

Supplemental Document*

to

Certification Memorandum

Additive Manufacturing

EASA CM No.: CM-S-008 Issue 04 issued 3 September 2025

Regulatory references:

Primarily impacted product CSs:

CS2x.305, CS2x.307, CS 2X.571, CS 2X.603, CS 2X.605, CS 2X.613, CS 2X.853, CS23.2260, CS E.70, CS E.100 (a), CS P.170, CS P.240, CS APU.60, CS-ETSO (see Appendix 1 for more detailed CS listing)

Other potentially impacted references:

21.A.15, AMC 21.A.15(b), 21.A.31, GM 21.A.91, 21.A.101, 21.A.131, 21.A.133, 21.A.147, 21.A.247, 21.A.307(b), 21.A.433, GM 21.A.435(a), , 21.B.100, 21L, 145.A.42(b), CAO.A.020, M.A.603(c)

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.

*Supplemental document raised in support of this CM revision to record supporting discussion necessary to provide context for the revision content, and also for potential future CM revision evolutions. Such supplemental documents are considered to be appropriate in the absence of complete and published reference documentation existing elsewhere, as may be typical for new and developing technologies and applications, whilst maintaining more acceptable and manageable formats for the main CM document.

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Supplemental - Appendix 2: Design Certification - further background discussion:

In support of Section 2 'Background' for this rapidly developing technology, the following text documents evolving context within which this issue of the CM content was developed.

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 Recommended Guidance for Certification of AM Components 2020, 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. 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. These are to be supported by appropriate software control and updating processes, including access and cyber security management, and operator and training procedures.

Note: The definition, and determination, of Key Variables, KPPs, and expectations for demonstration of the sensitivity, including acceptance criteria, 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.

A representative test programme requires test and analysis pyramid definitions, and test parameter identifications, supported by thorough 'end to end' stakeholder interaction.

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 more specific to AM, including part orientation during the build process and the need to consider 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 structures and mathematically optimised structures which rely on internal non-visible or uninspectible features intended to deliver potential performance attributes, e.g. mass benefits, require particular attention.

Design values can be established via the AM machine Operational Qualification (OQ) and Performance Process Qualification (PQ), supported by appropriate material allowable data, also noting that MMPDS AM data should not be used without further showing.

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 safety 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 established 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.855, 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 requirements 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 consult 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.

Supplemental - Appendix 4: Certification effort proportionality to part criticality - discussion:

Recent efforts to better formalise and prioritise regulatory expectations of industry demonstrating appropriate MoCs (including supporting test and analysis work), when meeting CSs and AMC needs in proportion to part criticality, has resulted in draft tables (and supporting discussions) below. This content has been included for awareness and visibility purposes in this revision and **does not represent policy**.

For example, debate continues regarding the interpretation of, and distinguishing between, actions necessary to support criticality classification relative to the actions necessary to demonstrate the showing of the means of compliance being proportionate to criticality (in support of interpretation of EASA Part 21 Appendix A to AMC 21.A.15(b)).

The tables in Appendix 4 are intended to support defining the likely EASA expectations for industry to initially demonstrate certification efforts being proportionate to criticality, novelty (to the industry and/or applicant and/or regulator), and complexity, and are intended to provide guidance in support of EASA MoC.

These tables do not attempt to address all regulations or alleviate the need to satisfy all relevant regulatory requirements (see Appendix 1 of this CM). For example, these tables do not attempt to systematically address flammability, conductivity, or similar specific performance requirements, but do illustrate where repeatability of the identified requirements and related 'engineering properties' may be significantly impacted by M&P controls.

Reminder: 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.

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), unintended or intended (stiffness matrix coupled designs), 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. This requires appropriate sharing of data and procedures between stakeholders, particularly in complex stakeholder chains. The proposed approach can include proportionality between the statistical analysis and the part criticality.

- the parameters defining the design value should be clearly identified (e.g. dimensions, location in the build volume, build orientation, wall thickness, surface finish, support details etc ...).

- 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 of 'similar' criticality 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 Threat Assessments and 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 and 3.

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, TBD = To Be Determined

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

**** ‘N’ Requires, at least, the applicant to demonstrate having completed the appropriate part criticality classification process, see Appendix 2 and 3, which includes actions which might also be interpreted as including detailed activities supporting MoCs.**

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

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

Large Aeroplanes – Footnotes:**Reminder: This content is part of Section 2 ‘background’ only, not Policy, and will be subject to future development**

(1) subject to design review by appropriate design authorities, e.g. TCH, DOAH, STCH, ETSO, DOA etc., no showing for Class D parts (and no showing for some requirements associated with Class C parts) may be accepted if no effect on safety can readily be demonstrated, including consideration of the material and process selected for construction. **Effective and safe use of this table relies significantly upon the appropriate part classification of criticality as being Class C or D, also see Appendices 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 are required, e.g. T90 or T99 data (e.g. C or D-Basis for AM data), or equivalent. It is unlikely that S-basis data will be accepted for Class A and B parts. 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 supported by test 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 and include representative Boundary Conditions. If material and process variability is not quantified, then recurring, element/part level acceptance testing can be used. Testing could include a ‘Point Design’, ‘Detail’ testing 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. **Although 25.571(a) only requires assessment for ‘each part of the structure that could contribute to a catastrophic failure’, the identification of such parts relies initially and significantly upon demonstrating understanding of failure modes, loads, locations etc, which may be challenging for new M&P, new configurations, reduced part count/load paths (made possible by AM) etc. Therefore, for less than full CS25.571 MoC to be accepted for any specific part and application, similarity and applicability will need to be demonstrated relative to established practices, including substantiated demonstration of understanding of part performance relative to anomalies, flaws, and potential defects. Such an approach would typically be associated with established TCHs.**

			Material and Process control	Design Values	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)	TBD(9)
	B	(MAJ)	X	X (3)	X (4)	TBD(9)
	C	(MIN)	S (2)	S (5)	S (4)	TBD9)
	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:

Reminder: This content is part of Section 2 ‘background’ only, not Policy, and will be subject to future development

- (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/or 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 less than full CS27/29.571 or 573 MoC to be accepted for any specific part and application, similarity and applicability will need to be demonstrated relative to established practices, including substantiated demonstration of understanding of part performance relative to anomalies, flaws, and potential defects. Such an approach would typically be associated with established TCHs.**

Note: ‘Critical Parts’, ref. CS27/29.602 are considered to be beyond the scope of discussion for this CM revision.

			Safety analysis - part class (9)	Average properties, Allowables and Design Values characterization	Material control	Process Control	Scale Factors - Design Values (7) (specific material properties required for part eg static strength, fatigue and vibration)	Damage Tolerance	Fire	Oxidation / Corrosion (8)
Requirements for	Engines		CS-E 510 Safety Analysis	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	X(1)	As required (3)	X
	MAJ	B	X	X(6)	X(6)	X	X(6)	NA(9)	As required (3)	X
	MIN	C	X	S (4) (6)	S(4) (6)	S	S(6)	NA(9)	As required (3)	S
	NSE	D	X	N(2) or S(5) if necessary	N(2) or S(5)	N(2) or S	S if necessary	NA(9)	N(3)	S

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

Engine - Footnotes:

Reminder: This content is part of Section 2 ‘background’ only, not Policy, and will be subject to future development

- (1) only applicable for Engine Critical Parts as per CS-E 515 definition (corresponding to Engine Life Limited Parts according to FAA, 14 CFR 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.** Safety analysis as per CS-E 510 (a) and (b) is to be performed for all engine parts in order to assess the likely consequence of all failures that can reasonably be expected to occur. If significant doubt exists as to the

effects of Failures and likely combination of Failures, any assumption may be required to be verified by test. For CS-E 515 non applicability acceptance (for B, C and D categories) for any specific part and application, appropriate safety evaluation and classification will need to be demonstrated relative to established practices, including substantiated demonstration of understanding of part performance relative to anomalies, flaws, and potential defects. **Such an approach would require significant work and use of well establish databases and practices, typically associated with established TCH.**

Supplemental - Appendix 5: 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, and which contributors have been prepared to share. 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: Part Criticality has not been assigned for these examples in this revision to the CM because they have been developed as the CM has been developed and further standardisation is required. These, and future new examples, may be assigned classifications in future CM revisions.

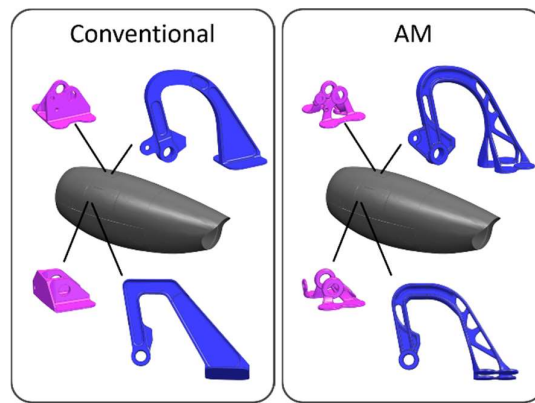
Note: EASA thanks the example contributors and, as communicated during various Working Group 1 meetings, understands that the examples are provided either by the DAH directly, or by the identified stakeholder with the responsible authority involvement and approval. Furthermore, the following examples follow similar, but not identical, formats and include similar levels of information as available to be shared on a 'case by case' basis.

Examples - Airframe:

Airframe Example 1 (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, 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 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 includes 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 which 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 is intended to ensure that even in the event of an unforeseen failure, system safety is maintained.

Airframe Example 3 (SOGELAIR): Airframe CS25: Camera housing.

Note: **Flight testing installation** (although not a certification project, this example is included in this CM revision because it was shared with the WG1 and covers similar MoCs)

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 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.

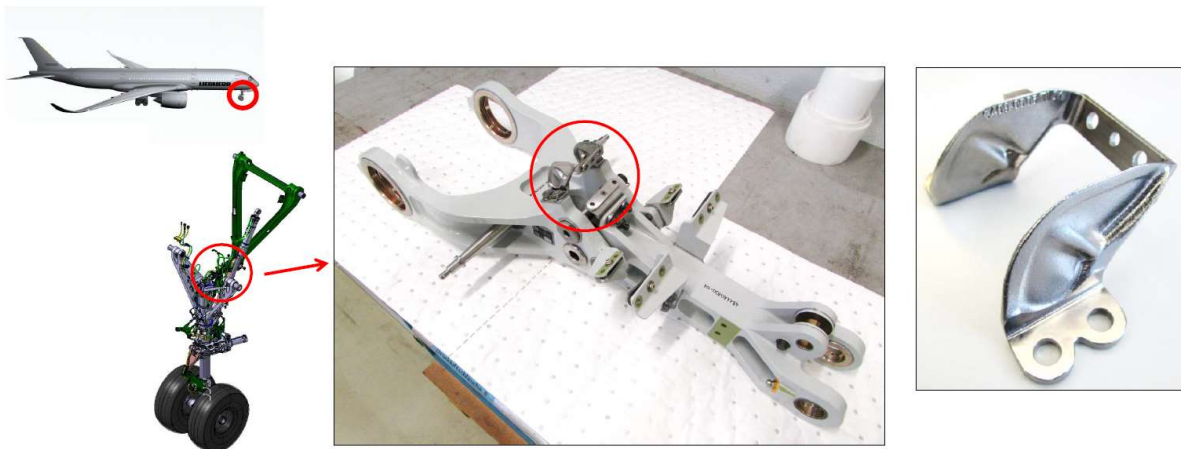
Static Strength: FE analysis + 6 tensile specimen (MOC: 2)

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 completed: In addition to the functional analysis and possible damage during use, a more comprehensive safety assessment was carried out. Not only the individual

component was considered, but also the effects on the complete system and its environment if all AM components fail. All results have been compared with the original configuration and evaluated.

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

Material and Process Control:

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

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

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

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

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

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

Further Comments: Two sections of the part with different thicknesses were chosen for part cut-up during the first article inspection and analysed for porosity, and microstructures compared, using in-house procedures. Production quality assurance is based on NDI of parts and destructive testing of witness samples. Beside tensile testing, microstructural analysis of one witness cube is completed.

Examples - Systems:

Systems (Interiors) Example 1 (Senior Aerospace BWT): Large business aircraft CS-25: FDM ULTEM system duct joining subcomponents and ancillary parts.

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



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

Extent of Safety Assessment, FHA, FMECA, 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 Senior Aerospace BWT (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)

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 and the machine printing parameters fixed.
- 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.

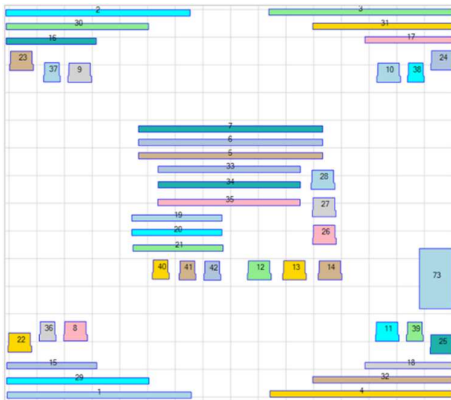
Design Values: (per CM-S-008 issue 1 in accordance with 21.A.31. SABWT's Primary FDM Machine Qualification and Secondary FDM Machine qualification) :

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.



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	✓	✓	✓

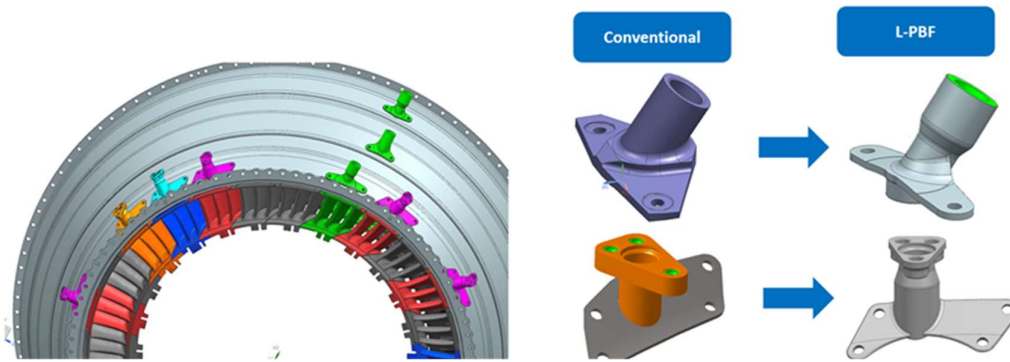
Flammability (FAR 25.583 (b)) : Tests were carried out to determine the effect printing orientation has on the flammability along with combinations of associated materials and adhesives used in the manufacture of the top assemblies. Additional to printing orientation, (*as mentioned*) toolpath design 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, 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.

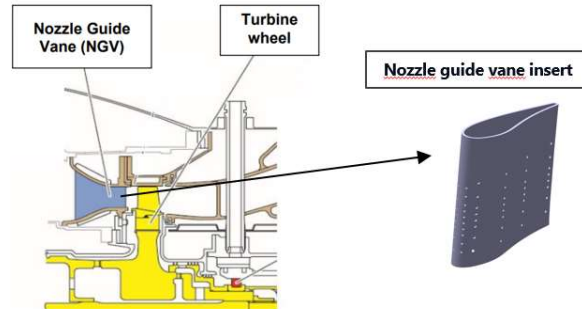
Static Strength: No tensile part testing conducted during qualification. Part and assembly tests supported by FE (using the established design values). The tensile design values are checked during the qualification of the part using witness coupon data.

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 - DAH): 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, 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

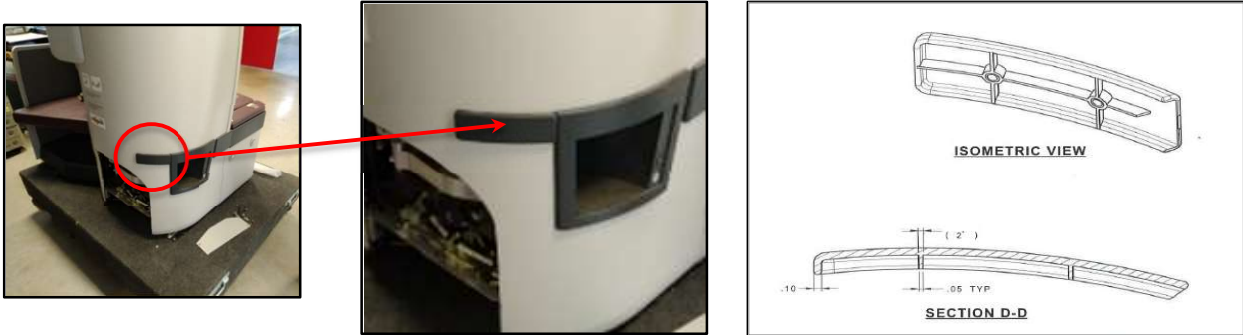
Further Comments:

- 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, completed: This is not located in the passenger interaction area, and therefore does not require occupant safety assessment. 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 Control Document.

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 flammability properties.

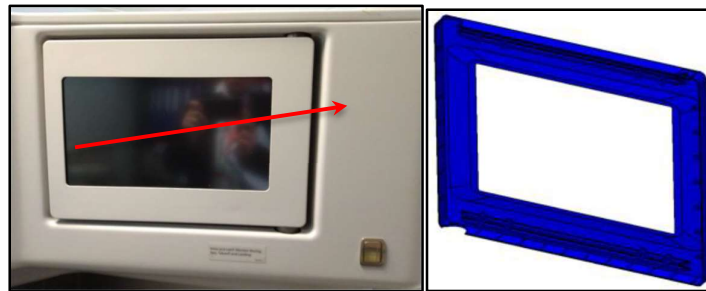
Static Strength: 3x part tests to failure, assembly static tests of each assembly (retention and cyclic impact loads). Mode of failure also established and compared to conventionally fabricated component.

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 (SAFRAN): CS25 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, completed: This is located in the passenger interaction area, and therefore requires occupant safety assessment. 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 component (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 Control Document.

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 flammability 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.

Interiors Example 3 (MATERIALISE): CS25 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, 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 Key Characteristics (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

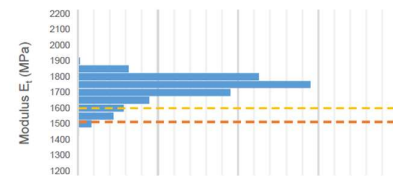
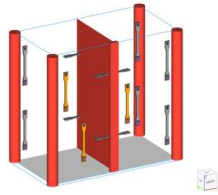
Design Values: (per CM-S-008 issue 1 in accordance with 21A20):

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 substantiation

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:

- Allowing for rapid decompression (airflow cabin to side-wall cavity) by opening of the pressure baffle
- Keeping dust and FOD out of the side wall cavity
- Allowing for low pressure airflow from the cabin to side-wall cavity (part of cabin air cycle) and vice versa
- 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>

Interiors Example 4 (ST AERO): Cabin Interiors CS25 (Neligious 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.

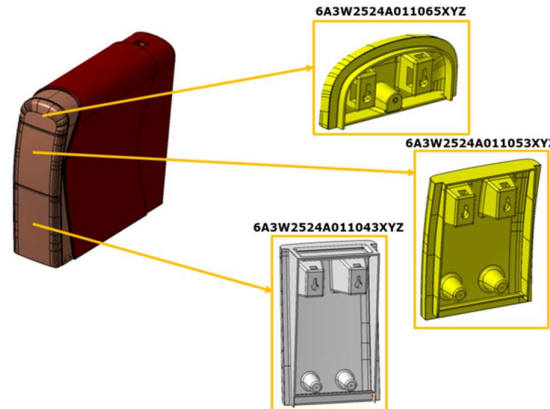
Static Strength:

- 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. Flammability testing completed iaw appropriate CS's and MoCs using the same material/process, machine and paint system.

**Example 5 (MAG): Cabin Interiors CS29 (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.

	[AW139 VIP 305 - FHA ADDITIVE MANUFACTURING PARTS]	[6AB1RAD-84]
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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	Classificati on/ Criticality*	Material	AM Process	MAG CVE	D&C	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	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	No
6A3W2524A0110 65XYZ	DRAWER UPPER INSERTED	3	Aesthetical cover of the interseat cabinet.	0,21kg	NO	D	ULTEM	FDM	D&C	No	No
6A3W2524A0110 53XYZ	DRAWER MID INSERTED	4	Aesthetical cover of the interseat cabinet.	0,5kg	NO	C	ULTEM	FDM	D&C	No	No
6A3W2524A0110 43XYZ	DRAWER INSERTED	5	Aesthetical cover of the interseat cabinet.	0,95kg	NO	C	ULTEM	FDM	D&C	No	No
6A3W2524A0113 21XYZ	Support USB	6	Aesthetical frame	<<0,45kg	NO	D	ULTEM	FDM	D&C	No	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	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:

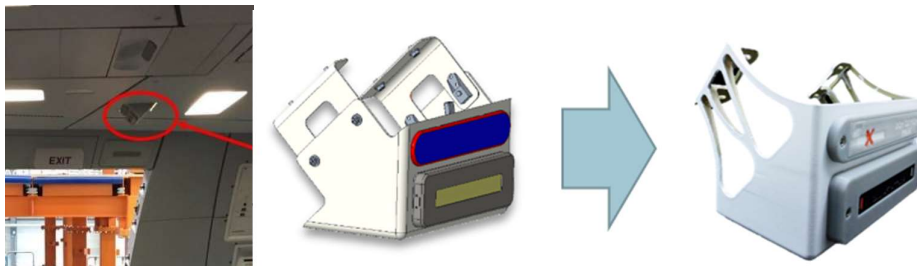
- All the stacking sequence are tested to be compliant with CS-29.853 requirements.
- 60 seconds vertical test according to CS 29.853 on minimum thickness (e.g. 0.8 mm) material usable in the actual parts, with specimen size of 300x100xminimum thickness

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 (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.