safe use of AM in certified parts.

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

Section 3 content provides Policy. This revision addresses early engagement with EASA regarding AM and applications of no or low criticality (Classifications C and D).

1.2. References

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Note: Although it is not common to include reference to draft guidance documents in regulatory guidance, EASA considers that the context of this CM development justifies such referencing in Section 2 (addressing rapidly developing new technology applications) only for the purposes of developing discussion, particularly noting the intent of a CM (see cover page text). However, in the case of any perceived conflict of information, existing established regulatory guidance, including this CM, takes precedent and/or EASA may be consulted.

Reference	Title	Code	Issue	Date
AIA	AIA Recommended Guidance for Certification of AM Components			February 2020
ASTM F3572-22	'Standard Practices for Additive Manufacturing – General Principles – Part Classifications for Additive Manufactured Parts Used in Aviation'			2022
DO160	'Environmental Conditions and Test Procedures for Airborne Equipment'			2010
EASA CM 21.A-K-001	Installation of new parts and appliances without an EASA Form 1 https://www.easa.europa.eu/en/document-library/product-certification-consultations/easa-cm-21a-k-001-certification-memorandum		Issue 2	June 2023
EASA CM-S-002	'Application of CS 25.561(c)(2) 1.33 'Wear and Tear' Factor – Frequent Removal of Interior Structures' https://www.easa.europa.eu/en/document-library/product-certification-consultations/easa-cm-s-002		Issue 1	June 2014
FAA AC 33.15-3	Powder Bed Fusion Additive Manufacturing Process for Aircraft Engine Parts			2023
FAA AC 43-18	Fabrication of Aircraft Parts by Maintenance Personnel		Chg 2	Feb. 2008
FAA memo	Applicant Specific Guidance Memorandum for Additive Manufactured Parts for Transport Airplanes' (outline as delivered by FAA at the EASA FAA AM Event 2021):			2021

Reference	Title	Code	Issue	Date
	https://www.easa.europa.eu/newsroom-and-events/events/easa-faa-industry-regulator-am-event-0			
FAA RAS	Risk Analysis Specification (RAS) – https://my.faa.gov/sites/my.faa.gov/files/org/linebusiness/avs/offices/air/sms/cos/RiskAnalysisSpec.pdf			October 2006
ISO/ASTM DIS 52927:2022	'Additive manufacturing – General principles – Main characteristics and corresponding test methods'			2022

1.3. Abbreviations and Definitions

1.3.1 Abbreviations:

ADOA	Alternative Procedures to Design Organisation Approval
AIA	Aerospace Industry Association
AM	Additive Manufacturing
AMC	Acceptable Means of Compliance
AMPs	Advanced Materials and Processes
ASGM	Applicant Specific Guidance Memorandum (FAA)
ASTM	American Society for Testing and Materials
CACRC	Commercial Aircraft Composite Repair Committee
CDI	Compliance Demonstration Item
CM	Certification Memoranda
CMH-17	Composite Materials Handbook – 17
CRI	Certification Review Item
CS	Certification Specification
DDP	Declaration of Design Performance
DEV	Deviation
DO	Design Organisation
DOA	Design Organisation Approval
EAAMIRG	European Aviation Additive Manufacturing Industry Regulator Group
EASA	European Union Aviation Safety Agency ("the Agency")

EB-PBF	Electron Beam Powder Bed Fusion
ECS	Environmental Control System
ESF	Equivalent Safety Finding
ETSO	European Technical Standard Order
FAA	Federal Aviation Administration
FDM	Fused Deposition Modeling
FE	Finite Element
FHA	Functional Hazard Assessment
FMEA	Failure Mode and Effects Analysis
FMECA	Failure Mode, Effects, and Criticality Analysis
FPI	Flourescent Penetrant Inspection
GA	General Aviation
GM	Guidance Material
KPP	Key Process Parameter
LoI	Level of Involvement
LL	Limit Load
L-PBF	Laser Powder Bed Fusion
M&P	Materials and Processes
MMPDS	Metallic Materials Properties Development and Standardisation
MoC	Means of Compliance
NDI	Non Destructive Inspection
PCD	Process Control Document
PDA	Part Departing Aircraft
PFMEA	Process Failure Mode and Effects Analysis
POA	Production Organisation Approval
PSE	Principal Structural Element
RAS	Risk Analysis Specification (FAA)
SAE	Society of Automotive Engineers

SC	Special Condition
SDO	Standards Development Organisation
SPC	Statistical Process Control
STC	Supplemental Type Certificate
STCH	Supplemental Type Certificate Holder
TC	Type Certificate
TCH	Type Certificate Holder
UL	Ultimate Load

1.3.2 Definitions:

Allowable (AMC 20-29): Material values that are determined from test data 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.

A-Basis (MMPDS): The lower value of either the statistically calculated number T99, or the specification minimum (S-basis). The statistically calculated number indicates that at least 99 percent of the population is expected to equal or exceed the statistically calculated mechanical property value with a confidence of 95 percent. This statistical calculated number is computed using MMPDS (Vol.1) procedures, or similar, e.g. CMH-17

B-Basis (MMPDS): This designation indicates that at least 90 percent of the population of values is expected to equal or exceed the statistically calculated mechanical property value, with a confidence of 95 percent. This statistical calculated number is computed using MMPDS(Vol.1) procedures, or similar, e.g. CMH-17

C-Basis (MMPDS): The lower of either a statistically calculated number, or the specification minimum (S-basis). The statistically calculated number indicates that at least 99 percent of the population of values is expected to equal or exceed the C-basis material allowable, with a confidence of 95 percent. This statistically calculated number is computed using the procedures specified in MMPDS Volume II, Section 9.5. Use of these values to demonstrate compliance with static strength requirements requires further showing; see MMPDS Volume II, Chapter 10

Criticality: See Section 2 in this CM

D-Basis (MMPDS): At least 90 percent of the population of values is expected to equal or exceed the D-Basis material allowable, with a confidence of 95 percent. This statistically calculated number is computed using the procedures specified in MMPDS Volume II, Section 9.5. Use of these values to demonstrate compliance with static strength requirements requires further showing; see MMPDS Volume II, Chapter 10.

Design Safety Assessment (for the purpose of this CM): Terminology used in this CM to encompass all appropriate 'top down' and 'bottom up' assessments, e.g. Safety Assessments, FHA, FMECA, RAS etc.

Design Value (AMC 20-29): 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.

'End to end' (for the purposes of this CM): Terminology used to indicate consideration throughout design, production, and in-service, including raw material supplier, AM machine manufacturers and suppliers, and other stakeholders.

S-Basis (MMPDS): At least 99 percent of the populations of values are excepted to equal or exceed the S-Basis material allowable, with a confidence of 95 percent. This statistically calculated number is computed using the procedures specified in MMPDS Section 9.2.4.1, or similar. Use of these values to demonstrate compliance with static strength requirements may require further showing.
Note : Also see ESDU 00932 MMDH

Threat Assessment (AMC 20-29): Determination of 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 manufacturing, operation or maintenance

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

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IMPORTANT REMINDER:

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

Section 3 content provides Policy. This revision addresses early engagement with EASA regarding AM and applications of no or low criticality (Classifications C and D).

Additive Manufacturing (AM), also known as 3-D printing, refers to a range of manufacturing methods where the as-purchased feedstock material (i.e. powder, wire, filament etc.) is consolidated by a machine into a near-finished part. For example, for metallic materials, typically the as-purchased material is deposited in the machine by various methods and fused using lasers, electron beams, plasma or electrical arc into a near final shape component or surface, whilst non-metallic materials may be heated and extruded through a moving nozzle to create a final part. Consequently, these methods can produce complex parts with 'engineering properties' which are highly material, process, and configuration dependent and which may generate significant variability if production is not governed by strict process control documentation. Therefore, design and production of parts using AM on certified products will rely upon close communication between design organisations, production organisations, equipment manufacturers (and/or equipment suppliers) and material manufacturers and/or suppliers.

Background - Design certification regulations:

EASA review (within the EASA AM Working Group, see Appendix 5 'contacts' list) indicates that no CS level change is required to specifically address the use of AM. However, some broader revisions to CS25.603, 25.605, 25.613 AMC were completed in 2021 (see CS25 amdt.27) in order to update the texts and to better reflect recent and emerging materials, processes, and fabrication methods (often referred to as 'Advanced Materials and Processes' (AMPs) or 'Advanced Manufacturing'). Although the CSs have not been changed specifically for AM, these AMC amendments are also intended to better support certification of products including AM technology, e.g. by placing explicit emphasis upon the need to determine representative design values which may be defined during consolidation in the near-finished complex part configuration and which may impact addressing CS2x.305, CS2x.307, including appropriate test and analysis pyramid definitions. Furthermore, these revisions to the AMC have been made to better align with the regulatory move towards the use of 'Performance Based Regulation*' and also the need for certification effort to be proportionate to 'criticality', in accordance with Level of Involvement (LoI) regulatory guidance, ref. AMC 21.B.100(a).

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

Note: CS25 amdt.27 AMC revision addresses 'Large Aeroplane' products. However, they have been written to also be broadly applicable for consideration when showing compliance with other product CSs. EASA plans to amend and further align the other product CS and AMC texts accordingly and/or produce a generic AMC 20-XX document 'Advanced Manufacturing'.

Noting the 'novelty' of AM applications in aviation, scope is limited regarding potential use of existing experience based quantitative data (e.g. to assess frequency of relevant events) necessary to develop complete Risk Assessments in conjunction with criticality classifications to support existing EASA LoI strategies, e.g. EASA Point 21.B.100 and AMC (LoI). Therefore, 'engineering judgement' will be important to an initial 'step by step' strategy regarding the use of AM relative to criticality.

Note: Work addressing other developing technologies is in progress to support 'similar' processes (largely from a qualitative perspective), e.g. 'Guidelines for Modifying Composite Aircraft Structures' (draft), being developed by SAE CACRC, as tasked by FAA.

Note: EASA recognises that much of the content in this CM, particularly that associated with applications of no or low criticality, is adequately generic to be more broadly applicable to materials, processes, and fabrication methods other than AM. Therefore, the scope of applicability of this CM content could potentially be developed accordingly.

Background - Design certification – further EASA comments:

Although this CM does not intend to either repeat existing broader EASA requirements and guidance, or repeat detail from evolving AM guidance documentation, e.g. AIA 2020 Guidance Document, FAA AC 33 15-3 etc., EASA continues to emphasise the importance of the points below relating to certification of safe AM parts throughout the 'end to end' process:

Materials, facilities, and stakeholders: Independent of the facility where parts are to be fabricated, the applicant should demonstrate by test and/or experience, that all materials in the supply chain, e.g. feedstock and support materials etc., are purchased per approved material specifications and supported by inspection and control methods accepted within processes supporting the certified product. It should be shown that any material strength and design values are based upon representative and statistically significant test data (to the level required by the applicable CS and application) produced under process specifications that identify and define the key variables and parameters which govern the engineering properties (also known as Key process parameters (KPPs)). Material strength and design values must include variation induced by the feedstock material as well as machine-to-machine variation and address all allowed limits of the process envelope. It is important to demonstrate consistency through manufacturing hardware control, including robust machine qualification, maintenance, calibration and monitoring processes.

Note: The definition of Key Variables, Key Parameters, and expectations for demonstration of the sensitivity of the engineering properties to these parameters are yet to be standardised by industry.

Representative testing: Certification of compliance with CS's is expected to be achieved by 'test' or 'analysis supported by test'. Recent rapid advances in Modelling and Simulation and computational capability have increasingly challenged the established understanding of the link between test and analysis. Furthermore, industry increasingly wishes to replace testing with Modelling and Simulation (at all levels from micro scale through to aircraft level) and to 'optimise' design. This is particularly challenging for some AM materials and processes due to anisotropy and competing damage modes which, if not thoroughly understood and properly modelled, can potentially result in lower safety margins. Therefore, it is particularly important that the most certification information be gained from appropriate representative test configuration selections. It should be shown that design values obtained from tests conducted on simple specimens (e.g. built in parallel with the part etc.) accurately represent the mechanical and other engineering properties of the intended parts. Complex parts and processes will likely require, dependent upon criticality, testing higher in the test/analysis pyramid in addition to coupon level bulk material tests to truly represent the engineering properties resulting from the material, processes, and features in the part. For some configurations, this approach could be supported using appropriate Fatigue and Damage Tolerance design principles, including crack propagation analysis, as required by the relevant CSs. However, such an approach should not be used in place of rigorous material and process controls.

Production considerations and Design Values: In addition to the need to consider established production process parameters, AM part properties are potentially influenced by multiple other factors, including part orientation during the build process and the support structure required during the build operation (which is subsequently removed). These need to be addressed when establishing design values during certification.

Similarly requiring particular attention, from both design and production perspectives, are inaccessible surfaces which may be difficult to inspect and cannot be machined or surface treated such that the engineering properties may be different to those of the bulk material and/or other machined or surface treated material. Furthermore, the machining or application of surface treatments to accessible AM surfaces may result in material properties which may be different from those resulting from machining or surface treating of more conventionally manufactured parts using the same material due to the existence of different manufacturing anomalies, flaws, or defects at, or near, the surface. Thin wall structure is another design feature that requires particular attention.

Anomalies, flaws, and defects: All potential material and process related production defects, including those defects resulting from repair processes in maintenance environments, are to be identified by the responsible organisations and the 'effects of defects' are to be characterised at the appropriate levels of part configuration complexity, such that the strength and other properties used in the design data can be defined and maintained using the specifications. Furthermore, in support of ensuring that a safe product is produced should any defects outside those already identified and characterised within specifications (i.e. often referred to as anomalies or flaws) remain undetected during production, all likely damage modes are to be identified and characterised at the appropriate levels of the configuration complexity. These can be addressed within fatigue and damage tolerance processes (supported by an appropriate threat assessment), as required by relevant CSs. Such considerations may be of increasing importance if the potential benefits of AM are to be fully exploited, e.g. weight optimised designs or optimised production processes may introduce new failure modes and expose the structure to more low safety margins when compared to more conventional designs. For example, damage mode changes may change the critical failure modes in a structural element of a critical system, e.g. parts typically designed to be static strength critical could become fatigue critical etc.. Furthermore, a strategy is yet to be validated to address MoCs for AM parts subjected to dynamic events, e.g. CS2x.561, CS2x.562, for which an 'acceptable' level of safety has been long established based upon 'engineering judgement', 'service experience', and a limited combination of static and dynamic tests, e.g. seats.

Variability: AM variability is to be controlled through material specifications of the finished material that is based upon controls for raw feedstock material in combination with process controls defined in process specifications, including post processing operations. The applicant is responsible for ensuring that design values used in the evaluation of any parts produced using AM are applicable to the material and process specifications used to fabricate the parts and the facilities at which the parts are fabricated. This should be supported by appropriate process and inspection controls throughout the process chain that ensure product integrity is maintained.

Specifications and Standards: The applicability and appropriate use of published industry standards should be demonstrated. Applicants should also provide evidence that materials, processes, and fabrication methods are addressed by specifications and/or fabrication control documents that are under revision control. As required by point 21.A.31 (and 21L.A.26), the specifications for materials, processes, and fabrication methods shall be introduced in the type design under the design approval holder responsibilities.

Flammability: Parts subject to flammability requirements remain so regardless of their structural criticality and must meet applicable flammability, fireproof, and fire-resistant requirements such as CS2x.853, 2x.863, 2x.1191, or 23.2325. Development work with some non-metallic AM applications has shown flammability performance to be dependent upon AM manufacturing details, such as hatching infill and print orientation etc.. Therefore, a feedstock supplier Certificate of Conformity has not been sufficient to satisfy flammability without some testing of an article printed at the production facility.

Note: Industry and the regulators have not yet agreed upon need for AM specific flammability MoCs. Therefore, applicants should conult their regulators accordingly.

Knowledge transfer and training: Historically, knowledge transfer and training has not been problematic for conventional technologies because the technology introduction has typically been at an adequately slow rate allowing much of the knowledge transfer to occur over time, often relying upon on the job training and/or staff movement throughout design, production, in-service, and regulatory organisations. However, as technology development and integration has accelerated, it has become an increasing challenge to develop a knowledgeable workforce at the rate desired by industry, particularly as more critical applications are planned. This has already been evident in the composite industry, as the recent step change to include large passenger aircraft with extensive composite PSE structures has occurred. This has required some additional focus upon knowledge transfer and training expectations, as evidenced in recent certification programmes and SDO activities, e.g. SAE CACRC, CMH-17.

The ultimate responsibility of the TCH/STCH/DOAH regarding the product TC, or STC, including changes, requires that appropriate knowledge transfer and training occurs to ensure a safe product or repair, paying particular attention to functional and organisation interfaces, e.g. between DOA holders and the POA holder, and between subcontractors. This knowledge transfer and training should ensure that all stakeholders have appropriate and current knowledge regarding the AM technologies being used and that all staff roles and responsibilities are fully understood in order to help ensure that parts produced according to the design data, including the approved manufacturing process specifications, will result in a consistently safe structure. Such interfaces have been challenging, in some cases, for more conventional technologies. For example, there have been potential safety issues associated with design-production-material supplier interfaces, and also discipline interfaces, such as engine-structure interfaces. Therefore, it is considered appropriate for organisations involved in AM technologies to benefit from 'lessons learned' and to pay particular attention to training and knowledge transfer, particularly in supply chains comprising of many small organisations.

Design certification 'Criticality' and proportionate certification effort:

For the purposes of this CM, use of the term 'criticality' primarily refers to safety related 'criticality', defined relative to catastrophic failure and passenger safety is maintained. It should not be confused with process 'criticality' which often more specifically refers to maintaining consistency and quality of a product regardless of safety considerations. However, it is recognised that safety related criticality is dependent upon process criticality, as evident in the CS's.

Historically, the CSs have been developed to apply to a broad range of parts, structures, and systems, which address a broad range of criticalities relative to safety. General guidance supporting the understanding and determination of criticality is available from various sources, including CS 2x.1309 and the definition used to support Point 21.B.100 which provides a recent example of a definition of ***safety related 'criticality'*** (to be used for the purposes of this CM, as below):

'… measure of the potential impact of a non-compliance with part of the certification basis on product safety or on the environment'.

The supporting guidance continues:
'…The potential impact of a non-compliance within a Compliance Demonstration Item (CDI) should be classified as ***critical*** *if, for example:*
— a function, component or system is introduced or affected where ***the failure of that function, component or system may contribute to a failure condition that is classified as hazardous or catastrophic at the aircraft level*** *…'*

Some product CS's include specific content which is applicable to subsets of parts, structures, or systems, which are considered to be more critical to maintaining safety than others.For example, parts the failure of which could contribute to a catastrophic failure such as Critical Parts, PSEs, etc..

Note that the 'criticality' terminology associated with parts, structure, and systems, is sometimes inconsistent across the range of products and CSs, although broadly addressing similar intents. This CM does not yet attempt to address these inconsistencies. This CM does not supercede any established criticality classification practices, e.g. part identification and management associated with 'Critical Parts', ref. PART 21, but attempts to start to standardise some aspects of these practices relative to certification effort being proportionate to criticality, when appropriate.

Noting that AM is relatively new to many in aviation, it will be a particular challenge to develop appropriate knowledge and a body of data to certify AM parts of any significant criticality in the near future. However, some simple applications can readily be determined to be of no or low criticality, i.e. being of no, or minimal, safety concern., provided that such determination is supported by an appropriate design safety assessment, e.g. some small interiors items, some minor systems-structures such as multiple redundant brackets supporting non-safety critical systems, etc., see Appendices 2, 3, and 4.

Industry - regulator work continues regarding the definition and management of criticality, e.g. ASTM published standard F3572-22, and related work with EAAMIRG attempts to identify commonalities in criticality across a range of products and applications to help better standardise and simplify industry certification approaches in a manner proportionate to the criticality. The table below identifies criteria defining commonality of classifications of criticality across products, the first 3 columns being common to ASTM F3572-22 (Table 1):

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 injury to passengers or cabin crews 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 passengers 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

Table 1: AM PART CRITICALITY CLASSIFICATION – STANDARDISATION ACROSS PRODUCTS

Certification effort proportionality to part criticality - Tables:

The tables below highlight subjects most likely to be affected when certifying AM parts. The list is not intended to be exhaustive or complete in detail. These tables are intended to support defining certification efforts proportionate to criticality, novelty (to the industry and/or applicant), and complexity. These tables do not attempt to address all regulations or alleviate the need to satisfy all relevant regulatory requirements appropriately (see Appendix 1 of this CM). For example, these tables do not attempt to address flammability, conductivity, or similar specific performance requirements, but do illustrate where repeatability of performance may be significantly impacted by M&P controls.

All aviation parts and products are required to meet the relevant certification specifications and other means prescribed or required by EASA as part of the type certification basis, e.g. strength, durability, flammability etc., regardless of the material and process combination. Historically, some certification effort proportionality to part criticality has long been accepted, if not formalised, for more conventional and established technologies. Therefore, the tables below represent an effort to provide some formalisation of this concept whilst identifying the subjects (the column headings) most likely to be of interest to the regulators.

Proportionate MoC Tables - General Notes:

- it is important that the intent of CS25/29.601 is satisfied in all cases for all products, although this CS is not specifically addressed in all product CSs.

- reference to part Criticality Classifications A,B,C, and D, as used in the tables, should not be confused with reference to statistical A-Basis, B-Basis, C-Basis, and D-Basis data used by MMPDS

- material properties generated from test specimens considered to provide 'representative' and repeatable material properties for the application should be produced with the selected feedstock material using the frozen AM process parameters including post-fabrication operations.

- if the results of testing indicate a directional variation in properties (anisotropy), design values should be developed for each orientation or the orientation yielding the lowest properties should be conservatively considered when establishing the minimum baseline material strength and design values.

- number of test specimens and associated statistical analysis must be determined according to recognized standards and/or documented company internal procedures (recognising industry diversity regarding use of recognised industry standards relative to substantiated and accepted in-house practices). The proposed approach can include proportionality between the statistical analysis and the part criticality.

- the parameters defining the design value should be clearly identified (type of part, dimensions…).

- applicants will perform at least one certification project (dependent upon criticality and agreement with the regulators) to demonstrate initial use of the design values derived from coupons to show relation to part application. Subsequent applications for 'similar' parts may re-use design values and other data, supported and substantiated by a summary of engineering developmental tests.
Note: This concept (sometimes identified as the 'part family' concept) is yet to be standardised, so will initially be expected to progress on a 'step by step' basis relative to criticality and in agreement with regulators on a 'case by case' basis.

- in accordance with EASA and industry intent to take a 'step by step' approach to AM adoption relative to criticality, regulators are unlikely to accept as a first step 'fail safe' and other multi-load path configurations for Class A parts relying fully upon AM for all load paths or other functionalities, e.g. all redundant parallel system functionalities. Note that the definition of the boundaries between systems and structures are yet to be standardised.

- effective and safe use of these tables relies significantly upon the correct classification of criticality, depending upon thorough design safety assessments extending beyond consideration of part functionality to consider the potential for other threats which may not have been evident using previous established technologies and applications, e.g., noting that Class A and B are, by definition, more significant to safety, it will be essential that the applicant clearly demonstrates that it has established proven design philosophies and practices to ensure that distinction between potentially 'Catastrophic' or 'Hazardous' outcomes is valid for the application such that the need to demonstrate full compliance with appropriate fatigue and damage tolerance requirements, e.g. CS25.571, CS E-515, etc. is correctly determined. Furthermore, acceptance of less rigorous, and proportionate, MoC for Class C and D is dependent upon a clear classification at these lower criticality levels, see Appendices 2, 3, and 4.

The following tables are provided for Large Aeroplanes, Large and Light Rotorcraft, and Engines. No General Aviation (GA) specific table is yet proposed due to very limited indication of industry intent to submit such proposals to EASA at the time of this CM revision. However, a 'similar' approach to that described below will likely be taken for GA until a GA specific table becomes necessary.

Table Key: X = full MoC*, S = Simplified MoC*, N = No/Negligible MoC*, (?) = 'footnote' number, see 'footnotes' following tables. CAT = 'Catastrophic', Haz = 'Hazardous', MAJ = 'Major', MIN = 'Minor', NSE = 'No Safety Effect', NA = Not Applicable

*reference being different for each box, each box to be referenced to 'conventional' MoC practice in each case.

			Material and Process control	Design Values / Material soundness	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)	N(9)	As required (6)	As required (7)
	B	(MAJ)	X	X (3)	X (4)	N(9)	As required (6)	As required (7)
	C	(MIN)	S (2)	S(5)	S (4)	N(1)	N(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:

(1) subject to design review by appropriate design authorities, e.g. TCH, DOAH, STCH, ETSO, etc., no showing for Class D parts (and no showing for some requirements associated with Class C parts) may be accepted because there is no effect on safety including consideration of the material and process selected for construction. Effective and safe use of this table relies significantly upon the correct classification of criticality as being Class C or D, also see Appendix 2 and 3.

(2) qualification can be simplified, for example by using a reduced number of tests subject to the application and supporting rationale, yet to be standardized, e.g. only minimum static strength values are defined. Note: competing failure modes evident at coupon level may limit scope for this approach.

(3) statistically valid material allowables and design values required, e.g. T90 or T99 data (e.g. C or D-Basis for AM data), or equivalent, but unlikely to be S basis data for Class A and B parts) only when showing compliance by analysis. The applicant will perform at least one certification project (dependent upon criticality) to demonstrate initial use of design values derived from coupons to show relation to part application (see 'Proportionate MoC Tables - General Notes' above):

(4) proof of structure can be shown by analysis or by element/ part level test (supported by appropriate boundary conditions). Full scale airplane level testing is not required. Non-recurring element/part level testing must account for material & process variability. If material and process variability is not quantified, then recurring, element/part level acceptance testing can be used. Testing could include a 'Point Design' or 'Proof Test' strategy (possibly supported by testing of prolongations from every part or build etc.) which may be dependent upon part complexity, competing damage modes, and extent of low safety margins. The definition of 'Point Design' and associated strategies are yet to be standardised.

(5) design values can be based upon analysis using specification minimums per (2) adjusted with any necessary influence factors that capture unique failure characteristics of the part (developed through engineering tests) and per the choice of appropriate design authority, e.g. TCH, DOAH, STCH, ETSO, DAH/TC Holder.

(6) windmilling aspect of CS25.901c and 25.903c can require fatigue substantiation for any applications potentially impacting Continued Safe Flight and Landing (CSF&L).

(7) demonstrate that the reliability thresholds are met. Material and Process characteristics and strength aspects are considered in the test program in support of system qualification (e.g. Declaration of Design Performance (DDP)).

(8) not applicable as no single failure may lead to catastrophic failure, systems typically being fail safe designed. However, demonstration may be necessary to support justification for this approach.

(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. **However, for 'N' to be accepted (i.e. CS25.571 MoC are not required) 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 anomolies, flaws, and potential defects.**

			Material and Process control	Design Values / Material soundness	Static Strength	Fatigue / Damage Tolerance
Requirements for Structures & CS 27/29.1309 Equipment, systems and installations (7)	Helicopters		CS 27/29.603 Materials and CS 27/29.605 Fabrication methods	CS 27/29.613 Material strength properties and Material Design Values	CS 27/29.305 Strength and deformation CS 27/29.307a Proof of structure	CS 27.571 Fatigue evaluation of flight structure CS 29.571 Fatigue tolerance evaluation of metallic structure CS 27/29.573: Damage tolerance and fatigue evaluation of composite rotorcraft structures
Part Classification (see new ASTM-F42 standard)	**A**	(CAT)	X	X (3)	X (4)	X
		(HAZ)	X	X (3)	X (4)	N (9)
	B	(MAJ)	X	X (3)	X (4)	N (9)
	C	(MIN)	S (2)	S (5)	S (4)	N (1)
	D	(NSE)	N (1)	N (1)	N (1)	N (1)

Table 2b: CERTIFICATION EFFORT PROPORTIONALITY TO PART CRITICALITY – Large and Light Rotorcraft (table key above)

Large and Light Rotorcraft - Footnotes:

(1) as 'footnote' (1) Large Aeroplanes above

(2) as 'footnote' (2) Large Aeroplanes above

(3) as 'footnote' (3) Large Aeroplanes above

(4) as 'footnote' (4) Large Aeroplanes above

(5) as 'footnote' (5) Large Aeroplanes above

(6) NA

(7) CS27/29 Subparts C and D are applied to Systems as soon as dealing with structural parts integrated into a system. Materials and Process characteristics and strength aspects are considered in the test programme in support of system qualification, e.g. DDP.

(8) N/A

(9) **effective and safe use of this table relies significantly upon the correct classification of criticality**. No need for application of CS27/29.571 and 573 is possible based upon demonstration of appropriate assessment of criticality as class A Haz or class B Major, as agreed with the regulator. For 'N' to be accepted (i.e. CS27/29.571 and 573 MoC are not required) 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 anomolies, flaws, and potential defects. Note: 'Critical Parts', ref. CS27/29.602 are considered to be beyond the scope of discussion for this CM revision.

			Average properties, Allowables and Design Values characterization	Material control	Process Control	Scale factors to define Design Values (7) *(Covering specific material properties required for the part eg static strength, fatigue and vibration)*	Damage Tolerance	Fire Precautions	Oxidation / corrosion (8)
Requirements for	Engines		CS-E 70 (a) Material and Manufacturing Methods	CS-E 70 (b) Material and Manufacturing Methods	CS-E 70 (b) Material and Manufacturing Methods	CS-E 100 (a) (c) Strength CS-E 520 Strength CS-E 650 Vibration Survey	CS-E 515 Engine Critical Parts (a)	CS-E 130 (b)(c)(d)(e)(g) Fire Protection	CS-E 90 Prevention of corrosion and deterioration
Part Classification	**(HAZ)**	**A**	X	X	X	X	X(1)	As required (3)	X
	(MAJ)	**B**	X(6)	X(6)	X	X(6)	N(9)	As required (3)	X
	(MIN)	**C**	S (4) (6)	S(4) (6)	S	S(6)	N(9)	As required (3)	S
	(NSE)	**D**	N(2) or S(5) if necessary	N(2) or S(5)	N(2) or S	S if necessary	N(9)	N (3)	S

Table 2c: CERTIFICATION EFFORT PROPORTIONALITY TO PART CRITICALITY – Engines (table key above)

Engine - Footnotes:

(1) only applicable for Engine Critical Parts as per CS-E 515 definition (corresponding to Engine Life Limited Parts according PART 33.70).
(2) no further demonstration required for parts defined through an appropriate use of standards.
(3) if specific material properties for Fire Resistance, Fireproofness or Firewall are needed for certification demonstrations, then Class D components should not directly contribute to Fire Resistance, Fireproofness or Firewall demonstrations.
(4) material and process specifications must be defined. Material qualification can be simplified, for example only minimum static strength values are defined for the whole operating temperature range of the part.
(5) material and process specifications must be defined. Material qualification can be simplified, for example only minimum static strength values are defined.
(6) statistically derived allowables and design values required only when showing compliance by analysis.
(7) generic scale factors:

- when applicable, scales factors must be defined.
- particular attention has to be paid to surface roughness

(8) manufacturing process influence on the oxidation / corrosion resistance of the part has to be assessed (see generic Table notes above)

(9) **effective and safe use of this table relies significantly upon the correct classification of criticality**. For 'N' to be accepted (i.e. CS E-515 MoC are not required) 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 anomolies, flaws, and potential defects.

~~2.~~3. EASA Certification Policy and Guidance for DOA, ADOA and POA Holders*

*see Appendix 1 for associated regulations

IMPORTANT REMINDER:

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

Section 3 content provides Policy. This revision addresses early engagement with EASA regarding AM and applications of no or low criticality (Classifications C and D).

All aviation products, parts and appliances are required to meet the relevant certification specifications or other means agreed or prescribed by EASA, e.g. DEV, ESF, SCs etc., respectively, including the ETSO minimum performance standards, according to the type certification basis, e.g. regarding strength, durability, flammability etc.., regardless of the material, process, or fabrication methods used to generate the engineering properties. Therefore, the significance of using additive manufacturing should be considered when establishing the certification programme (and MoCs) in accordance with 21.A.15, 21.A.93, 21.A.432C, 21.A.605, or the compliance demonstration plan in accordance with 21L.A.24 and 21L.A.43.

3.1. Design Certification – early engagement with EASA

Individuals or organisations responsible for the design and certification of AM parts (or any repair activities using AM) should pay special attention to the many important considerations, including those below, in the development of AM parts or repairs, ideally before initiating discussion with EASA:

- identify, and demonstrate understanding of, the criticality of the application (inclusively accounting for potential new damage and failure modes introduced by AM etc., see Section 2) supported by an appropriate threat assessment and design safety assessments, e.g. FHA, FMECA, RAS etc., including both 'top down' and 'bottom up' assessments.
  Note: EASA would expect applicants to use a 'step by step' approach to product criticality evolution, i.e. initially develop experience with applications of no or low criticality (significantly below potentially hazardous or catastrophic), prior to considering more critical applications. Furthermore, EASA certification expectations of an applicant will be proportionate to the application criticality, ,novelty, and complexity, see Appendix 2, 3, and 4 regarding parts of no or low criticality (C and D Classifications only, higher criticality applications are likely to be addressed in future CM revisions).
- identification of the Key Variables and Key Parameters and demonstration of understanding of the sensitivity of the engineering properties important to the safety of the final parts and products to the Key Parameters.
  Note: The definition of Key Variables, Key Parameters, and expectations for demonstration of the sensitivity of the engineering properties to these parameters are yet to be standardised by industry.
- statistical coverage of engineering properties important to safety (noting the potential for many influencing parameters, variability, and different competing damage and failure modes). When certification is predominantly by analysis, it is essential that design values account for variables introduced throughout the AM process used to fabricate production parts, including consideration of the variables associated with the constituent materials (e.g. powder or wire) and post processing.
  Note: The statistical management of complex part design value development by 'Point Design' or 'Detail' testing is yet to be standardised.

- appropriate and substantiated use of standards
- 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.

Note: Applications to EASA may also be supported by applicable information included in the recently introduced FAA Applicant Specific Guidance Memorandum (ASGM) intended to encourage early project preparation and engagement with FAA for AM projects, as presented at the EASA FAA AM Event 2021. The ASGM is further identified in the FAA product specific 'Issue Lists':
Transport:
https://www.faa.gov/aircraft/air_cert/design_approvals/transport/media/rptTAIListForPublicWeb.PDF
Small Aircraft:
https://www.faa.gov/aircraft/air_cert/design_approvals/small_airplanes/small_airplanes_regs/media/SAIL_FY22_Q1.pdfRotorcraft:
https://www.faa.gov/aircraft/air_cert/design_approvals/rotorcraft/media/RD_SPL.pdf
Engines:
https://www.faa.gov/aircraft/air_cert/design_approvals/engine_prop/issues_list/

3.2. Certification Programmes and MoCs

As required by standard EASA certification processes, e.g. for TC or a major type change, EASA typically expects applicants to submit a certification plan, referenced to the appropriate CSs and other means prescribed or required by EASA in the certification basis, supported by MoCs identifying how the applicant intends to demonstrate compliance with the certification basis.

Regulations already include some guidance supporting MoC expectations for some parts and products (particularly those of higher criticality), e.g. , CS 27.602 and CS 29.602 for rotorcraft Critical Parts requires a critical parts plan whilst CS-E, e.g. CS-E-515 for Critical Engine Parts, requires an Engineering Plan, a Manufacturing Plan, and a Service Management Plan. These are considered to be useful means of communicating and standardising delivery of 'end to end' data (design, production, and in-service) to the regulatory authority for integrated technologies, such as AM. Therefore, EASA encourages applicants using AM to consider developing project documentation content using these concepts, e.g. Engineering, Manufacturing, and Service Management Plans, if an established means of communication with the regulatory authority does not already exist. The content and extent of data included can be adapted to be proportionate to criticality for broader use beyond critical engine applications, e.g. for other product parts of no or low criticality.

Applicants engaged with post TC activities are also reminded that Instructions for Continued Airworthiness are required to ensure that the product, and changes to it, can be maintained in an airworthy condition.

~~2.1.~~3.3. Design Certification - Changes and Repairs

In accordance with the Guidance Material contained in Appendix A to GM 21.A.91, the use of AM in Changes and Repairs to Type Certificates and Supplemental Type Certificates is considered to be a change to the material, process, and method of manufacture and should be evaluated as such when classifying changes and repairs. For repair, and repair design, the guidance contained in this CM (including relevant guidance under Appendix 1 of this CM) should also be considered when evaluating the use of AM, including consideration of the impact of AM upon the original baseline structure materials and engineering properties when appropriate. The 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 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.

~~2.2.~~3.4. Impact of AM on design organisations

Design Organisation Approval Holders as well as Design Organisations using ADOA are advised to involve the Agency at the earliest opportunity during the development and implementation of AM. It is envisaged that the use of AM will initially lead to a higher level of involvement of EASA in compliance verification. In addition, specific audits may be scheduled to examine the introduction and use of AM within the scope of the design organisation audit cycle. These audits may take place concurrently with the review of AM applications rather than post approval.

Note: The 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.

~~2.3.~~3.5. Impact of AM on production organisations

Production Organisation Approval holders are advised to inform their respective competent authorities at the earliest opportunity before the implementation of AM processes.

Implementation of an AM process by a POA holder is controlled through the applicable design data identified and transferred to the POA holder under the responsibility of the design approval applicant or holder. The design approval applicant or holder is also responsible for showing that the applicable design data complies with the requirements of point 21.A.31. The POA holder shall ensure compliance to the applicable design data of the items it produces under its POA.

Implementation of an AM process that is new for the POA holder is a change to the approved production organisation that may be 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.

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 (which includes 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.131.

To ensure that such a change to the approved production organisation does not result in any non-compliance with Part 21 Section A Subpart G, it is in the interest of both the competent authority*and the POA holder, to establish a relationship and exchange information that will permit the necessary evaluation work to be conducted before the implementation of the change. In case of such a change, the competent authority is recommended to inform EASA, and, as usual, these parties are also recommended to cooperate closely. It is recommended that the use of AM will be subject to specific oversight by the competent authority, either in the frame of significant change(s) according to point 21.A.147 (when applicable) and/or continued surveillance of the POA holder.

*reference point 21.A.234 and point 21.A.134 for DOA holder and POA holder considerations respectively

Transfer of knowledge and training:

In support of existing regulations, applicants are required to demonstrate that staff have appropriate levels of knowledge and training throughout design, manufacture, and in service activities, e.g. PART 21.A.145(a), GM 21.A.139(b)(1) etc.. This also applies to the regulatory authorities, ref. PART 21.B.25(c) 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.

4. Whom this Certification Memorandum affects

This Certification Memorandum is applicable to individuals and organisations introducing AM during 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 in CS-22, CS-VLA, CS-23, CS-25, CS-VLR, CS-27, CS-29, CS-E, CS-P, CS-APU, CS-ETSO's etc., including other emerging product Certification Specifications (CSs) and Special Conditions (SCs), e.g. those addressing eVTOL etc.. 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.

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.

5. Remarks

1. Suggestions for amendment(s) to this EASA Certification Memorandum should be referred to the Certification Policy and Planning Department, Certification Directorate, EASA. E-mail CRT@easa.europa.eu.
2. For any question concerning the technical content of this EASA Certification Memorandum, please contact the appropriate EASA focal point as identified in Appendix 5.

Appendix 1: Applicable regulations and guidance

All aviation parts and products are required to meet the relevant certification specifications and other means prescribed or required by EASA as part of the type certification basis, e.g. regarding strength, durability, flammability etc.,, regardless of the material and process combination used to generate the engineering properties. However, those CSs likely to require particular attention associated with the introduction of AM include (see also Section 2, tables 2a, 2b, 2c):

Reminder: CS23 at amendment 5 or later amendments do not carry the same CS numbering as CS-23 until Amdt 4.

- CS 2X.305 Strength and Deformation
- CS 2X.307 Proof of Structure
- CS 2 X.561 Emergency Landing Conditions
- CS 2X.562 Emergency Landing Dynamic Conditions
- CS 2X.571 Fatigue & Damage Tolerance
- CS 2X.601 Design
- CS 2X.603 Materials
- CS 2X.605 Fabrication Methods
- CS 27/29.602 Critical Parts
- CS 2X.613 Material Strength Properties and Material design Values
- CS 2X.853 Compartment Interiors
- CS 2X.901c Powerplant Installation
- CS 2X.903c Engines (control of engine rotation)
- CS 2X.1191 Firewalls
- CS 2X.1309 Equipment, systems and installations
- CS 2X.1435 Hydraulic Systems
- CS 23.2240 Structural Durability
- CS 23.2260 Materials and processes
- CS 23.2325 Fire Protection
- CS APU 60 Materials
- CS APU 130 Mount Strength
- CS APU 150 Critical Parts
- CS APU 210 Safety Analysis
- CS APU 300 Vibration
- CS E 70 Materials and Manufacturing Methods
- CS E 90 Prevention of Corrosion and Deterioration
- CS E 100 Strength (a)
- CS E 170 Engine Systems and Component Verification
- CS E 510 Safety Analysis
- CS E 515 Engine Critical Parts
- CS E 520 Strength
- CS E 650 Vibratory Survey
- CS P 170 Materials and Manufacturing Methods
- CS P 150 Propeller Safety Analysis
- CS P 160 Propeller Critical Parts Integrity
- CS P 240 Strength

Note: The need to specifically include CS2x.619* in the highlighted list above has been discussed between industry and competent authority on several occasions. However, the current consensus is that the material, process, fabrication requirements, and other specifications listed above, should be adequate to address the material, process, and fabrication, aspects of Cx.619, as has generally been the case for the use of composite materials and processes. However, the need to consider the other aspects of CS2x.619, and

the other specifications listed in CS2x.619, should be considered independently based upon the part configuration and the relationship between test and analysis, noting that the need for additional factors should also become evident via representative testing of the complex AM part (and/or details) as defined in an appropriate test and analysis pyramid.
*CS 23.2265 for CS23
Note: The potential to adapt CS25.621 'Casting Factors' for use with some AM technologies and applications is yet to be established.

Further to the CSs above, the showing of compliance with the following PART 21 regulations may be impacted by the introduction of AM into aviation products:

- Point 21.A.15 Application
- AMC 21.A.15(b) Content of the Certification Programme
- Point 21.A.31 Type Design
- GM 21.A.91 Classification of Changes to type design
- Point 21.A.93 Application
- Point 21.A.101 Designation of applicable certification specifications and environmental protection requirements
- Point 21.A.131 Scope – Applicable Design Data
- Point 21.A.133 Eligibility
- Point 21.A.147 Changes to the approved production organisation
- Point 21.A.247 Changes in design assurance system
- Point 21.A.307 The eligibility of parts and appliances for installation
- Point 21.A.432C Application for repair design approval
- Point 21.A.433 Requirements for approval of a repair design
- Point 21.A.435 Classification and approval of repair designs
- GM 21.A.435 (a) Classification of Repairs
- Point 21.A.608 Declaration of Design Performance
- Point 21.A.805 Identification of Critical Parts
- Point 21.A.807 identification of ETSO articles
- Point 21.B.100 Level of Involvement
- Point 145.A.42(b) Components
- CAO.A.020 Terms of approval
- M.A.603(c) Extent of Approval

Note: See also PART 21 Light – Making Design & Manufacturing Easier

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

For parts of no or low criticality (criticality classifications C and D ONLY, see ASTM 3572-22 Table 1), i.e. being of no, or minimal, safety concern, either at aircraft or passenger level, and considering the 'Certification Effort Proportionality to Part Criticality' tables and 'footnotes', see Section 2 in this CM, the applicant will be required to demonstrate, at least:

- 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. The extent of initial work is likely to be beyond that expected for a similar application of no or low, criticality using 'conventional' technologies until use of the novel AM material and/or process (novel to the industry and/or applicant) has been successfully established, also see comments in Appendix 4 'Examples' introduction text.
- that criticality has been correctly assessed, supported by an appropriate design safety assessment including both 'top down' and 'bottom up' processes, see Appendix 3, such that it may be easily demonstrated that the AM part does not adversely impact safety, e.g. relative to conventional technologies used for similar applications, allowing for all likely defect, damage and failure modes including consideration of potential non-conformities. etc.
- conservative design practices have been used, including consideration of attachments to surrounding structure etc..
  Note: Although inclusion of redundant attachment points may be beneficial, e.g. in order to help ensure that part separation does not occur, care will also be necessary to ensure that the baseline structure or product is not adversely affected, e.g. due to 'wear and tear', fretting, galvanic incompatibility, contamination, misalignment, access for inspection etc..
- an appropriate use of standards, e.g. SDO standards, or in-house specifications etc.. Subject to clear demonstration of no or low criticality classification, appropriate use of some test standards not specific to aviation could 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 limited low loads (see note below), 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.
- direct part testing (certification by 'Point Design' or 'Detail' testing supporting CS2x.305 etc.) in addition to, or in place of, coupon testing may be more appropriate in order to determine unique failure characteristics, particularly for complex parts, which could be supported by appropriate use of further conservative factors in design. However, such an approach may be challenging for many reasons, including the definition of representative load cases (and boundary conditions), and because testing may be difficult, e.g. due to practical limitations regarding representative load transfer into small complex parts etc.. A standardised approach is yet to be developed and agreement with a competent authority will be necessary until such standards are developed.
  Note: The need to address vibration loads and potential related degradation relative to the identification and assessment of parts of no or low criticality is yet to be established and standardised. However, although certification effort expectations are likely to be minimal for C and D classified parts, some justification regarding performance in a vibratory environment would be expected (and/or including reference to previous similar experience), e.g. demonstration of durability, testing in accordance with DO-160 etc.etc.. EASA is of the opinion that such consideration is likely to have formed part of any commercially driven material and process selection decision, so should also (at least) form part of any potentially safety related assessment.

Note: For products intended for both civil and military use, inconsistencies may exist between civil and military standards addressing vibration and fatigue. Any differences should be identified and addressed accordingly.

- flammability requirements are potentially the first regulatory requirements challenging many parts which would otherwise be considered to be of no and low criticality, e.g. some smaller interiors parts. However, the need for AM specific actions for flammability considerations has not been agreed or standardised, although some variation in practices has been noted, also see Section 2 and 3. Therefore, flammability MoCs should be agreed with the regulator on a 'case by case' basis until such standardisation is completed.
- agreement to use the approach described in this Appendix with the regulatory authority on a 'case by case' basis, unless the repair or replacement application can be readily shown to fall within the scope of this CM guidance and previous regulatory agreement, in which case such data would need to be available to the regulatory authority in accordance with established regulatory authority practices, e.g. during audits, upon request etc., as required by the scope of the applicants approval.
- the use of small datasets should follow acceptable statistical practices.

No and low criticality classification – further EASA comments: In order to help further support identification of parts which might be considered as being potential candidates for such consideration, without intending to be exhaustive, EASA makes the following references....:

PART 21.A.307 'Parts without Form 1': PART 21.A.307(b)3 and (b)4 provides some guidance regarding identification of 'parts with negligible safety effect' for which release does not require a EASA Form 1, i.e. https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-airworthiness-and?page=1&kw=307

(a) for ELA1 and ELA2 aircraft, at worst:
(1) slightly reduces the operational or functional certified capabilities of the aircraft or its safety margins;
(2) causes some physical discomfort to its occupants; and
(3) slightly increases the workload of the flight crew; and

(b) for any other aircraft:
(1) has no effect on the operational or functional certified capabilities of the aircraft, or on its safety margins;
(2) causes no physical discomfort to the occupants; and
(3) has no effect on the flight crew.'

EASA CM 21.A-K-001 'Installation of new parts and appliances without an EASA Form 1': This provides further guidance regarding the determination of appropriate part classification for parts potentially not requiring a Form 1. This emphasises the importance of an appropriate assessment, including consideration of the significance of the impact of a non-conformances upon safety outcomes..

EASA CM-S-002 'Frequent removal of interior structures': Furthermore, interior parts which might be considered as being candidates for no or low criticality classification could include those below the mass thresholds , as adapted from EASA CM –S-002 Note 1:

'Interior items of mass < 0,45 kg (1lb) (or < 0,15 kg (1/3lb) if attached to a seat, ref. AC 25.562-1). However, this low criticality candidate threshold will not be considered for any safety equipment mountings (PBE, Fire Extinguishers, Oxygen Bottles, etc.. Such critical applications will require full certification MoC consideration).'

Items addressed by ETSO will be expected to demonstrate similar considerations.

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 and do not constitute any legal obligation'. However, for the purposes of pursuing proportionate regulation 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 applicant 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.

Note: For smaller and less complex GA aircraft, see also PART 21 Liight – Making Design & Manufacturing Easier

Note: Design organisations are reminded of their responsibilities regarding engagement with POA Holders and other stakeholders in the supply chain, including AM machine manufacturers and suppliers.

Note: For the purposes of certification efficiency, particularly for parts of no or low criticality, being of no, or minimal, safety concern either at aircraft or passenger level, and in order to help to provide a 'level playing field', EASA is of the opinion that industry may benefit from:

- developing common standards supporting expectations for compliance data, e.g. statistics, testing etc..,
- developing simple common data presentation protocols for the purposes of supporting certification

These actions may aid the efficiency of certification and regulatory authority audit processes.

Such tasks could be addressed through use of an appropriate standardisation organisation, or other industry/regulatory authority groups, and should not compromise the classification and criticality assessment of the product as agreed between applicants and the regulatory authorities through normal product certification processes.

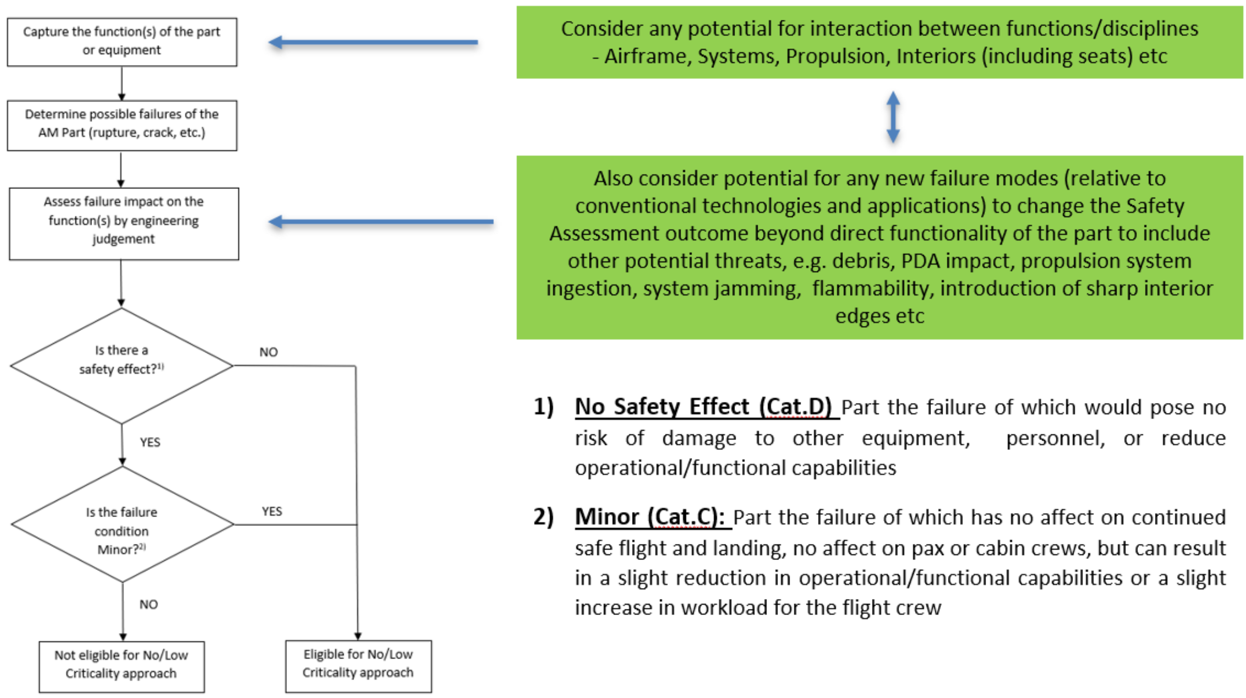
Appendix 3: Design safety assessment for AM parts of no or low criticality (Class C and D)

Note: At the time of this CM revision, the majority of AM applications of no or low criticality being proposed for, or having already been accepted in, certified parts are either new parts or parts produced for the purpose of 'repair by replacement'. Therefore, the following text addresses such applications. However, as the use of AM expands to more broadly address repairs, e.g. repairs involving material build up on baseline structure damaged (and prepared) surfaces, further amendments may be required in future revisions.

Aviation products are subject to safety assessments, e.g. FHA, FMECA, RAS etc., as required by the appropriate CS requirements accordingly. These requirements are to be considered by all stakeholders, e.g. TCHs, STCHs, DOAs supporting MROs, ETSOs etc.. However, recognising that many stakeholders do not have direct access to the TCH, STCH, or other original DOA design safety assessments, e.g. some DOAs supporting MROs, ETSOs etc., it is important that the design and manufacture of any AM parts conservatively address the potential impact of part failure upon safety, including the baseline product, relative to all potentially impacted disciplines beyond the direct functionality of the part, e.g. airframe, systems, propulsion, interiors (including seats) etc.. This should include consideration of the potential for non-compliance (note: a consideration not intended to allow poor process) and any new failure modes and/or new debris forms which could potentially change the outcome of an original configuration design safety assessment relative to more conventional materials and processes, e.g. the AM part may introduce new debris threats, resulting in potential impact, system ingestion, system jamming, fire threats, or the potential to introduce sharp edges for interior parts (either as a completed part or in its likely damaged states). Such a review is of particular importance at interfaces between disciplines, e.g. propulsion-structure, system-structure applications etc., due to the increased potential for unintended consequences resulting from incomplete knowledge of the product and/or the TCH's design safety assessments.

Noting that many design safety assessments involve some element of 'engineering judgement', it is important that even applications which have been assessed to be of no criticality (Class D) are adequately controlled, at least, by commercial specifications to ensure that multiple and repeated failures are not to be expected because quantitative data typically does not yet exist to support meaningful risk assessments for such new technologies and applications. Such an approach may be important when failure could result in loose debris, or release of some energy due to existing load in the part.

If the potential benefit from certification effort being proportionate to criticality is to be realised by an applicant, and accepted by the regulator, it is essential that applicants can demonstrate that the points above have been considered in this assessment in order to ensure a safe criticality classification. If the applicant does not have direct access to the TCH design safety assessment or direct TCH support, then the simple figure below is included to encourage this thought process in order to support a no or low criticality classification, i.e. both 'top down' and' bottom up' design safety assessment approaches should have been considered in order to support any demonstration of a no or low criticality classification as being appropriate.



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

Fig.1: Design safety assessment for AM parts of no or low criticality

Appendix 4: Early AM applications in certified parts of no or low criticality

The following are 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. These parts of no or low criticality, taken from a range of products (metallic and non-metallic), are representative of first development practices. (being part of a 'step by step' approach relative to 'criticality'). These examples include reference to developing standards when considered to be appropriate by the organisations providing the examples.

This content should not be considered to represent a complete package of information necessary for certification for each example, but only guidance regarding some aspects of the content which have been considered to be necessary for this purpose. Until further standardisation is achieved, the need to consider applications on a 'case by case' basis is likely to continue.

It is important to understand that these examples often include initial conservative practices, supported by considerable development work, considered to be necessary by applicants and regulators for the safe introduction of a new technology into aviation when taking a 'step by step' approach relative to criticality. It is also important to understand that some such practices may finally be considered to be excessively conservative for some applications of no or low criticality once confidence is better established. However, inclusion of these examples in the CM at this time is considered to help clarify to stakeholders new to AM and/or new to aviation, the extent of work which has been considered to be necessary for this purpose by those organisations already established in AM application development and certification.

Note: The following examples are loosely grouped under the following titles for the purposes of document format, i.e. Airframe, System, Propulsion, and Interiors (including Seats). However, it is recognised that many applications include considerations across product and/or discipline boundaries, e.g. system - structures. Furthermore, discussion is also loosely organised around the following themes, i.e. material control, process control, design values, static strength, flammability (and other design drivers when necessary). For the purposes of brevity, only the more significant issues and points of note will be highlighted in each example.

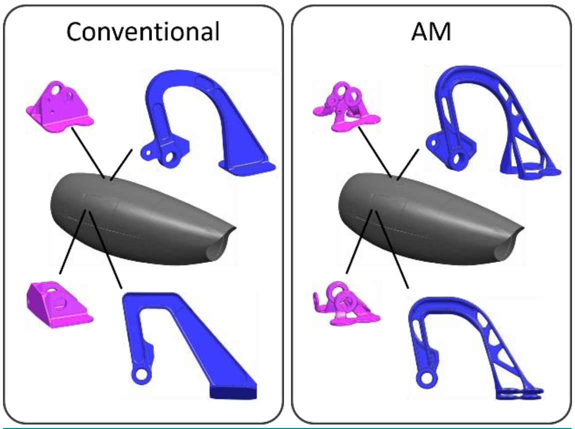
Note: It is recognised that differences exist regarding the definition of 'criticality' across products (safety and commercial definitions), although regulatory development in support of 'performance based regulation' may result in better standardisation of the definitions across products in the future from a safety perspective.

Examples - Airframe:

Airframe Example 1 (Pilatus/GKN): Airframe CS23: Nacelle Access Panel Assemblies (2 off), AM hinges and goosenecks, on fuselage mounted engines, T-tail configuration.

Note: part introduced to already certified product (change of type design)). Note: small access cover not attached to critical structure or systems

Note: Parts production is outsourced from the type certificate holder to an external supplier.



Design Driver: Satic Strength (handling loads)

Extent of Safety Assessment, FHA, FMECA, RAS completed: Safety Assessment, including consideration beyond functionality, e.g. potential for PDA impact, system jam etc

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

Material and Process Control *(per CM-S-008 issue 1 in accordance with 21A31):*

- the qualified supplier for the process provides the supplier specs which detail the basic requirements of the process specification from the type certificate holder.
- separate specs for powder and melted material. Process specification for virgin powder based upon AMS 4998 (min. requirements) and AMS 7002 (powder production). The manufacturing approval only valid for specific powder (type and manufacturer). Handling of recycled/blended powder is detailed in a supplier spec (ref. AMS 7002 and ASTM F2924).
- for manufactured parts, selective use of the majority of AMS7003 and partial use of AMS7028 (draft). AMS7028 para. 3.2., 3.3.1 - stress relief (not HIP).
- for a new process, additional production process controls (compared to standard production process controls of conventional processes) are specified in the process specification from the type certificate holder.
- details on sampling are specified in supplier spec.
- control supported by Statistical Process Control (SPC), PCD, and other broader supplier documented processes.

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

Post Processing: Machining of the part interfaces is performed according to the process specification from the type certificate holder.

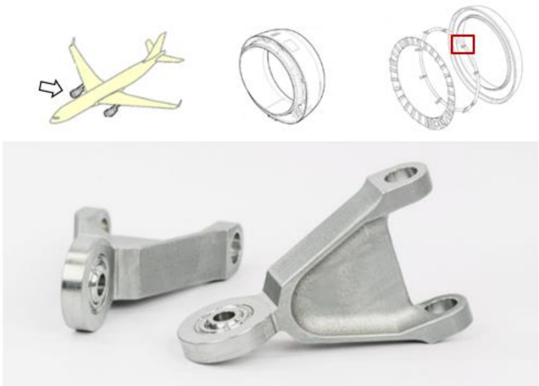
Design Values: (per CM-S-008 issue 1 in accordance with 21A20):
Material Qualification tests to determine design values. 300 coupons from parallel builds (10 batches - 3 virgin powder, 7 recycled powder), at qualification. Specimen orientation selected with lowest mechanical properties.

Static Strength: 10x part tests to failure (2 batches – supported by batch witness coupon data, i.e. tensile, chemical, and micro/macro inspect), assembly static tests of each assembly (UL and 1.5xUL, ground handling loads). No fatigue or vibration testing. Part and assembly tests supported by FE (using the established design values).

Flammability (and/or other considerations): EASA Interpretative Material documented from the project CRI (D-54) issued for this application: "Most commonly used (on engine and APU mounts) and previously accepted materials, such as steel (AISI 4100 series, 15-5PH CRES), nickel-chromium (Inconel 718) and titanium (Ti-6Al-4V, Ti-6Al-2Sn-4Zr-2Mo) alloys, can be considered fireproof without further substantiation."

Further Comments: The structure is redundant, i.e. more than one point must fail until the door detaches in flight. As shown in the attached pictures, the parts are easy accessible and inspectable. The quality controls are specified in the PIL process specification. More detailed information for supplier staff may be documented in supplier specs.

Airframe Example 2 (LHT): Inlet Cowl Anti-Ice A-Link
It is located behind the Lip Skin of the Engine Inlet Cowl, Nine of these A-Links connect the anti-ice ring with the Inlet cowl structure



Design Driver: Static Strength

Extent of Safety Assessment, FHA, FMECA, RAS completed: In addition to the pure functional analysis and possible damage during use, a more comprehensive safety assessment was carried out. Here, 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 (per CM-S-008 issue 1 in accordance with 21A31):
- Material and process specification provided by the qualified 21/G supplier. The Material specification incudes all relevant material details (material properties) of the blank material.
- The process specification defines the technical and quality requirements for titanium parts produced by additive manufacturing with Laser Powder Bed Fusion process, including feedstock, personal, machine und process.
- Required material testing methods based on ASTM standards. Process specification follows requirements given in AMS 7003 "LPBF 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: (per CM-S-008 issue 1 in accordance with 21A20):

Design values are determined by material qualification tests program. The qualification program includes 10 builds with more than 350 test specimens for hardness, tensile, shear, compression, fatigue, bearing and crack grow.

Static Strength:
Accompanying test specimens for tensile strength and hardness are tested for each build job. Additional tensile tests specimens have been included in the first three qualification build jobs. Fatigue tests were also carried out on one of these build jobs.
Nine parts have been cut and hardness tested over the whole area to check for homogenous structure and uniform microstructure.
Three parts have been pulled apart to check tensile strength. Results have been compared with given material property data and original configuration.

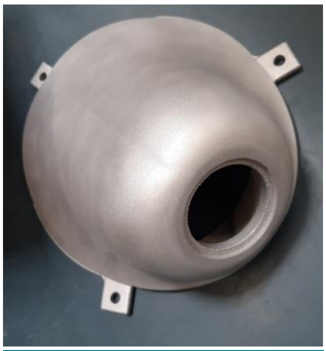
Flammability (and/or other considerations):
The parts are made out of TI-6AL-4V, and are not located in passenger and crew compartment interiors, thus flammability is not an issue. Resulting overheat and fire damages witch could occur in case of failure at the surrounding parts are considered in the safety assessment.

Further Comments:
The structure is redundant, with nine links connecting the anti-ice ring to the inlet cowl structure. As the area is closed by the surrounding structure after assembly, unforeseen damages, e.g. due to vibrations, are not visible. In order to detect a change in wear at an early stage, the first components are regularly checked by means of additional borescopes inspections (Fleet-leader approach).

Until it is proven that no special wear occurs due to the AM part installation, only every second A-Link (max. four out of nine) may be replaced by an AM component. This ensures that even in the event of an unforeseen failure, system safety is guaranteed in any case

Airframe Example 3 (SOGECLAIR): Airframe CS25: Camera housing.
Note: **Flight testing installation**
Part installed on nose cone upper area in place of sideslip angle sensor.
The housing contains a forward looking camera system and its electronics.
The system is in development and under flight testing
Housing:
- 250mm diameter
- Less than 1kg

Airframe:
- Large aeroplane (MTOW 300T)
- Wing mounted engine



Design Driver: Static Strength

Extent of Safety Assessment, FHA, FMECA, RAS completed: Equipment is not essential (in development flight test); the part is operated only a few months, it is not subjected to high vibrations frequencies
Safety analysis lead to birdstrike analysis to ensure that the part could sustain damage without damaging further the A/C (no separation or big debris, load transfer to airframe lower than allowable)

Material and Process: AlSi7Mg0,6, Laser Powder Bed Fusion

Material and Process Control:

- Supplier spec. based on AMS 7003; based on statistical control process
- Supplier spec. based on AMS 7003 & AMS 7032; using traction coupon built at the same time as the part on each corner of the built plate

Machines/Locations: The manufacturing was done on one specific AM printer.

Post Processing: Machining/painting of the parts is performed by the type certificate holder.

Design Values:
Based on supplier specification established on over 100 coupons. Specimen orientation selected with lowest mechanical properties.

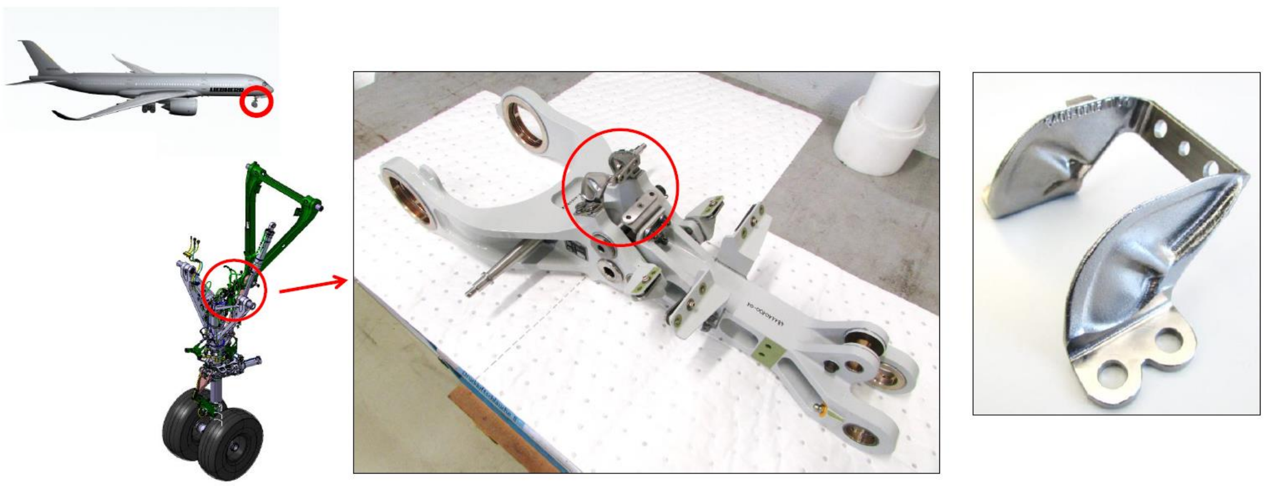
Static Strength: FE analysis + 6 tensile specimen (MOC: 2)

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

Further Comments: N/A

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 afew 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

Further Comments: In the first production lot one part was cutted and analysed.

Examples - Systems:

Systems (Interiors) (Example Senior Aerospace BWT): Large business aircraft CS-25: FDM ECS system duct joining subcomponents and ancillary parts.

5.1.1. Note: Replacement of aluminium or composite subcomponents with FDM ULTEM thermoplastic parts. Bonded onto or into our composite thermoplastic ducts.

Design Driver: Lead-time, weight, material rationalisation, cost, reduced impact of impending REACH regulations on chromic anodising of traditional aluminium parts.

5.1.2. Extent of Safety Assessment, FHA, FMECA, RAS, PFMEA: The AM components used in the ducting design are not located in the passenger interaction area,

and therefore do not require occupant safety assessment. Furthermore, they are bonded to and housed inside the composite duct should they become fragmented or detached the FDM is captured inside the composite duct and being a lightweight thermoplastic poses no risk to puncture the composite. There is no risk to PDA impact. FMEA showed the effects of failures are similar to the metallic equivalent although failure likelihood is greater, through testing it was demonstrated that FDM components MTBF remains far in excess of requirements. All test results were considered relative to the metallic equivalent.

Material and Process: Ultem 9085 Fused Deposition Modelling (FDM) using defined Stratasys 450mc Gen II printers.
All AM parts in this example are sub-components of SA BWT top assembly ducting components.

Material and Process Control (NIAR NCAMP CAM-RP-2018-013, CMH-17, OEM Specialist DAD to Transport Air Worthiness Authority per CM-S-008 issue 1 in accordance with 21.A.31)

5.1.3. The material provider, SABIC controls the applicable specification used to manufacture the raw material and conversion to pellets. Certificate Of Analysis confirms FAR 25.853 and physical properties by manufactured lot/batch.

- The material converter, Stratasys (pellet to filament to canister) supplies the filament material in accordance with specifications SSYS 107988-0001 (Production of ULTEM 9085 Black for Fortus Canisters) and NMS 085 NCAMP. Certificate Of Conformance confirms the converted material by lot/batch and links to the filament by canister lot/batch. In addition, the CoC links to the CoA by lot/batch.
- Evaluation of the filaments are defined in SABWT's FDM Process Variable Evaluation , Material Data Sheet for Thermoplastic Ultem 9085 Black and Process Control Document for FDM.
- The Machine, software and environment are also defined in the PCD and as such firmware and software revision changes can only implemented following assessment of the suppliers revision notes and appropriate testing.
- The build files for all AM parts are revision controlled I.e. 3D machine printing parameters cannot change from build to build.
- AM process specifications have been created for FDM in 2018 by the POA, revised in 2021, which details the basic requirements of the process specification and is reviewed by the DOA
- Machines are qualified, in accordance with the specifications, by the POA and overseen by project DOA.
- Part testing and sampling are defined in SABWT's inspection schedule and visual inspection criteria of FDM Manufactured Parts.
- Initial and periodic process capability analysis (Cpk).

Machines/Locations: The manufacturing qualification is only valid for specified AM printers in a defined locations and are specified within the PCD.

Post Processing : Only foundation layers of support material are used as parts have no build angles >45° from vertical. Potential defects are reviewed against defect criteria established in the PCD in addition to those highlighted by the machine manufacturer's user manual. In >90% of cases the parts manufactured are tubes with thin-walled extrusion contours with no raster infill and thus both the part's interior and exterior are readily accessible to inspection.

Design Values: (per CM-S-008 issue 1 in accordance with 21.A.31. SABWT's Primary FDM Machine Qualification and Secondary FDM Machine qualification) :

In addition to ASTM coupon physical testing >30 customer parts were tested as follows :

- High and Low Temperature with Proof and Burst Pressure (-55°C to +85°C, PP= 0.63 to +0.63psig and BP = 1.24 to +1.24psig).
- 180,000 pressure cycles per top assembly product.
- 14 CFR 25.853a (12 second vertical) >5 material combinations tested.
- RTCA/DO 160G Environmental Tests.
- Shaker testing.

Tool path design for both physical and flammability test coupons were controlled to be representative of those used in the parts to manufactured. Tool path optimisation was evaluated using mechanical tests and created a baseline for material mechanical performance when specifically printing POA designed product.

Static Strength: 3 x material batches were used to print 369 test coupons. Samples were tested for tensile, compression and flexural properties at 3 different temperatures between 23°C and 105°C, and 5 x samples for each orientation, print bed location and batch. In addition, the glass transition temperature was also tested.

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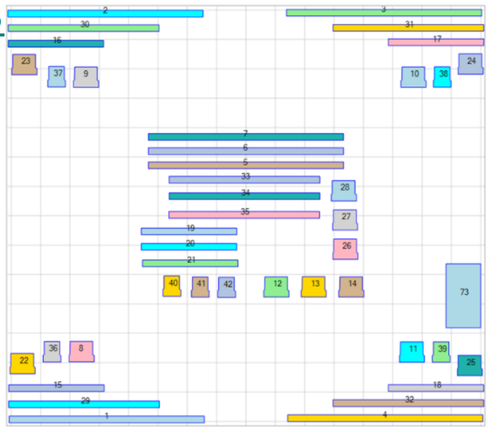


BWT Primary Machine

Test	Batch A (BWT – Machine 1)	Batch B BWT – Machine 1)	Batch C BWT – Machine 1)
ASTM D638 (orientations XZ & ZX)			
23±3°C	✓	✓	✓
85±3°C	✓	✓	✓
105±3°C		One batch only	
ASTM D695 (orientations XZ & ZX)			
23±3°C	✓	✓	✓
85±3°C	✓	✓	✓
105±3°C		One batch only	
ASTM D790 (orientations XZ & ZX)			
23±3°C	✓	✓	✓
85±3°C	✓	✓	✓
105±3°C		One batch only	
ASTM D7028	✓	✓	✓
ASTM E1640	✓	✓	✓
ASTM D7426	✓	✓	✓

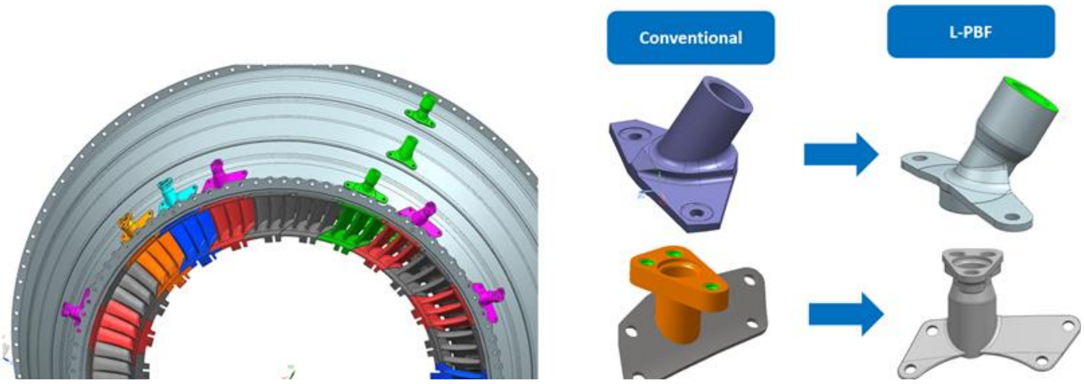
Flammability (FAR 25.283 (b)) : Tests were carried out to determine the effect printing orientation has on the flammability along with combinations of associated materials and adhesives used in the manufacture of the top assemblies. Additional to printing orientation, *(as mentioned)* toolpath design of the parts and test coupons were taken into account for both flammability and physical testing. Additional flammability coupons are printed and tested at each change of material lot/batch. To date no failures have occurred during this testing.

Further Comments: All AM parts in this example are defined as sub-components that will need to withstand aircraft specific environmental conditions. These conditions are defined in the aircraft Original Equipment Manufacturers (OEM) technical requirements document and relate to specific systems, sub-systems or ducts and have been considered in the design and qualification of these components. These components will need to withstand typical handling and installation loads as well as customer defined storage conditions. All of the process development, machine qualification and product testing was led by the POA with oversight and input by the project DOA.

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.
-

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

Post Processing: Several bosses are manufactured in the same build. Once heat treated the parts are separated from the platform by EDM (Electro Discharge Machining), then sand blasted to be finally machined in the interfaces.

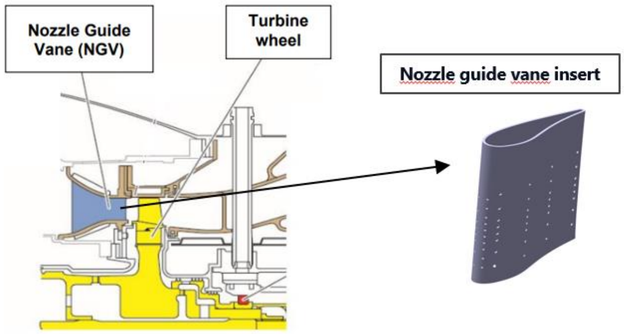
Design Values: Material qualification tests programme conducted to determine design values according to internal specification. Design values generated taken into account the effect of powder (virgin and recycled), machine, etc.. together with the thickness and surface condition. Specimen orientation selected with lowest mechanical properties.

Static Strength: No tensile part testing conducted during qualification. Part and assembly tests supported by FE (using the established design values). The tensile design values are checked during the qualification of the part using witness coupon data.

Fatigue Strength: No fatigue or vibration part testing conducted. Part and assembly tests supported by FE (using the established design values).

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

Propulsion Example 2:(Safran Helicopter Engines): Turbine Engine HP nozzle guide vane inserts.
Inserts are localized inside the HP (high pressure) NGV (Nozzle guide vane) blades. Their functionality is to canalize and calibrate the secondary air flow. Inserts' holes participate to the high pressure NGV blades cooling SLM inserts replace, with similar design, historical inserts manufactured from welded-drawn sections (metal sheet).



Design Driver: Thermal loading and high temperature oxidation / corrosion, no significant mechanical loading

Extent of Safety Assessment, FHA, FMECA, RAS completed: FMECA and Safety Assessment

Material and Process: NC22FeD (Hastelloy X), Laser Powder Bed Fusion (LPBF)

Material Control: Internal SafranHE specifications for powder and SLM material are based on statistical analysis of mechanical and metallurgical tests.

Process Control:
- LPBF qualified under internal Safran specifications.
- Periodic destructive (tensile and metallography) tests are performed to control the manufacturing process
- Non destructive controls: X-ray and airflow controls

Machines/Locations: The manufacturing approval is only valid for one specific AM printer. Therefore the Machine Type and Serial number (S/N) is specified within the Process Control Document.

Post Processing: Several inserts are manufactured in a same batch. Each insert is cut off from the support by means of electro discharge machining, along its upper surface. Each insert is subsequently TIG welded to the NGV.

Design Values: Material Qualification by tests to determine design value

Static Strength: 152 tests results, from 5 batches of powder (between 0 and 20 recycling cycles) and manufactured according several melting batches.

Fatigue Strength (LCF): fatigue properties resulted from analysis of 52 tests results

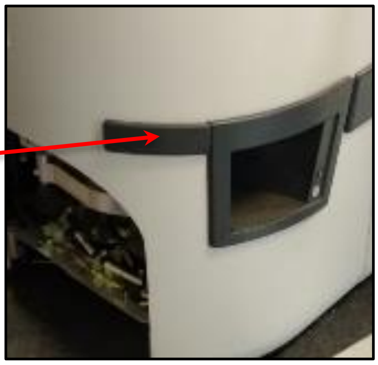
Flammability (and/or other considerations): not applicable to this part

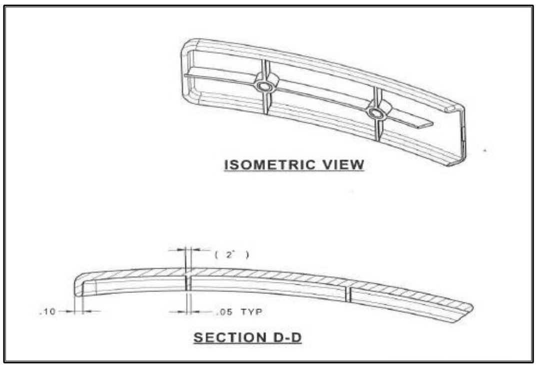
Further Comments:
- Burner rig tests for environmental stability validation (high temperature corrosion / oxidation)
- Bench test and analysis for permeability and cooling performance evaluation
- Engine tests for certification of the first application (including Part 33.90 / CS-E 25 AMT test and CS-E 740 endurance test).

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)

Material and Process Control *(per CM-S-008 issue 1 in accordance with 21A31):*:

- The qualified material provider controls the applicable specification used to manufacture the raw materials(from pellets into filament form).
- The qualified material provider manufactures and supplies the filament raw material in accordance with approved Safran specification requirements.
- Specifications for the filaments are defined based on Safran test campaign that define the design allowables.
- The Machine, software and environment are also defined and controlled throughout the parts manufacturing phase.
- The Specification defines the type and grade of the material used for the FDM process..
- Details on test sampling are specified in the Safran Specification.
- Control of the fabrication is via the PCD, and other documented processes applicable to the FDM process.

***Machines/Locations:** The manufacturing approval is only valid for one specific AM printer. Therefore the Machine Type and Serial number (S/N) is specified within the Process Specification.*

***Post Processing:** Removal of support material per approved processes. Any defects post processing/printing of the part, are reviewed against an already agreed defect criteria established in the process.*

Design Values: *(per CM-S-008 issue 1 in accordance with 21A20):*

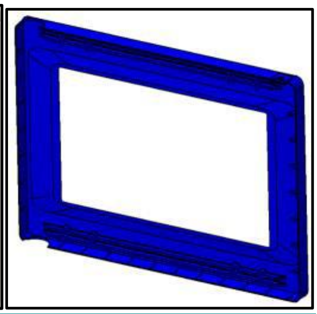
4 material batches, at qualification. 3 Machines, and 4 samples for each orientation and batch.
All Specimen orientations selected with and worst orientation taken further to identify lowest mechanical and flamability properties.

Static Strength: 3x part tests to failure, assembly static tests of each assembly (retention and cyclic impact loads). Mode of failure also established and compared to conventionally fabricated component.

Flammability (and/or other considerations): Tests were carried out to determine the effect printing orientation has on the flammability performance of the part. This was used to define the critical test specimen constructions to meet flammability certification requirements.

Further Comments: The bumper is intended to protect the shroud assembly from damage as a result of trolley impacts. From the impact loading perspective, failure of the component is allowed, so long as it does not affect occupant egress. Evaluation was carried out against the original injection moulded component failure mode.

Interiors Example 2 Large Aircraft CS25 (SAFRAN): ***Monitor Bezel (Trim) around IFE Monitor, installed on Seat Surrounding Furniture assembly.***
Note: Monitor surrounding trim installed around the monitor and retained with fasteners.

Design Driver: Tooling, Ease of manufacture & reduction in part count.

Extent of Safety Assessment, FHA, FMECA, RAS completed: This is located in the passenger interaction area, and therefore requires occupant safety assessment (i.e. Cat B). This is required to ensure that compliance to CS25.562 and CS25.785 requirements are not adversely affected by this change. Compliance demonstration takes into consideration the occupant head trajectory and headstrike (if any) at the monitor area, potential damage and any potential unsafe features as a result of damage to the compoent (sharp edges).

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

Material and Process Control ***(per CM-S-008 issue 1 in accordance with 21A31):***:
- The qualified material provider controls the applicable specification used to manufacture the raw materials(from pellets into filament form).
- The qualified material provider manufactures and supplies the filament raw material in accordance with approved Safran specification requirements.
- Specifications for the filaments are defined based on Safran test campaign that define the design allowables.
- The Machine, software and environment are also defined and controlled throughout the parts manufacturing phase.
- The Specification defines the type and grade of the material used for the FDM process..
- Details on test sampling are specified in the Safran Specification.
- Control of the fabrication is via the PCD, and other documented processes applicable to the FDM process.

***Machines/Locations:** The manufacturing approval is only valid for one specific AM printer. Therefore the Machine Type and Serial number (S/N) is specified within the Process Specification.*

***Post Processing:** Removal of support material per approved processes. Any defects post processing/printing of the part, are reviewed against an already agreed defect criteria established in the process.*

Design Values: ***(per CM-S-008 issue 1 in accordance with 21A20):***
4 material batches, at qualification. 3 Machines, and 4 samples for each orientation and batch.
All Specimen orientations selected with and worst orientation taken further to identify lowest mechanical and flamability properties.

Static Strength: Static retention test carried out to substantiate retention means in accordance with CS25.789.

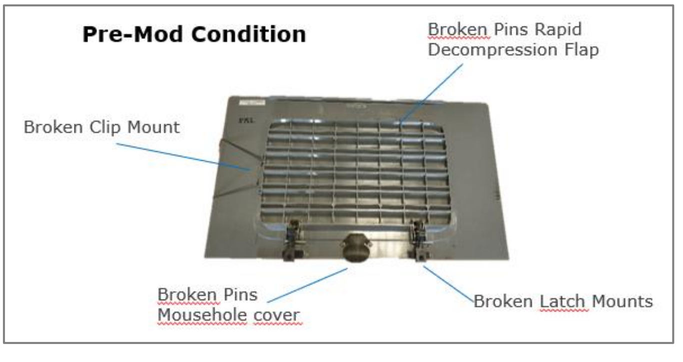
Flammability (and/or other considerations): Tests were carried out to determine the effect printing orientation has on the flammability performance of the part. This was used to define the critical test specimen constructions to meet flammability certification requirements.

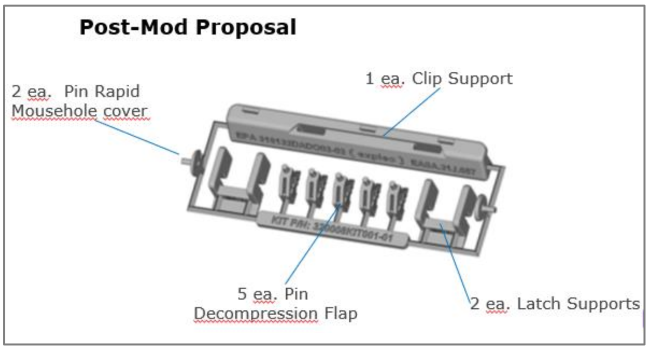
Further Comments: In both examples shared, external (ASTM) standards are used to ensure material tests are in accordance with standard test methods.

Example 3 (MATERIALISE): Part 25 aircraft interior panel repair kit

Part introduced to already certified product (change of type design)

Notes: Failure of the repair would not impact the pressure equalisation functionality of the panel. Very low-level structural requirements





Design Driver: sustainable, cost-effective repair solution with low lead time rather than component replacement (scrapping), possibility to provide strengthening of the original design to prevent breakage.

Extent of Safety Assessment, FHA, FMECA, RAS completed: Engineering assessment of functionality of the panel and the associated rapid decompression flap. Fire hazard assessment.

Material and Process: PA2241-FR, Selective Laser Sintering

Material and Process Control (per CM-S-008 issue 1 in accordance with 21A31): The qualified supplier for the process provides the supplier specs which detail the basic requirements of the process specification (internal process document) from the type certificate holder.

Material: Control on several KC (Particle size distribution, bulk density , pourability, melting point,Flammability,) through COA (certificate of analysis) by raw material supplier,

Machines/Locations: The manufacturing approval is only valid for a specific process applied at the POA :Materialise

Process	PCD AERO_PA2241-FR
Material	PA2241-FR
Machine Type	EOS P760, P770
Test Method	ISO527-2/A1

Production Process: control supported by Statistical Process Control (SPC), PCD, and other broader supplier documented processes. 30+ KC defined and controlled (from data prep over maintenance to breakout) eg: layer thickness, recoater speed, nesting density, ..

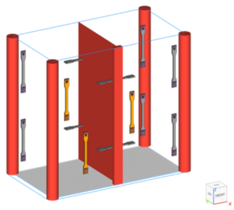
Post Processing: standard blasting

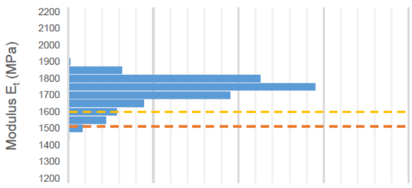
Design Values: (per CM-S-008 issue 1 in accordance with 21A20):
DOA relied on material data sheet

POA (materialise) performed Material Qualification and gathered production performance to determine design values on tensile , elongation,modulus which Doa could use for substantion

MECHANICAL PROPERTIES

Production Period	11/2019	to	10/2021
# Measurements	1966 (ZX) &		635 (XY)
# Production Builds	232		
# Raw Material Batches	8		
# Mixed Material Batches	128		





Static Strength: Case based on engineering judgements mostly. Verification and possible substantiation by materialise provided on: tensile, elongation, modulus, and density.

Flammability (and/or other considerations): PA2241-FR is inherently flame resistant. The repair components are of very small volume and weight which allows flammability assessment based on coupons tested by EOS (powder manufacturer) during material development.

Verification by POA through substitute KC: density

Further Comments: The interior panel fulfils the following functions:

a) Allowing for rapid decompression (airflow cabin to side-wall cavity) by opening of the pressure baffle
b) Keeping dust and FOD out of the side wall cavity
c) Allowing for low pressure airflow from the cabin to side-wall cavity (part of cabin air cycle) and vice versa
d) Closing the lower end of the sidewall aesthetically

None of the functionality's a), b) or c) are affected by failure of one of more of the repair kit components. Furthermore, even panels that aren't fully secured in place anymore, are prevented to moving out of location by the adjacent seats (very common finding in non-repaired pre-mod condition)
More info on the specific case : https://www.materialise.com/en/inspiration/articles/expleo-aerospace-3d-printed-spare-parts

Example 4 (ST AERO): Cabin Interiors CS25 – Classification D (Neligible or No consequence of failure) as per ASTM F3572 – 22. Kickstrip End Cap, manufactured via Polymer Laser Sintering (PLS), for capping the end of kickstrips on monuments

Note: part introduced to TC product (change of TC design)

Design Driver: Static Strength against handling loads

Extent of Safety Assessment, FHA, FMECA completed: Safety assessment on the aircraft, crew and passengers, and in the event failure potential impact to continued operations, etc.

Material and Process: Flame Retardant Nylon 12, Laser Powder Bed Fusion

Material and Process Control *(per CM-S-008 issue 1 in accordance with 21A31):*

- AM process specifications have been created for PLS in 2018 which details the basic requirements of the process specification and is implemented in own DOA and POA.
- Suppliers are qualified, in accordance with the specifications, by the POA.
- The specifications cover –powder acceptance and management; machine configuration including interfaces and control; AM process definition and control; machine/process/material qualification and parts qualification; design values; process instruction including digital file control and management, and quality control such as details on sampling. With more standards available, harmonization have been incorporated in the newer revisions, such as ISO 13320 / 60 / 6186 / 11357.

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

Post Processing:

- Painting of parts are done according to the paint specifications that has passed paint adhesion test as per ASTM D3359.

Design Values: *(per CM-S-008 issue 1 in accordance with 21A20):*

- Material Qualification tests to determine design values. 278 coupons from 5 builds to derive design values. Specimen orientation selected with lowest mechanical properties. Design values established from previous STC project.

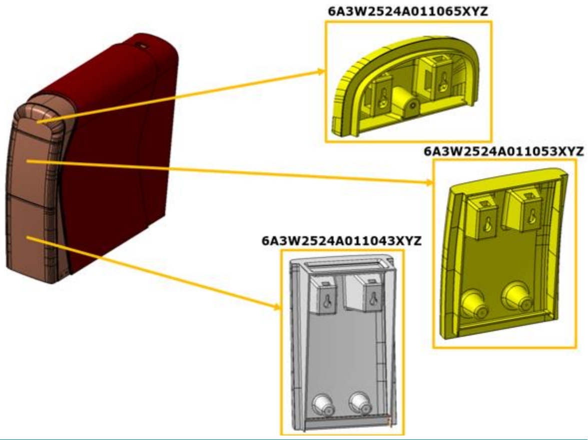
Static Strength:

- 79 tensile coupons from 5 independent builds; virgin and recycle powders have been tested (CoV is <5%)
- Co-printed coupons are printed and tested to demonstrate the consistency of mechanical performance.

Further Comments on CAW: The final part has been inspected at each processing step, per AM process specifications and drawings. The inspection method (visual) and maintenance instruction (condition-based replacement) from the type certificate holder is assessed to be applicable to this AM part.

Example 5 (MAG): Cabin Interiors CS29 – Classification C (Negligible or No consequence of failure)- Aesthetical cabinet cover- FDM process- Ultem 9085 material

Note: *part introduced to STC product (change of STC design)*



Design Driver: Static Strength and stiffness, compliance to CS-29. 561 emergency landing loads

Extent of Safety Assessment, FHA, FMECA completed: Safety assessment on the helicopter interior , crew and passengers, and in the event failure potential impact to continued operations, etc.

MECAER | AVIATION | GROUP	[AW139 VIP 305 - FHA ADDITIVE MANUFACTURING PARTS]	[6AB1RAD-847]
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5 LIST OF PARTS WITH RELATED CRITICALITY, MATERIAL AND PROCESS

This table is intended to provide the dashboard of the ALM parts, their criticality, material, process, and EASA Panel and/or CVE Terms of Reference involved (depending on minor classification, the sole CVE would be involved).

5.1 VIP 305 MC 9 6AB1KT308-031

AM Part/ Structure	Description	FMECA IDs	FUNCTION	MASS	used for any safety equipment mountings	Classification/ Criticality*	Material	AM Process	MAG CVE	AM changes certification safety reference points Yes/No**
6AB1ME215-575	FRONT COVER	1	Aesthetical frame fixed to the cockpit cabinet	0,55+0,2 kg	NO	D	ULTEM	FDM	D&C	No
6AB1ME433-165	NEW ICS COVER RH	2	Aesthetical cover for handset installation.	0,288+ 0,216 kg	NO	C	ULTEM	FDM	D&C	No
6A3W2524A0110 65XYZ	DRAWER UPPER INSERTED	3	Aesthetical cover of the interseat cabinet.	0,21kg	NO	D	ULTEM	FDM	D&C	No
6A3W2524A0110 53XYZ	DRAWER MID INSERTED	4	Aesthetical cover of the interseat cabinet.	0,5kg	NO	C	ULTEM	FDM	D&C	No
6A3W2524A0110 43XYZ	DRAWER INSERTED	5	Aesthetical cover of the interseat cabinet.	0,95kg	NO	C	ULTEM	FDM	D&C	No
6A3W2524A0113 21XYZ	Support USB	6	Aesthetical frame.	<<0,45kg	NO	D	ULTEM	FDM	D&C	No
6A3W2524A0113 21XYZ	Support Structural	7	Aesthetical frame inside the cabinet, visible when the upper drawer is opened. The part has just an aesthetical function and, in case of failure, it will be confined inside the drawer.	<<0,45kg	NO	D	ABS ULTRA STRONG	FDM	D&C	No

Material and Process: Flame Retardant Ultem 8095, Fused Deposition Molding process

Material and Process Control *(per CM-S-008 issue 1 in accordance with 21A31):*

- AM process and materials specifications have been issued on early 2023 with the minimum requirements for the process and material to be reached for the production of parts to be used in MAG projects.

- Suppliers are qualified, in accordance with MAG DOA procedure.
- The specifications cover:
  - material wire acceptance and management
  - machine set up including interfaces and control;
  - AM process parameters definition and control;
  - machine/process/material qualification
  - parts qualification;
  - parts quality control

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

Post Processing:
- Painting of parts are done according to the paint specifications
- Application of finishing, as veneer or carbon look are made according to proprietary specification

Design Values: (per CM-S-008 issue 1 in accordance with 21A20):
- Design values made on 18 coupons @ room temperature and 18 coupons @ hot/wet conditions

Static Strength:
- Static test @ultimate load performed on each part to verify the compliance with CS29.561 requirements

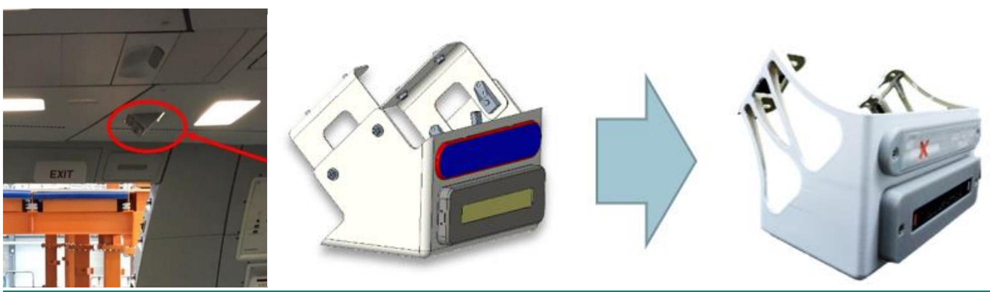
Flammability:
- All the stacking sequence are tested to be compliant with CS-29.853 requirements.
- 60 seconds vertical test according to CS 29.853 on minimum thickness (e.g. 0.8 mm) material usable in the actual parts, with specimen size of 300x100xminimum thickness

Further Comments on CAW: The final part has been inspected at each processing step, per AM process specifications and drawings. The inspection method (visual) and maintenance instruction (condition-based replacement) from the type certificate holder is assessed to be applicable to this AM part.

Examples – Interiors (Including Seats): Metallic

Example 1 (ST AERO): Cabin Interiors CS25 – Classification C (Low consequence of failure) as per ASTM F3572 – 22. Housing Assembly, manufactured via Direct Metal Laser Sintering (DMLS), for housing signages on the cabin ceiling

Note: *part introduced to already certified own STC product (change of STC design)*



Design Driver: Static Strength; compliance with CS25.341 gust loads, CS25.561 emergency landing loads

Extent of Safety Assessment, FHA, FMECA completed: Safety assessment on the aircraft, crew and passengers, and in the event failure potential impact to continued operations, etc.

Material and Process: AlSi10Mg, Laser Powder Bed Fusion

Material and Process Control *(per CM-S-008 issue 1 in accordance with 21A31):*

- AM process specifications have been created for DMLS in 2018 which details the basic requirements of the process specification and is implemented in own DOA and POA.
- Suppliers are qualified, in accordance with the specifications, by the POA.
- The specifications cover – powder acceptance and management; machine configuration including interfaces and control; AM process definition and control; machine/process/material qualification and parts qualification; design values; process instruction including digital file control and management, and quality control such as details on sampling. With more standards available, harmonization have been incorporated in the newer revisions, such as ASTM F3318 / B212 /B417/B214/ ASTM E1019; ISO 13320.

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

Post Processing:

- Heat treatment of the completed builds is performed according to the AM process specifications.
- Machining of the part interfaces is performed according to the process specification from the supplemental type certificate holder.

Design Values: *(per CM-S-008 issue 1 in accordance with 21A20):*

- Material Qualification tests to determine design values. 325 coupons from 27 builds to derive design values. Specimen orientation selected with lowest mechanical properties.

Static Strength:

- 220 tensile coupons from 27 independent builds (including net shaped and machined coupons; virgin and recycle powders) have been tested (CoV is <5%)
- Proof static load tests have been performed to all 6 directions on the completed assembly. Deformation data is correlated with the FEM simulation results where design values have been deployed.
- Co-printed coupons are printed and tested to demonstrate the consistency of mechanical performance.

Corrosion Resistance: Surface treatment is implemented before paint application. Corrosion resistance and paint adhesion tests are performed per ASTM B117 and ASTM D3359 respectively. Tensile coupons with the surface finishes are also tested to verify the mechanical performance.

Further Comments on CAW: The final part has been inspected at each processed step, per AM process specifications and drawings. The sample part has successfully passed proof load tests. The inspection method (visual) and maintenance instruction (condition-based replacement) from the supplemental type certificate holder is assessed to be applicable to this AM part.

Appendix 5: EASA AM contacts

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

Materials	S. Waite	simon.waite@easa.europa.eu
Aircraft Structures	W. Hoffmann	wolfgang.hoffmann@easa.europa.eu
Propulsion (Engines, Propellers & APU)	O. Kastanis M. Mercy*	omiros.kastanis@easa.europa.eu matthew.mercy@easa.europa.eu
Cabin Safety	T. Ohnimus F. Negri	thomas.ohnimus@easa.europa.eu fabrizio.negri@easa.europa.eu
Systems	M. Weiler	michael.weiler@easa.europa.eu
Design Organisation Approvals	C. Caruso A. Enache*	claudio.caruso@easa.europa.eu alexandru.enache@easa.europa.eu
Production Organisation Approvals	A. Duranec	ana-marija.duranec@easa.europa.eu
Maintenance Organisation Approvals	R. Tajes	rosa.tajes@easa.europa.eu

*original EASA contact addressing theme