pages approved by EASA. In this way, changes to CMRs following certification will not require an amendment to the TCDS.

c. Since CMRs are based on statistical averages and reliability rates, an 'exceptional short-term extension' for CMR intervals may be made on one aeroplane for a specific period of time without jeopardising safety. Any exceptional short-term extensions to CMR intervals must be defined and fully explained in the applicant's CMR documentation. The competent authority must concur with any exceptional short-term extension allowed by the applicant's CMR documentation before it takes place, using procedures established with the competent authority in the operators' manuals. The exceptional short-term extension process is applicable to CMR intervals. It should not be confused with the operator's 'short-term escalation' program for normal maintenance tasks described in the operators' manuals.

(1) The term 'exceptional short-term extension' is defined as an increase in a CMR interval that may be needed to cover an uncontrollable or unexpected situation. Any allowable increase must be defined either as a percent of the normal interval, or a stated number of flight hours, flight cycles, or calendar days. If no exceptional short-term extension is to be allowed for a given CMR, this restriction should be stated in the applicant's CMR documentation.

(2) Repeated use of exceptional short-term extensions, either on the same aeroplane or on similar aeroplanes in an operator's fleet, should not be used as a substitute for good management practices. Exceptional short-term extensions must not be used for the systematic escalation of CMR intervals.

(3) The applicant's CMR documentation should state that the competent authority must approve, prior to its use, any desired exceptional short-term extension not explicitly listed in the CMR document.

13 *POST-CERTIFICATION CHANGES TO CMRs* (New, revised or deleted)

a. The introduction of a new CMR or any change to an existing CMR should be reviewed by the same entities that were involved in the process of CCMR/CMR determination (refer to paragraphs 10 and 11 of this AMC) at the time of initial certification. To allow operators to manage their own maintenance programs, it is important that they be afforded the same opportunity for participation that they were afforded during the initial certification of the aeroplane.

b. Any post-certification changes to CMRs must be approved by EASA which approved the type design.

c. Since the purpose of a CMR is to limit the time of exposure to a given significant latent failure, or a given wear out, as part of an engineering analysis of the overall system safety, instances of a CMR task repeatedly finding that no failure has occurred may not be sufficient justification for deleting the task or increasing the time between repetitive performances of the CMR task. In general, a CMR task change or interval escalation should only be made if experience with the aeroplane fleet in service worldwide indicates that certain assumptions regarding component failure rates made early during the engineering analysis were too conservative, and a re-calculation of the system's reliability with revised failure rates of certain components reveals that the task or interval may be changed.

d. If later data provides a sufficient basis for the relaxation of a CMR (less restrictive actions to be performed), the change may be documented by a revision to the applicant's CMR documentation and approved by EASA.

e. To address an unsafe condition, EASA may determine that the requirements of an existing CMR must be modified (more restrictive actions to be required) or a new CMR must be created. These modified requirements will be mandated by an Airworthiness Directive (AD) and the applicant's CMR documentation will be revised to include the change.

f. New CMRs that are unrelated to in-service occurrences may be created and they should be documented and approved by EASA. New CMRs can arise in situations such as:

(1) the certification of design changes, or

(2) updates of the applicant's certification compliance documentation. These may result from regulatory changes, actions required by an AD on similar systems or aeroplanes, awareness of additional Hazardous or Catastrophic Failure Conditions, revised failure rates, consideration of extended service goals, etc.

APPENDIX 1 SUPPLEMENTAL GUIDANCE FOR THE USE OF CMRs

1. The TC/STC applicant should choose a system design that minimises the number of significant latent failures, with the ultimate goal that no such failures should exist, if this is practical. A practical and reliable failure monitoring and flight crew indication system should be considered as the first means to detect a significant latent failure. If the cost of adding practical and reliable failure monitoring and flight crew indication system is high, and the added maintenance cost of a CMR is low, the addition of a CMR may be the solution of choice for both the type certificate applicant and the operator, provided all applicable regulations are met. Substituting a CMR with an MRBR task does not necessarily reduce maintenance costs.

2. The decision to create a CMR may include a trade-off of the cost, weight, or complexity of providing mechanism or device that will expose the latent failure, versus the requirement for the operator to conduct a maintenance or inspection task at fixed intervals.

3. The following points should be considered in any decision to create a CMR in lieu of a design change.

a. What is the magnitude of the changes to the system and/or aeroplane needed to add a reliable failure monitoring and flight crew indication system that would expose the latent failure? What is the cost in added system complexity?

b. Is it possible to introduce a self-test on power-up?

c. Is the monitoring and flight crew indication system reliable? False warnings must be considered, as well as a lack of warnings.

d. Does the failure monitoring or flight crew indication system itself need a CMR due to its latent failure potential?

e. Is the CMR task reasonable, considering all aspects of the failure condition that the task is intended to address?

f. How long (or short) is the CMR task interval?

g. Is the proposed CMR task labour intensive or time consuming? Can it be done without having to 'gain access' and/or without workstands? Without test equipment? Can the

CMR task be done without removing equipment from the aeroplane? Without having to re-adjust equipment? Without leak checks and/or engine runs?

h. Can a simple visual inspection be used instead of a complex one? Can a simple operational check suffice in lieu of a formal functional check against measured requirements?

i. Is there 'added value' to the proposed task (i.e. will the proposed task do more harm than good if the aeroplane must be continually inspected)?

j. Have all alternatives been evaluated?

APPENDIX 2 ROLE OF THE CERTIFICATION MAINTENANCE COORDINATION COMMITTEE (CMCC)

1. The CMCC functions as an advisory committee for the applicant and proposes the disposition of each presented CCMR. EASA is the authority that ultimately approves CMRs as airworthiness limitations of the type certificate as per Part-21.

2. In order to grant aeroplane operators the opportunity to participate in the selection of CMRs, and to assess the CCMRs and the proposed MRBR tasks and intervals in an integrated process, the applicant should convene a CMCC as early as possible in the design phase of the aeroplane program, and at intervals as necessary. This CMCC should comprise TC/STC holder representatives (typically maintenance, design, and safety engineering personnel), operator representatives designated by the Industry Steering Committee (ISC) chairperson, EASA certification specialist(s), and the MRB chairperson(s). EASA certification specialist participation in the CMCC is necessary to provide regulatory guidance on the disposition of CCMRs.

3. The CMCC should review CCMRs and their purposes, the Failure Conditions and their classifications, the intended tasks and their intervals, and other relevant factors. In addition, where multiple tasks result from a quantitative analysis, it may be possible to extend a given interval at the expense of one or more other intervals, in order to optimise the required maintenance activity. However, once a decision is made to create a CMR, then the CMR interval should be based solely on the results of the SSA or other relevant analysis. If the SSA does not specify an interval shorter than the life of the aeroplane, then the CMR interval may be proposed by the CMCC considering factors that influence the outcome of the failure condition, such as the failure mode(s) to be detected, the system(s) affected, field experience, or task characteristics.

4. The CMCC should address all CCMRs. Alternatively, the applicant may coordinate with EASA to define a subset of CCMRs to be presented to the CMCC.

5. The CMCC discusses compatible tasks (if any) that the MRB generates. The CMCC may select an MRBR task in lieu of a CMR in accordance with paragraph 11 of this AMC.

6. The CMCC may request the ISC to review selected CMCC results (e.g. proposed revised MRBR tasks and/or intervals). Upon ISC review, the proposed revised MRBR tasks and/or intervals accepted by the ISC are reflected in the MRBR proposal, and the proposed revised MRBR tasks and/or intervals rejected by the ISC result in CMRs. Following consideration by the ISC, the applicant submits the CMRs to EASA for final review and approval.

APPENDIX 3 MEANS OF PROTECTION PROPOSED BY THE DESIGN APPROVAL HOLDER (DAH) AGAINST FUTURE EVOLUTIONS OF THE COMPATIBLE MRBR TASKS AND DERIVED TASKS OF THE OPERATOR'S AEROPLANE MAINTENANCE PROGRAM — EXAMPLES

1. With reference to paragraph 11.c of this AMC, this Appendix provides examples to facilitate the implementation of the means to ensure that the CCMRs are protected in service.

2. These examples describe acceptable means, but not the only means. Any means should be presented to EASA for acceptance.

<u>EXAMPLE 1 — Traceability of CCMRs and MRBR tasks in the Airworthiness Limitations Section</u>

a. The CMR designation may not be necessary if there is a compatible MRBR task to accommodate the CCMR, provided that the design approval holder (DAH) shows direct traceability between the MRBR task and the accommodated CCMR in the airworthiness limitations section (ALS).

b. The compatible MRBR task and its interval are not airworthiness limitations. The status of the compatible MRBR task with regard to the MRB process remains unchanged.

c. Traceability between the CCMR and the compatible MRBR task should be provided in the ALS of the instructions for continued airworthiness to ensure that the CCMR is respected during in-service operation of the aeroplane and any future evolution of the maintenance program.

Table 1 illustrates one possible means for traceability.

CCMR task reference	CCMR interval	Compatible MRBR task reference
CCMR task #NN	60 months	MRBR task #XX
CCMR task #MM	10 000 flight hours	MRBR task #YY
…	…	…

Appendix 3 — Table 1

d. If the DAH changes the compatible MRBR task to the extent that the intent of the corresponding CCMR task is adversely affected, this corresponding CCMR task is no longer accommodated. Therefore, the DAH could either propose a new compatible MRBR task, if one exists, or create a new CMR in line with the intent of the previously referenced CCMR limitation. These changes to the ALS require EASA approval.

e. If the DAH escalates the interval of the compatible MRBR task beyond the corresponding CCMR limitation, this corresponding CCMR is no longer accommodated and the DAH needs to create a CMR in order to satisfy the corresponding CCMR limitation. Alternatively, the DAH could assess the feasibility of escalating the interval of the corresponding CCMR by re-evaluating the system safety assumptions that lead to the CCMR at the time of initial certification. These changes to the ALS require EASA approval.

f. Furthermore, the DAH shall describe in the ALS what the operator needs to observe when changing the operator's aeroplane maintenance program (AMP). For tasks included in an AMP, which are based on compatible MRBR tasks, the following applies:

   i. Should the operator propose to change the intent of a task, the operator should ask for the DAH's confirmation that this change does not adversely affect the intent of the corresponding CCMR task. If the corresponding CCMR task is no longer accommodated, the operator needs to propose to include a mandatory task in the AMP in order to satisfy the intent of the referenced CCMR limitation. These changes to the AMP require the approval of the competent authority responsible for the oversight of the operator.

   ii. If the operator proposes to escalate the interval of a task, the corresponding CCMR limitation must not be exceeded.

EXAMPLE 2 — Uniquely identifying the compatible MRBR tasks

a. The CMR designation may not be necessary if there is a compatible MRBR task to accommodate the CCMR, provided that the DAH uniquely identified each compatible MRBR task in the existing MRBR task listing. Table 2 illustrates one possible means for marking.

MRBR task reference	MRBR task description	Failure effect category (FEC)	Interval	Tracking
MRBR task #XX	Functional check of […]	FEC 8	60 months	
MRBR task #YY	Detailed inspection of […]	-	72 months	EWIS
MRBR task #ZZ	Operational check of […]	FEC 8	10 000 flight hours	CCMR
…	…	…	…	…

Appendix 3 — Table 2

b. The purpose of the marking and the policies to be observed for appropriate change control of the marked MRBR tasks should be stated in the MRB report.

c. The status of the compatible MRBR task with regard to the MRB process remains unchanged.

d. If the DAH changes the marked MRBR task to the extent that the intent of the corresponding CCMR task is adversely affected, the DAH needs to create a CMR to satisfy the intent of the initial CCMR task. This change to the ALS requires EASA approval.

e. For future escalations of MRBR tasks, the DAH should have procedures in place to ensure that these escalations do not increase the interval of the marked MRBR task beyond the corresponding CCMR interval.

f. However, should the DAH escalate the marked MRBR task beyond the CCMR interval, the DAH needs to create a CMR in order to satisfy the corresponding CCMR. This change to the ALS requires EASA approval. Alternatively, the DAH could assess the feasibility of escalation of the interval of the corresponding CCMR by re-evaluating the system safety assumptions that lead to the CCMR at the time of initial certification. This change to the CCMR interval requires EASA involvement in accordance with the process described in paragraph 11 of this AMC.

g. Furthermore, the DAH shall describe in the MRBR what the operator needs to observe when changing the operator's aeroplane maintenance program (AMP). For tasks included in the AMP, which are based on marked MRBR tasks, the following applies:

   i. If the operator proposes to change the intent of a task, the operator should ask for the DAH's confirmation that this change does not adversely affect the intent of the corresponding CCMR task.

   ii. If the operator proposes to escalate the interval of a task, the operator should ask for the DAH's confirmation that this escalation does not increase the interval beyond the corresponding CCMR interval. These changes to the AMP require the approval of the competent authority responsible for the oversight of the operator.

[Amdt 25/20]
[Amdt 25/21]

AMC 25-24 Sustained Engine Imbalance

ED Decision 2009/017/R

1. PURPOSE

   This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the aircraft design for sustained engine rotor imbalance conditions.

2. RELATED CS PARAGRAPHS

   a. CS-25:

      CS 25.302 "Interaction of systems and structures"

      CS 25.571 "Damage tolerance and fatigue evaluation of structure"

      CS 25.629 "Aeroelastic stability requirements"

      CS 25.901 "Installation"

      CS 25.903 "Engines"

   b. CS-E:

      CS-E 520 "Strength"

      CS-E 525 "Continued Rotation"

      CS-E 810 "Compressor and Turbine Blade Failure"

      CS-E 850 "Compressor, Fan and Turbine Shafts"

3. DEFINITIONS. Some new terms have been defined for the imbalance condition in order to present criteria in a precise and consistent manner. In addition, some terms are employed from other fields and may not be in general use as defined below. The following definitions apply in this AMC:

   a. **Airborne Vibration Monitor (AVM).** A device used for monitoring the operational engine vibration levels that are unrelated to the failure conditions considered by this AMC.

   b. **Design Service Goal (DSG).** The design service goal is a period of time (in flight cycles/hours) established by the applicant at the time of design and/or certification and used in showing compliance with CS 25.571.

   c. **Diversion Flight.** The segment of the flight between the point where deviation from the planned route is initiated in order to land at an en route alternate airport and the point of such landing.

   d. **Ground Vibration Test (GVT).** Ground resonance tests of the aeroplane normally conducted in compliance with CS 25.629.

   e. **Imbalance Design Fraction (IDF).** The ratio of the design imbalance to the imbalance (including all collateral damage) resulting from release of a single turbine, compressor, or fan blade at the maximum rotational speed to be approved, in accordance with CS-E 810.

   f. **Low Pressure (LP) Rotor.** The rotating system, which includes the low pressure turbine and compressor components and a connecting shaft.

   g. **Well Phase.** The flight hours accumulated on an aeroplane or component before the failure event.

4. BACKGROUND

a. Requirements. CS 25.901(c) requires the powerplant installation to comply with CS 25.1309. In addition, CS 25.903(c) requires means of stopping the rotation of an engine where continued rotation could jeopardise the safety of the aeroplane, and CS 25.903(d) requires that design precautions be taken to minimise the hazards to the aeroplane in the event of an engine rotor failure. CS-E 520(c)(2) requires that data shall be established and provided for the purpose of enabling each aircraft constructor to ascertain the forces that could be imposed on the aircraft structure and systems as a consequence of out-of-balance running and during any continued rotation with rotor unbalance after shutdown of the engine following the occurrence of blade failure, as demonstrated in compliance with CS-E 810, or a shaft, bearing or bearing support, if this results in higher loads.

b. Blade Failure. The failure of a fan blade and the subsequent damage to other rotating parts of the fan and engine may induce significant structural loads and vibration throughout the airframe that may damage the nacelles, equipment necessary for continued safe flight and landing, engine mounts, and airframe primary structure. Also, the effect of flight deck vibration on displays and equipment is of significance to the crew's ability to make critical decisions regarding the shut down of the damaged engine and their ability to carry out other operations during the remainder of the flight. The vibratory loads resulting from the failure of a fan blade have traditionally been regarded as insignificant relative to other portions of the design load spectrum for the aeroplane. However, the progression to larger fan diameters and fewer blades with larger chords has changed the significance of engine structural failures that result in an imbalanced rotating assembly. This condition is further exacerbated by the fact that fans will continue to windmill in the imbalance condition following engine shut down.

c. Bearing/Bearing Support Failure. Service experience has shown that failures of bearings/bearing supports have also resulted in sustained high vibratory loads.

d. Imbalance Conditions. There are two sustained imbalance conditions that may affect safe flight: the windmilling condition and a separate high power condition.

(1) Windmilling Condition. The windmilling condition results after the engine is shut down but continues to rotate under aerodynamic forces. The windmilling imbalance condition results from bearing/bearing support failure or loss of a fan blade along with collateral damage. This condition may last until the aeroplane completes its diversion flight, which could be several hours.

(2) High Power Condition. The high power imbalance condition occurs immediately after blade failure but before the engine is shut down or otherwise spools down. This condition addresses losing less than a full fan blade which may not be sufficient to cause the engine to spool down on its own. This condition may last from several seconds to a few minutes. In some cases it has hampered the crew's ability to read instruments that may have aided in determining which engine was damaged.

e. The information provided in this AMC is derived from the recommendations in the report "Engine Windmilling Imbalance Loads - Final Report," dated July 1, 1997, which is appended to this NPA for information.

f. The criteria presented in this AMC are based on a statistical analysis of 25 years of service history of high by-pass ratio engines with fan diameters of 1.52 metres (60 inches) or greater. Although the study was limited to these larger engines, the criteria and methodology are also acceptable for use on smaller engines.

5. EVALUATION OF THE WINDMILLING IMBALANCE CONDITIONS

a. Objective. It should be shown by a combination of tests and analyses that after:

i) partial or complete loss of an engine fan blade, or

ii) after bearing/bearing support failure, or

iii) any other failure condition that could result in higher induced vibrations

including collateral damage, the aeroplane is capable of continued safe flight and landing.

b. Evaluation. The evaluation should show that during continued operation at windmilling engine rotational speeds, the induced vibrations will not cause damage that would jeopardise continued safe flight and landing. The degree of flight deck vibration[1] should not prevent the flight crew from operating the aeroplane in a safe manner. This includes the ability to read and accomplish checklist procedures.

This evaluation should consider:

(1) The damage to airframe primary structure including, but not limited to, engine mounts and flight control surfaces,

(2) The damage to nacelle components, and

(3) The effects on equipment necessary for continued safe flight and landing (including connectors) mounted on the engine or airframe.

c. Blade Loss Imbalance Conditions

(1) Windmilling Blade Loss Conditions. The duration of the windmilling event should cover the expected diversion time of the aeroplane. An evaluation of service experience indicates that the probability of the combination of a 1.0 IDF and a 60 minute diversion is on the order of 10-7 to 10 -8 while the probability of the combination of a 1.0 IDF and a 180 minute diversion is 10-9 or less. Therefore, with an IDF of 1.0, it would not be necessary to consider diversion times greater than 180 minutes. In addition, the 180 minute diversion should be evaluated using nominal and realistic flight conditions and parameters. The following two separate conditions with an IDF of 1.0 are prescribed for application of the subsequent criteria which are developed consistent with the probability of occurrence:

(a) A 60 minute diversion flight.

(b) If the maximum diversion time established for the aeroplane exceeds 60 minutes, a diversion flight of a duration equal to the maximum diversion time, but not exceeding 180 minutes.

(2) Aeroplane Flight Loads and Phases

(a) Loads on the aeroplane components should be determined by dynamic analysis. At the start of the windmill event, the aeroplane is assumed to be in level flight with a typical payload and realistic fuel loading. The speeds, altitudes, and flap configurations considered may be established according to the Aeroplane Flight Manual (AFM) procedures. The analysis should take into account unsteady aerodynamic characteristics and all significant

[1] An acceptable level of cockpit vibration in terms of vibration frequency, acceleration magnitude, exposure time and direction may be found in ISO 2631/1 “International Standard, Evaluation of Human Exposure to Whole-Body Vibration, Part I: General Requirements”, 1985.

structural degrees of freedom including rigid body modes. The vibration loads should be determined for the significant phases of the diversion profiles described in paragraphs 5c(1)(a) and (b) above.

(b) The significant phases are:

1 The initial phase during which the pilot establishes a cruise condition;

2 The cruise phase;

3 The descent phase; and

4 The approach to landing phase.

(c) The flight phases may be further divided to account for variation in aerodynamic and other parameters. The calculated loads parameters should include the accelerations needed to define the vibration environment for the systems and flight deck evaluations. A range of windmilling frequencies to account for variation in engine damage and ambient temperature should be considered.

(3) Strength Criteria

(a) The primary airframe structure should be designed to withstand the flight and windmilling vibration load combinations defined in paragraphs 1, 2, and 3 below.

1 The peak vibration loads for the flight phases in paragraphs 5c(2)(b)1 and 3 above, combined with appropriate 1g flight loads. These loads should be considered limit loads, and a factor of safety of 1.375 should be applied to obtain ultimate load.

2 The peak vibration loads for the approach to landing phase in paragraph 5c(2)(b)4 above, combined with appropriate loads resulting from a positive symmetrical balanced manoeuvring load factor of 1.15g. These loads should be considered as limit loads, and a factor of safety of 1.375 should be applied to obtain ultimate load.

3 The vibration loads for the cruise phase in paragraph 5c(2)(b)2 above, combined with appropriate 1g flight loads and 70 percent of the flight manoeuvre loads up to the maximum likely operational speed of the aeroplane. These loads are considered to be ultimate loads.

4 The vibration loads for the cruise phase in paragraph 5c(2)(b)2 above, combined with appropriate 1g flight loads and 40 percent of the limit gust velocity of CS 25.341 as specified at VC (design cruising speed) up to the maximum likely operational speed of the aeroplane. These loads are considered to be ultimate loads.

(b) In selecting material strength properties for the static strength analyses, the requirements of CS 25.613 apply.

(4) Assessment of Structural Endurance

(a) Criteria for fatigue and damage tolerance evaluations of primary structure are summarised in Table 1 below. Both of the conditions described in paragraphs 5c(1)(a) and (b) above should be evaluated. Different levels of structural endurance capability are provided for these conditions. The criteria for the condition in paragraph 5c(1)(b) are set to ensure at least a 50 percent probability of preventing a structural component failure. The criteria for the condition in paragraph 5c(1)(a) are set to ensure at least a 95 percent probability of preventing a structural component failure. These criteria are consistent with the probability of occurrences for these events discussed in paragraph 5(c)(1) above.

(b) For multiple load path and crack arrest “fail-safe” structure, either a fatigue analysis per paragraph 1 below, or damage tolerance analysis per paragraph 2 below, may be performed to demonstrate structural endurance capability. For all other structure, the structural endurance capability should be demonstrated using only the damage tolerance approach of paragraph 2 below. The definitions of multiple load path and crack arrest "fail-safe" structure are the same as defined for use in showing compliance with CS 25.571, "Damage tolerance and fatigue evaluation of structure."

1 Fatigue Analysis. Where a fatigue analysis is used for substantiation of multiple load path “fail-safe” structure, the total fatigue damage accrued during the well phase and the windmilling phase should be considered. The analysis should be conducted considering the following:

(aa) For the well phase, the fatigue damage should be calculated using an approved load spectrum (such as used in satisfying the requirements of CS 25.571) for the durations specified in Table 1. Average material properties may be used.

(bb) For the windmilling phase, fatigue damage should be calculated for the diversion profiles using a diversion profile consistent with the AFM recommended operations, accounting for transient exposure to peak vibrations, as well as the more sustained exposures to vibrations. Average material properties may be used.

(cc) For each component, the accumulated fatigue damage specified in Table 1 should be shown to be less than or equal to the fatigue damage to failure of the component.

2 Damage Tolerance Analysis. Where a damage tolerance approach is used to establish the structural endurance, the aeroplane should be shown to have adequate residual strength during the specified diversion time. The extent of damage for residual strength should be established, considering growth from an initial flaw assumed present since the aeroplane was manufactured. Total flaw growth will be that occurring during the well phase, followed by growth during the windmilling phase. The analysis should be conducted considering the following:

(aa) The size of the initial flaw should be equivalent to a manufacturing quality flaw associated with a 95 percent probability of existence with 95 percent confidence (95/95).

(bb) For the well phase, crack growth should be calculated starting from the initial flaw defined in paragraph 5c(4)(b)2(aa) above, using an approved load spectrum (such as used in satisfying the requirements of CS 25.571) for the duration specified in Table 1. Average material properties may be used.

(cc) For the windmilling phase, crack growth should be calculated for the diversion profile starting from the crack length calculated in paragraph 5c(4)(b)2(bb) above. The diversion profile should be