Certification Memorandum

Non-Hazardous Features of Engine Critical Parts

CM-PROP-001 Issue 01 issued 12 January 2022

Regulatory requirement(s): CS-E 515

EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

Log of issues

Issue	Issue date	Change description
01	12.01.2022	First issue.

Table of Content

1. Introduction

1.1. Purpose and scope

The purpose of this Certification Memorandum is to provide specific guidance for applicants when demonstrating compliance with CS-E 515 (a) for Engine Critical Parts. This CM provides guidance concerning the recognition of non-hazardous features (an area, a region, or a zone whose localised failure will not result in a Hazardous Engine Effect) within an Engine Critical Part and how such features may be credited within the Engineering Plan of CS-E 515 (a).

Additional guidance is also provided for static critical parts where the Approved Life may be based on the crack initiation life plus a portion of the residual crack growth life, as described in AMC E 515.

1.2. References

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

Reference	Title	Code	Issue	Date
CS-E 100	Strength	CS-E	6	24 June 2020
CS-E 130	Fire Protection	CS-E	6	24 June 2020
CS-E 510	Safety Analysis	CS-E	6	24 June 2020
CS-E 515	Engine Critical Parts	CS-E	6	24 June 2020
CS-E 520	Strength	CS-E	6	24 June 2020
CS-E 540	Strike and Ingestion of Foreign Matter	CS-E	6	24 June 2020
CS-E 640	Pressure Loads	CS-E	6	24 June 2020
CS-E 650	Vibration Surveys	CS-E	6	24 June 2020
CS-E 780	Icing Conditions	CS-E	6	24 June 2020
CS-E 790	Ingestion of Rain and Hail	CS-E	6	24 June 2020
CS-E 800	Bird Strike and Ingestion	CS-E	6	24 June 2020

Reference	Title	Code	Issue	Date
CS-E 810	Compressor and Turbine Blade Failure	CS-E	6	24 June 2020
CS-E 840	Rotor Integrity	CS-E	6	24 June 2020
CS-E 850	Compressor, Fan and Turbine Shafts	CS-E	6	24 June 2020
CS-E 1040	ETOPS	CS-E	6	24 June 2020
EASA CM-PIFS-007	Engine Critical Parts - Damage Tolerance Assessment - Manufacturing and Surface Induced Anomalies	CS-E	1	22 February 2013
Regulation (EU) No. 748/2012 Annex I (Part 21)	Commission Regulation (EU) No 748/2012 of 3 August 2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations	-		3 August 2012

1.3. Abbreviations

Part 21	Regulation (EU) No. 748/2012 Annex I (Part 21)
IBR	Integrally bladed rotor
ARIZ	Aerofoil-Rotor Interaction Zone

1.4. Definitions

Hazardous Engine Effect	An Effect identified as such under CS-E 510
Approved Life	The mandatory replacement life of a part which is approved by the Agency
Feature	An area, a region, or a zone of the Engine Critical Part
Non-Hazardous Feature	An area, a region, or a zone in-separable from an Engine Critical Part whose localised failure (e.g., loss of material, loss of function, or cracking) will not result in a Hazardous Engine Effect
Aerofoil-Rotor Interaction Zone	Root section of an IBR or centrifugal impellor aerofoil where cracks have been shown to propagate into the disc body due to steady and vibratory loads (from both aerofoil and disc modes)

2. Background

In accordance with CS-E 15, an Engine Critical Part means a part that relies upon meeting prescribed integrity specifications of CS-E 515 to avoid its Primary Failure, which is likely to result in a Hazardous Engine Effect.

The integrity of the Engine Critical Parts identified under CS-E 510 must be established by the provisions of CS-E 515 with respect to an Engineering Plan, a Manufacturing Plan, and a Service Management Plan. The execution of the Engineering Plan establishes and maintains that the combinations of loads, material properties, environmental influences and operating conditions, including the effects of parts influencing these parameters, are sufficiently well known or predictable by validated analysis, test, or service experience- to allow each Engine Critical Part to be withdrawn from service at an Approved Life before Hazardous Engine Effects can occur.

However, it is recognised that not all localised failures within an Engine Critical Part will lead to Hazardous Engine Effects. Failure of certain features of an Engine Critical Part may occur in such a manner that the outcome does not present a Hazardous Engine Effect.

No guidance is provided for the evaluation of features of an Engine Critical Part whose failure will not result in a Hazardous Engine Effect. For this reason, EASA is issuing this CM to aid applicants in the appropriate treatment of such features when demonstrating compliance with CS-E 515.

Additional guidance is also provided for static critical parts where the Approved Life may be based on the crack initiation life plus a portion of the residual crack growth life, as described in AMC E 515.

3. EASA Certification Policy

3.1. Identification and credit for non – hazardous features within the Engineering Plan

AMC E 515 provides guidance and acceptable means of compliance on the determination of the Approved Life for Engine Critical Parts that is required to be performed with the establishment of an Engineering Plan under CS-E 515 (a).

Within that guidance all features of an identified Engine Critical Part are treated equally, be that a rotating part, a static pressure loaded part, or any Engine Critical Part as identified by CS-E 510.

An Engine Critical Part, as defined by CS-E 15, is a part that relies upon meeting the prescribed integrity specifications of CS-E 515 to avoid its Primary Failure, which is likely to result in a Hazardous Engine Effect. However, it is recognised that an Engine Critical Part may include one or more features, the failure of which will not lead to a Hazardous Engine Effect, and in some instances, credit may be taken for such features within the Engineering Plan when determining the Approved Life of the part.

Where credit is taken for a non-hazardous feature or features within the Engineering Plan (required by CS-E 515), the Engineering Plan should identify those features of Engine Critical Parts assessed as having no Hazardous Engine Effect and the assumptions upon which they are identified. The Engineering Plan should also establish the actions necessary to ensure that the appropriateness of those assumptions is validated and maintained over the lifetime of the design. When changes are made to the Type Certificate, applicants may use this opportunity to reassess the assumptions made previously.

When features of an Engine Critical Part are credited for being non-hazardous (i.e. their failure has no Hazardous Engine Effect), the following additional information should be included in the Engineering Plan:

- The features deemed non-hazardous
- Assumed crack location and crack path that is deemed non-hazardous
- Justification of how the feature or features were deemed non-hazardous
- Demonstration by test or validated analysis that the Primary Failure (as defined in CS-E 15) of the feature or features does not result in a Hazardous Engine Effect

- Justification by test or validated analysis that the consequence of failure of the non-hazardous feature, or features, is appropriately addressed within the determination of the Approved Life of the part (see sections 3.3 and 3.4)

The Engineering, Manufacturing, and Service Management Plans as required by CS-E 515, should continue to ensure the closed-loop system which links the assumptions made in the Engineering Plan to how the part is manufactured and maintained in service, see EASA CM-PIFS-007 for details regarding Service Damage Monitoring.

Where credit is taken for a non-hazardous feature, or features, within the Engineering Plan (required by CS-E 515), the Safety Analysis of CS-E 510 should also evaluate the failure modes and effects of those features of Engine Critical Parts identified as non-hazardous, including the impact of engine installation assumptions, common mode effects, and ETOPS (CS-E 1040).

Note: The above discussion concerns the basis for a non-hazardous feature receiving credit within the Engineering Plan of CS-E 515, because its failure does not result in a Hazardous Engine Effect. However, failure of such features should not be an expected condition due to the Type Certificate's compliance with CS-E 100, 650 and 520 (see also section 3.5).

3.2. Features which may be identified as non-hazardous

To illustrate the principles for consideration of non-hazardous features, the examples below show features types which have historically demonstrated positive experience when identified as non-hazardous within individual certifications:

- Integrally bladed rotor (IBR) aerofoils (figure 1a) and centrifugal rotor / impellor aerofoils (figure 1b) above the black dashed line (Schematic representation of the start of ARIZ zone) shown in figure 1 (see Section 3.4.2.1)
  Note: the black dashed line is positioned at a radial position above the fillet, outboard of which defines the aerofoil. Failure of an aerofoil is contained (see CS-E 810) and does not lead to rotor burst.
- Features of static critical parts outside of load paths, (examples of load paths may include engine mounts, engine carcass, containment cases and high-pressure cases)

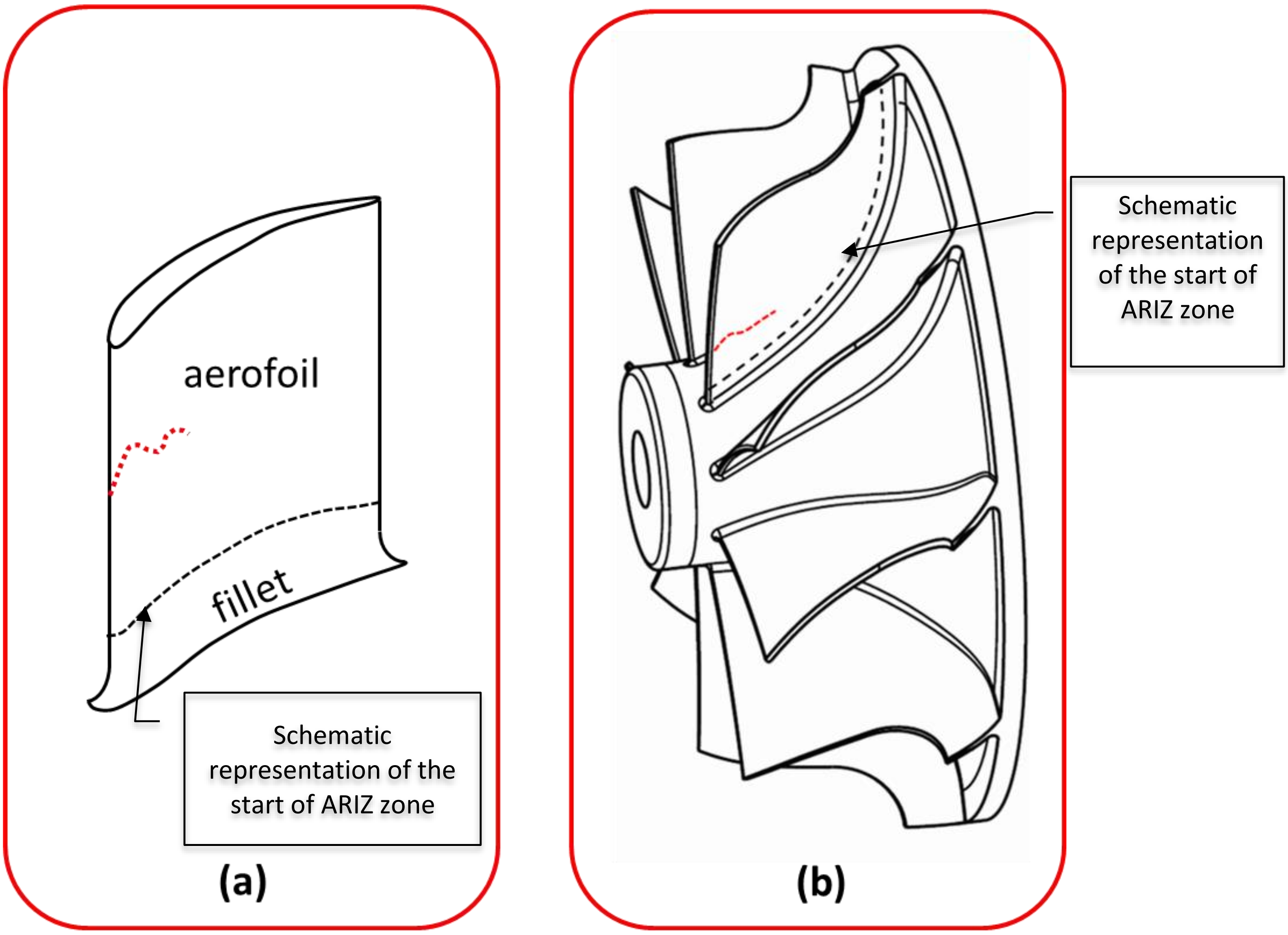

Figure 1Illustrations of potential types of features that may be non-hazardous

The above list identifies the features where the Agency considers that a non-hazardous evaluation may be acceptable during type certification. Additional feature types, should they meet the objectives of this CM, could be accepted as part of the Engineering Plan. Likewise, after entry into service of the engine, other feature types may also be proposed after analysis of in-service occurrences in the frame of continued airworthiness activities.

In order to demonstrate that a feature may be considered as non-hazardous and credited within the Engineering Plan of CS-E 515, the conditions specified in 3.3 and 3.4 should be satisfied.

3.3. Acceptance of non-hazardous features within the Engineering Plan

The failed feature should be shown to fail in such a way that the outcome does not result in a Hazardous Engine Effect and be consistent with the applicant's service and design experience gathered with other similar engine and critical part designs. Both the immediate consequences of a single failure and any continued operation must be considered in this assessment. Furthermore, secondary components, systems, and whole engine effects should also be evaluated.

It should be shown that the failure:

(a) Either results in a safe shutdown requiring immediate maintenance rectification, or
(b) may be tolerated until the next scheduled inspection (of the concerned part, and also any secondary components or systems), or
(c) is detectable (e.g. loss of EGT margin) during operation such that required near-term engine maintenance and rectification (e.g. engine removal) is assured

In cases (b) and (c) above, the engine may operate for several flights after the failure of the non-hazardous feature. Unless a crack initiation life is calculated for the feature and accounted for in the Approved Life, the consequences of this failure should be considered in all other relevant certification specifications. Continued compliance with the integrity requirements of CS-E (e.g. CS-E 100, 130, 520, 540(a), 640, 810(a) and (c), 840(a),(b) and (c), 850) should be ensured in meeting the objective that no Hazardous Engine Effect can occur.

The failed aerofoils of bladed rotor configurations have demonstrated positive field experience with respect to safety and meeting the relevant certification specifications (CS-E 510, CS-E 810). Therefore, the IBR or impeller aerofoil (as shown in figure 1) identified as a non-hazardous feature, need not be assessed, within the engine critical part life assessment methodology.

Field experience records and non-hazardous definitions are not yet available for other rotor non-hazardous features. As a result, the life and the consequence of failure of rotor non-hazardous features, other than IBR aerofoils and centrifugal rotor / impellor aerofoils, should be included within the Approved Life of the engine critical parts. The life assessment principle applied to such rotor non-hazardous features may however be less restrictive (i.e. have reduced statistical life margin) than features of the engine critical part whose failure would lead to a Hazardous Engine Effect.

3.4. Additional considerations when identifying a feature as non-hazardous

In order to identify a feature as a non-hazardous feature and take credit for this within the Engineering Plan (required by CS-E 515), the ultimate effects of the failure should be assessed and accounted for. The assessment may include, but may not be limited to:

3.4.1. Primary Containment

Failure does not lead to the non-containment of high-energy debris.

3.4.2. Crack growth behaviour

It is demonstrated by test, validated analysis, or experience that crack growth does not propagate in such a manner that may cause Hazardous Engine Effects. This assessment should consider all relevant effects which may include, but may be not limited to, high cycle fatigue, multi-axial stress fields, material composition, environmental effects, aeromechanical effects, thermo-mechanical fatigue, dwell, and minor cycles.

Crack growth models should comply with the applicant's approved lifing methodology for the rotor component material across the range of temperatures and stresses applicable to the part operating environment and/or CS-E-515 assumed aircraft flight profile(s).

3.4.2.1. IBR / centrifugal compressor / impellor rotor aerofoils - Establishment of an Aerofoil-Rotor Interaction Zone (ARIZ)

Damage to or cracking of a rotor aerofoil is shown not to grow into the body of the disc or any other area that may result in the release of high energy debris.

In IBR aerofoils and centrifugal impellors, it is possible for a crack nucleated in the root section (lower diameter region of the aerofoil for an IBR) of the aerofoil to grow into the rotor body through the combination of steady and vibratory stresses. Vibratory stresses can arise from disc body modes as well as aerofoil modes. This root section of the aerofoil is termed the aerofoil-rotor interaction zone (ARIZ). Crack nucleation within the ARIZ can occur from damage such as impact by foreign objects in the flowpath (i.e., foreign object damage (FOD)). Since cracking in the ARIZ may lead to a Hazardous Engine Effect (growth of a crack into the rotor body leading to burst), the ARIZ is considered a portion of the rotor body subject to the damage tolerance requirements of CS-E-515. By definition, the start of the ARIZ represents the limits of the aerofoil which may be considered non-hazardous.

Industry experience has identified the radial position in the aerofoil (as illustrated by the black dashed line (noted as Schematic representation of the start of ARIZ zone) in Figures 1(a) and 1(b)) above which a crack will liberate the aerofoil, and below which a crack may grow into the rotor body. The portion of the aerofoil which may grow a crack into the rotor body is the ARIZ, failure in this area may lead to a Hazardous Engine Effect.

A default ARIZ may be established as the radial distance from the inner annulus flowpath (gas washed surface representing the limit of the rotor body) to a height determined as the maximum of criteria (1) or (2):

1. 200% of the maximum aerofoil fillet height found anywhere around the root perimeter of the aerofoil. For IBRs, the fillet height is measured as the radial distance from the fillet runout on the aerofoil to the fillet runout on the inner annulus flowpath. For impellors, the fillet height is measured as the distance from the fillet runout on the aerofoil to the fillet runout on the inner annulus flowpath such as measured normal from the platform.
2. 150% of the maximum root aerofoil thickness as measured at the aerofoil fillet runout. The aerofoil thickness is defined as the diameter of the largest sphere tangent to the aerofoil fillet runout and the opposite side of the aerofoil.

The above criteria provide a default ARIZ height which may be used without further validation. An applicant may reduce the ARIZ height determined from these default criteria through the use of an appropriate damage tolerance methodology (such as a validated 3D crack growth assessment), tests, experience, or a combination thereof. A validated 3D crack growth assessment has the capability of assessing crack turning and should include the impact of steady and vibratory stresses. The assessment justifying the modification of the ARIZ height from the defaults above should consider the impact of vibratory modes of the disc body as well as the vibratory contribution from aerofoil high cycle fatigue modes and their interaction.

3.4.2.2. Static Critical Parts

As identified in the AMC E 515, the general principles that are used to establish the Approved Life of static critical parts are similar to those used for rotating parts. However, for static parts, the AMC states that the Approved Life may be based on the crack initiation life plus a period of crack growth life. For this reason, particular care is needed when evaluating a static critical part.

The Approved Life should be the minimum life of the feature whose failure could lead to a Hazardous Engine Effect (Note: AMC E 515 does recognise that manufacturing and in-service inspections are an option to address the potential fracture). It should therefore be demonstrated that crack growth does not propagate in such a manner that may cause Hazardous Engine Effects within the Approved Life of the part. For example, a crack length which compromises engine mount redundancy, high pressure structural integrity, or blade containment would not meet this objective.

For all features in a static Critical Part that have a predicted minimum material crack initiation life less than the Approved Life of the part, the part, with the crack length predicted at the Approved Life, should be shown, as relevant, to support without Hazardous Effect:

- the pressure loads defined by CS-E 640

- the structural loads following the blade failure in any fan, compressor, or turbine, including those loads sustained during the remainder of operation before schedule inspection or detection (CS-E 520 (c))

- the vibratory loads/stresses induced by normal or fault conditions (CS-E 650 (f) and (g))

Where it cannot be shown that the above conditions are the most limiting, the following specifications should also be considered CS-E 780, CS-E 790, and CS-E 800.

If the static Critical Part is a containment case (refer to the guidance of AMC 520 (d)), cracking or localised failure could lead to the release of uncontained high energy debris following compressor or turbine blade failure (refer to CS-E 810). Therefore, the following should be demonstrated for all features:

- cracks are not predicted to initiate in, or propagate into, any containment area within the Approved Life of the part

or

- the case, with the crack length predicted at the Approved Life of the part, is still able to contain a failed blade

If the static Critical Part is designed, constructed, and installed to act as a firewall (refer to CS-E 130), cracking or localised failure could lead to an uncontrolled fire. Therefore, the following should be demonstrated for all features:

- The part, with the crack length predicted at the Approved Life of the part, continues to act as an engine firewall

3.4.3. Secondary Effects

The failure of a non-hazardous feature should not affect the Approved Life, integrity, or function of the engine critical part in question, or other parts, in a manner that could lead to a Hazardous Engine Effect.

Failure of a non-hazardous feature may lead to a change in conditions and operating environment of neighbouring features or components. The consequences of these changes and their effect on the life of other features or parts should be included in the safety assessment of CS-E 510 and where relevant, the Engineering Plan of CS-E 515. It should also be identified whether single or multiple feature failure leads to more severe conditions elsewhere on the component. If a Hazardous Engine Effect is identified because of such assessment, then the feature should not be included within the list of non-hazardous features.

Secondary effects or damage may occur as a result of the primary failure, an example of this is blade aerofoil separation or the balling of released material causing damage to surrounding or downstream hardware. The resultant consequences of any material loss should be considered in addition to the primary effect within CS-E 510. If a Hazardous Engine Effect is identified because of such assessment, then the feature should not be included within the list of non-hazardous features.

3.4.4. Out of balance loads

The loss of portions of a rotating part causes unbalanced loading in both a transient and steady state manner. The effects of such abnormal loading should be considered for both rotating parts and static load paths. If a Hazardous Engine Effect is identified because of such assessment, then the feature should not be included within the list of non-hazardous features.

3.5. In-service findings and repairs

It is not the intention of this CM to allow failed or cracked hardware to return to service. The identification of a non-hazardous feature enables credit to be taken in the Engineering Plan when assessing the Approved Life. It is not an approval to consider a cracked or failed part as airworthy.

When the engine type enters service, in accordance with point 21.A.3A of Part 21, the Type Certificate holder must collect, investigate, and analyse reports related to cracking or failure of a critical part. The TC holder should investigate the root cause and determine if the certification assumptions remain valid.

The part in question should be considered unserviceable unless an appropriately approved repair design can be established to restore compliance to airworthiness requirements.

When credit is taken for a non-hazardous feature within the Engineering Plan in determining the Approved Life of a critical part, this does not constitute an approval of repair designs (production concession, non-conformances, or unrepaired damage), for individual parts found with failed (including cracked) non-hazardous features.

3.6. Classification of changes and repairs

The classification of changes and repairs in accordance with Part 21 remains unaffected.

3.7. Who this Certification Memorandum affects

This Certification Memorandum affects applicants for new turbine engine Type Certification (TC) when showing compliance with CS-E 515, as well as major changes to TCs where the affected areas include critical parts with identified non –hazardous features.

4. Remarks

1. For any question concerning the technical content of this EASA Certification Memorandum, please contact:
   Name, First Name: Mercy, Matthew
   Function: Propulsion PCM / Expert
   Phone: +49 (0)221 89990 4336
   E-mail: matthew.mercy@easa.europa.eu

