COMMENT-RESPONSE DOCUMENT (CRD) TO NOTICE OF PROPOSED AMENDMENT (NPA) 2010-12

for amending the Executive Director Decision No 2003/16/RM of 14 November 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large rotorcraft ('CS-29')

'Vibration Health Monitoring'

Executive Summary

1. NPA 2010-12 was issued in October 2010 with the aim of introducing a new Certification Specification (CS 29.1465) and associated AMC (AMC 29.1465) covering the design and certification of VHM systems for large rotorcraft. CS 29.1465 does not in itself mandate the installation of VHM systems but sets the minimum design and performance standards for approval of such systems if installed. Compliance with CS 29.1465 can either be to comply with an operational requirement, as a compensating provision to mitigate a Hazardous/Catastrophic failure condition identified through a design assessment, or installed on a voluntary basis.

2. Comments received on NPA 2010-12 generally supported the intent, but indicated a lack of clarity in the intended rule and AMC. In particular, the proposed rule text was unclear regarding the VHM system capabilities required for compliance with an operational rule, and could also be interpreted as restricting approval of partial VHM systems used for specific applications, which have a safety benefit and should not be discouraged.

3. As a result of comments received, a Review Group was established in accordance with the Agency's rulemaking procedures. This consisted of the original drafting group, augmented with 2 additional members drawn from the Agency's Standardisation Department and from the FAA (representing dissenting views of stakeholders).

4. Based on stakeholders' comments and the Review Group's assessment, the text proposed in NPA 2010-12 has been amended. The main changes introduced with this CRD are:

   a. The rule is subdivided so that CS 29.1465(a) is applicable to certification of all VHM systems requested by the applicant. This will enable partial and full VHM systems to be certificated.

   b. CS 29.1465(b) is now dedicated to compliance with an operational rule and provides additional requirements to supplement paragraph (a). The scope of the VHM system will require consideration of all typical VHM capabilities (Table 1 of the AMC) plus any additional capabilities that may arise as a result of the safety analysis. Any reduction in capabilities from this "full" VHM system will only be permitted if it can be substantiated that other reliable means of health monitoring are provided which can replace VHM for particular failure modes.

   c. Further guidance is added on failure condition categorisation and related software standards.

Explanatory Note

I. General

1. The purpose of the Notice of Proposed Amendment (NPA) 2010-12, dated 15 October 2010 was to propose an amendment to Decision 2003/16/RM of the Executive Director of the European Aviation Safety Agency of 14 November 2003 on certification specifications, including airworthiness code and acceptable means of compliance, for large rotorcraft ('CS-29')[1].

II. Consultation

2. The draft Executive Director Decision amending Decision 2003/16/RM was published on the website (http://www.easa.europa.eu/) on 15 October 2010.

   By the closing date of 15 January 2011, the European Aviation Safety Agency (hereafter referred to as the 'Agency') had received 54 comments from 8 National Aviation Authorities, professional organisations and private companies.

III. Publication of the CRD

3. All comments received have been acknowledged and incorporated into this Comment-Response Document (CRD) with the responses of the Agency.

4. In responding to comments, a standard terminology has been applied to attest the Agency's acceptance of the comment. This terminology is as follows:

   - **Accepted** — The comment is agreed by the Agency and any proposed amendment is wholly transferred to the revised text.
   - **Partially accepted** — Either the comment is only agreed in part by the Agency, or the comment is agreed by the Agency but any proposed amendment is partially transferred to the revised text.
   - **Noted** — The comment is acknowledged by the Agency but no change to the existing text is considered necessary.
   - **Not accepted** — The comment or proposed amendment is not shared by the Agency.

   The resulting text highlights the changes as compared to the published NPA.

5. The Executive Director Decision will be issued at least two months after the publication of this CRD to allow for any possible reactions of stakeholders regarding possible misunderstandings of the comments received and answers provided.

6. Such reactions should be received by the Agency not later than the **22nd of October 2012** and should be submitted using the Comment-Response Tool at http://hub.easa.europa.eu/crt.

[1] As last amended by Decision 2008/10/RM dated 10 November 2008 (CS-29 Amendment 2).

IV. CRD table of comments, responses and resulting text

(General Comments)	-

comment	*6* comment by: *Luftfahrt-Bundesamt* The LBA has no comments on NPA 2010-12.
response	*Noted*

comment	*29* comment by: *Swedish Transport Agency, Civil Aviation Department (Transportstyrelsen, Luftfartsavdelningen)* The Swedish Transport Agency, Civil Aviation Department is supporting Option 3 (Non-mandatory rulemaking action) of the NPA 2010-12.
response	*Noted*

TITLE PAGE	p. 1

comment	*23* comment by: *FAA Rotorcraft Directorate* Thank you for the opportunity to provide our feedback on the proposed Vibration Health Monitoring (VHM) NPA. Our understanding of the EASA/FAA/Industry VHM working group (VHM WG) was that this group was organized to update the HHMAG VHM specification for use as guidance by updating the current HUMS AC 29, MG-15 and was not intended to be a rulemaking group. We do not see a need to move forward with our own rulemaking at this time. Since our involvement with the VHM WG was not for rulemaking purposes, and based on the number of comments that we have with the proposed VHM NPA and associated AMC 29.547, 29.917 and 29.1465, we request an opportunity to further discuss the objective, applicability and approach taken by this NPA and associated AMC before it is issued since previously submitted comments by the FAA were not incorporated into your rulemaking proposal. We do agree with your concept of developing an alternative approach for VHM systems whose failure condition category is assessed to be Minor or No Safety Effect if this concept is applied to VHM installations that request Maintenance Credits as defined in the current AC 29-2C , MG-15. However, the examples described in the proposed AMC 29.1465 go beyond what we would assess as Minor or No Safety Effect. Also, we would like to note that based on our review, the proposed rule and associated AMC material will result in confusion to the industry due to the lack of clarity with respect to certifying VHM for Maintenance Credit or for showing compliance with 29.547 & 29.917. This confusion will further be exacerbated if the FAA does not reciprocate EASA's NPA and associated AMC.
response	*Noted* You are correct in that the original intent of this task was to develop AC. However, in early group discussions it was clear that simply providing additional design guidance would not create the necessary link with mandatory operational rules or ensure that, when installed, VHM systems met a given minimum standard. In Europe there is an operational rule to meet ICAO

Annex 6 that mandates installation of VHM systems for certain types of operations, but gives no details of the expected system functionality. Clearly the design of the VHM system resides in the airworthiness domain, and so it is seen as appropriate to create a design rule that caters for all situations and makes the link with operations.

It is considered that adding this requirement to CS-29, as a difference to FAR Part 29, would not present a significant problem to industry.

The Review Group established to disposition comments received on NPA 2010-12 and to draft this CRD, was attended by additional FAA personnel.

A. Explanatory Note - I. General p. 3

comment

12 comment by: *Eurocopter*

The proposed amendment is not in accordance with the Terms of Reference for rulemaking task 27&29.019 published on the EASA website as required by the Rulemaking Procedure. It rather anticipates what could be an outcome of the inventory task 27&29.020 included in the 4-year Rulemaking Programme 2011-2014 to adopt ICAO recommendations on the fitment of VHM systems to helicopters.

response

Not accepted

The group's ToR was extended to include rulemaking in April 2008 following due consultation with stakeholders in accordance with the rulemaking procedure (although due to a clerical oversight, this was not published on the Agency's website).

The proposed amendment to CS-27/29 does not mandate the fitment of VHM systems. Task RMT.0350 (OPS.074) will assess the need to mandate equipment and comply with ICAO recommendations, starting in 2013.

A. Explanatory Note - IV. Background p. 4-5

comment

7 comment by: *CHC*

Conflict in document: Final sentence of Para.13 says that Engine Monitoring is to be excluded from the proposal. Pg.16 Table 1 however, then details engines as one of the areas to be monitored. Pg.17 below para (vi), then goes on to say, that any area that is listed but not covered by HUMS, must be substantiated.

Recommend to remove Engines monitoring from Table 1.

response

Accepted

comment

13 comment by: *Eurocopter*

The NPA does not really clarify the situation:

- according to the published ToR 27&29.019, AC 27&29 MG15 guidance is "considered obsolete", but no additional guidance is proposed for the

certification of VHM systems on small rotorcraft.

- CS-27 Appendix C remains unchanged, although small rotorcraft to be type certificated for Category A operation are subject to rotors and rotor drive systems design assessment requirements of CS 29.547 and CS 29.917.

response *Noted*

MG15 is retained in its current form. Further development of this document to bring it up-to-date will now be pursued separately.

At this time, there is no intent to adopt these requirements for CS-27 rotorcraft. The safety standards associated with CS-27 and CS-29 are not intended to be identical and the prime safety focus remains with large helicopters. Rulemaking task RMT.0350 (OPS.074) will determine the need to mandate VHM systems and the applicability. In the meantime, AMC 29.1465 can be used on a voluntary basis for CS-27.

comment *17* comment by: *CAA-NL*

CAA-NL concurs with the initiative to harmonize the requirements for VHM systems.

response *Noted*

comment *24* comment by: *FAA Rotorcraft Directorate*

Reference page 5, Section IV, paragraph 14: "The update to MG15 and compatibility with CS 29.1465 and AMC 29.1565 will now be performed in association with rulemaking task 27&29.029, using the existing rulemaking group." ***The FAA has not officially agreed to this rulemaking task.***

response *Noted*

The task was proposed both by EASA and FAA and accepted on to the workplan. However, it is now understood that FAA have no intention to pursue this task due to the absence of associated operating regulations.

A. Explanatory Note - V. Content of the draft Decision p. 5

comment *22* comment by: *Eurocopter*

The envisaged changes do not clarify the situation for small rotorcraft (see comment #13). Changes to Decision 2003/15/RM should also be proposed for more clarity.

The creation of an AMC 20 to address airworthiness certification and operational approval of VHM systems would be preferable to the creation of a new CS 29.1465 (see comment #14).

response *Not accepted*

The intent is to apply the new proposals to CS-29 only, as this has been identified as the prime safety focus for VHM systems. The regulatory impact assessment has been completed with large helicopters in mind and may be invalid in terms of the cost/safety benefits of VHM systems for smaller

rotorcraft. As VHM technology develops and more capable systems are widely available at lower weight and costs, then the Agency will consider the need to include these or similar proposals in CS-27.

As stated in the NPA, the Rulemaking Group considered a number of options prior to embarking on developing a new rule. The main advantage of a dedicated certification specification addressing VHM is to clearly define the design considerations and VHM functionality necessary to be compliant with the minimum acceptable design standards of CS-29 and operational requirements.

comment 25 comment by: *FAA Rotorcraft Directorate*

Reference page 5, Section V, paragraph 16: Add ***"Severe Major"*** and ***"Major"*** to the failure modes listed (Hazardous/Catastropic).

response *Not accepted*

The design assessments referred to are CS 29.547 and CS 29.917. The associated AMCs (FAA AC 29.547A and AC 29.917A) only refer to Hazardous/Catastrophic. Failures classified as "Major" are not required to be mitigated under the design assessments.

A. Explanatory Note - VI. Regulatory Impact Assessment p. 6-11

comment 14 comment by: *Eurocopter*

Option 2: Provide additional AMC
Additional AMC were provided for FADEC (AMC MG4, AMC 20-1, AMC 20-3). It is not understood why an additional AMC MG15 and/or an additional AMC 20 could not be considered as a viable option.

response *Not accepted*

The difference is that FADEC systems are fully within the airworthiness domain, are not mandated, and are not a function of the type of operation.

The primary concern here was that VHM systems mandated by operational rules had no design standard associated with them. The parallel could be drawn with helicopter ditching, which is optional under the airworthiness rules but is mandated by JAR-OPS 3 for certain overwater operations.

comment 15 comment by: *Eurocopter*

Option 3: Non-mandatory rulemaking action

Part 21 § 21A.16A requires that airworthiness codes "shall be sufficiently detailed and specific to indicate to applicants the conditions under which certificates will be issued.". If 21A.16A is to be considered as being satisfied with the proposed CS 29.1465 airworthiness requirement, then the AMC goes far beyond the scope of this requirement by specifying design and performance requirements and addressing aspects not clearly underlying behind the proposed specific requirement.

An AMC 20 dealing with airworthiness certification and operational approval of VHM systems, without creating a new dedicated certification specification,

would be preferable.

response

Not accepted

The nature of VHM systems is such that the design and performance aspects cannot be divorced from each other. Furthermore, the design of the VHM system must consider its intended function and all aspects of its design, operation and performance in reaching this objective.

The approach taken in these proposals is in line with the Agency's objective of a 'total system approach'.

The option to develop an AMC-20 was considered and dismissed as it lacked the necessary regulatory status and would be unenforceable.

comment

16 comment by: *Eurocopter*

c. Final assessment and recommendation of a preferred option:

"... no additional burden on industry would be created as it will not mandate the installation or use of VHM."

This statement is incorrect since the applicant will no longer be allowed to use VHM for a given component failure mode unless he substantiates the non-use of VHM for other failure modes and for other components failure modes (see AMC 29.1465 e. System Design Considerations last paragraph).

response

Partially accepted

The intent is not to restrict the limited use of VHM for specific applications. Only when an applicant takes credit in showing compliance with an operational rule, will there be a need to consider VHM as a mitigation for all failure modes. The proposed CS 29.1465 and associated AMC have been amended to clarify this intent.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 1: Add a new CS 29.1465 to Book 1 p. 12

comment

5 comment by: *Francis Fagegaltier Services*

According to the proposals of this NPA, the certification specifications for VHM systems cannot be found in CS 29.1465. They are in two other, separate, documents : in an AMC 29.1465 in CS-29 book 2 (constituting "rulemaking by advisory material") and in a document which is not even part of CS-29 book 2 (FAA AC). This is not good practice.

This is also contrary to what is explained in the explanatory note (paragraph A.V subparagraph 16) : " CS 29.1465 does not in itself mandate the installation of VHM systems but sets the minimum design and performance standards if such a system is fitted.". The minimum design and performance standards are not in CS 29.1465.

There should be additional paragraphs in CS 29.1465 defining the certification specifications for VHM systems, which would then be explained in AMC.

response | *Not accepted*

Due to the diversity of VHM systems and the technological advances still being made, it was considered to be inappropriate to provide prescriptive requirements on a detailed level. Instead, guidance based on existing design and certification experience is proposed, which allows a degree of flexibility by offering applicants the ability to apply alternative AMC.

FAA AC is formally adopted as AMC to CS-29 (See Book 2 AMC 29 General).

comment | *26* comment by: *FAA Rotorcraft Directorate*

Reference page 12, Book 1, SUBPART F – EQUIPMENT, 29.1465, Vibration Health Monitoring: The proposed 29.1465 is not clear. One could conclde from the proposed regulation wording in 29.1465(a) and (b) that an applicant requesting VHM approval only has to do a safety analysis.

response | *Accepted*

The wording of CS 29.1465 is further amended to clarify the intent.

The intention of paragraph (a) is that the applicant will define the scope of failure modes to be monitored and then apply the design practise of AMC 29.1465. For paragraph (b), compliance with operational requirements will require all failure modes and all existing VHM indicators and techniques as identified by the safety analysis and Table 1 to be considered. VHM must be provided where a reliable means of early detection provides a safety benefit.

comment | *30* comment by: *Eurocopter*

In practice, this specification requires that, as soon as a VHM system for rotors and/or rotor drive systems is presented for certification, the VHM system must cover all hazardous and catastrophic failure modes likely to be detected by VHM techniques. As explained in AMC 29.1465 e. System Design Considerations, partial implementation of VHM is not acceptable unless substantiated by the applicant. In the particular case, such an all or nothing requirement could defeat the object and should not be adopted as proposed.

response | *Accepted*

CS 29.1465 and AMC have been amended to clarify that non-required and partial VHM systems are permitted if installed voluntarily or as compensating provisions to the design assessments of CS 29.547 and CS 29.917. However, a partial VHM system would not be appropriate in meeting the intent of the operational rule.

comment | *47* comment by: *UK CAA*

Paragraph No:
Book 1 Subpart F Equipment
CS 29.1465 Vibration Health Monitoring

Comment:
To better meet the intent of selecting Option 3, it is suggested that the text of the new CS 29.1465 be amended to explicitly include the case when VHM might be required by operational rules, in a similar manner to the Cockpit Voice and

Flight Data Recorders at CS 29.1457 and 1459

Justification:
Clarification of purpose.

Proposed Text:
Amend paragraph: CS 29.1465 Vibration Health Monitoring

If certification of a rotorcraft with vibration health monitoring of the rotors and/or rotor drive systems is requested ***or required by the applicable operating rules***, then the design and performance of the vibration health monitoring system must meet the requirements of this paragraph.

response *Partially accepted*

CS 29.1465 has been amended and CS 29.1465(b) is now dedicated to meeting operational rules.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 2: Add a new AMC 29.547 p. 12

comment *2* comment by: *Francis Fagegaltier Services*

The reference to AMC 29.1465 is wrong : the VHM system should comply with CS 29.1465.

response *Partially accepted*

In the NPA, reference to the AMC was deliberate to avoid the need for a complete VHM system. Further changes introduced to CS 29.1465 now allow direct reference to CS 29.1465(a) and clarifies the intent.

comment *27* comment by: *FAA Rotorcraft Directorate*

Reference page 12, Book 2, SUBPART F – EQUIPMENT, paragraph 2, AMC 29.547 & paragraph 3, AMC 29.917: Based on our interpretation of the proposed NPA and associated AMC material, VHM systems used for showing compliance with 29.547 and 29.917 would be assessed to be Minor or No Safety Effect. We do not agree with this assessment. The failure condition category will be dependent on the level of reliance placed on the VHM to monitor for specific conditions on the specified component/system when using VHM for showing compliance with 29.547 & 29.917.

response *Accepted*

Text added to clarify the rationale for Level D software. (See AMC 29.1465 para m. Software.)

comment *41* comment by: *Eurocopter*

If a certification specification dedicated to vibration health monitoring of the rotors and/or rotor drive systems is adopted, their is no need for such an AMC 29.547.

response *Not accepted*

While the AMC may not be strictly necessary, it is believed to aid understanding

by providing a direct link between CS 29.547 and CS 29.1465(a).

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 3: Add a new AMC 29.917 p. 12

comment *3* comment by: *Francis Fagegaltier Services*

The reference to AMC 29.1465 is wrong : the VHM system should comply with CS 29.1465.

response *Partially accepted*

In the NPA, reference to the AMC was deliberate to avoid the need for a complete VHM system. Further changes introduced to CS 29.1465 now allow direct reference to CS 29.1465(a) and clarifies the intent.

comment *28* comment by: *FAA Rotorcraft Directorate*

Reference page 12, Book 2, SUBPART F – EQUIPMENT, paragraph 2, AMC 29.547 & paragraph 3, AMC 29.917: Based on our interpretation of the proposed NPA and associated AMC material, VHM systems used for showing compliance with 29.547 and 29.917 would be assessed to be Minor or No Safety Effect. We do not agree with this assessment. The failure condition category will be dependent on the level of reliance placed on the VHM to monitor for specific conditions on the specified component/system when using VHM for showing compliance with 29.547 & 29.917.

response *Accepted*

Text added to clarify the rationale for Level D software. (See AMC 29.1465 para m. Software.)

comment *42* comment by: *Eurocopter*

If a certification specification dedicated to vibration health monitoring of the rotors and/or rotor drive systems is adopted, their is no need for such an AMC 29.917.

response *Not accepted*

While the AMC may not be strictly necessary, it is believed to aid understanding by providing a direct link between CS 29.917 and CS 29.1465(a).

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 p. 12

comment *1* comment by: *Francis Fagegaltier Services*

In paragraph (a)(1) of the proposed AMC 29.1465 we find the following sentence : " The purpose of this AMC is to provide an Acceptable Means of Compliance and Guidance Material for the design and certification of Vibration Health Monitoring (VHM) applications.".
This is not true because there is nothing in CS 29.1465 calling for all the activities "required" by the AMC. This AMC is therefore providing "rulemaking by advisory material".

There should be a new subparagraph (c) in CS 29.1465 (or perhaps more than one subparagraph) defining the certification specifications for a VHM system.

response *Partially accepted*

The revised CS 29.1465(a) now provides a generic statement that the "design and performance of an installed [VHM] system must provide a reliable means of early detection ...". The means of compliance is then developed in the AMC.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - a. Explanation p. 12-13

comment *4* comment by: *Francis Fagegaltier Services*

In paragraph (a)(4) we find the following : "VHM systems compliant with this AMC ….. can be accepted without the need for additional compliance with AC 29-2C MG15."

Again, VHM system should comply with CS 29.1465 not with any adisory material, especially when this material is not part of CS-29.

Either this FAA AC is embodied into CS-29 or this reference is deleted.

response *Partially accepted*

FAA AC 29-2c is adopted in Book 2 of CS-29 (See AMC 29 General).

In order to satisfy the statement
"…can be accepted without the need for additional compliance with AC 29-2C MG15." it is necessary to extend the AMC paragraph (U) addressing CSI. Accordingly, this is amended to consider acceptance of maintenance credits where the "credit" is only granted after a period of acceptable service experience or on completion of the CSI.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - b. Procedures p. 13

comment *18* comment by: *CAA-NL*

Regardless of whether a VHM system is required, any VHM system installed must meet the requirements of this AMC. It should be possible, however, to install on a voluntary a 'baby' monitoring system on a 'no-hazard basis'. I.e. certify that it does not harm the aircraft, with benefits that may not be proven to any standard, but which still may be found worthwhile by the operator. If we do not allow for this, then the undesirable effect of this regulation change could be that less monitoring systems are installed, because of the burden of compliance. If we allow operators to choose 'baby'-systems, they can tailor their installation to their requirements (and wallet). AMC 29.1465(b)1 states that CS 29.1465 is non-mandatory in itself, but CAA-NL would like to see it more clearly stated that the above interpretation applies. Therefore, CAA-NL proposes to add the following note to AMC 29.1465(b)1(iii):
"Note: for systems installed on a voluntary basis, applicants could also apply for certification on a no-hazard basis. In that case, no credits can be claimed for the VHM system, such as demonstrating compliance with a (future) operational requirement."

response | *Partially accepted*

CS 29.1465(a) now provides for this flexibility by allowing partial system approval to a limited scope defined by the applicant.

A note added under AMC 29.1465(a)(4) clarifies that VHM systems that do not meet full compliance with CS 29.1465 can still be accepted on a no hazard/no credit basis.

comment | *31* comment by: *FAA Rotorcraft Directorate*

Reference page 13, paragraph b.(2): Add Hazardous/"***Severe Major***" and "***Major***" to the failure modes listed (Catastrophic and Hazardous) that could prevent continued safe flight or safe landing. The term "Severe Major" is used interchangeably with "Hazardous". Also, "Major" failures should be included in this list since they too can have an effect on continued safe flight, although not to the same degree as Catastrophic and Hazardous/Severe Major.

response | *Not accepted*

The design assessments referred to are CS 29.547 and CS 29.917. The associated AMCs (FAA AC 29.547A and AC 29.917A) only refer to Hazardous/Catastrophic. Failures classified as "Major" are not required to be mitigated under the design assessments.

comment | *32* comment by: *FAA Rotorcraft Directorate*

Reference page 13, paragraph b.(3): Change ***"… VHM must be provided…"*** to ***"… VHM may be provided…"***

response | *Not accepted*

This is just a quotation from the rule.

comment | *43* comment by: *Eurocopter*

In order to "give applicants prior knowledge of what is acceptable to the Agency" and "minimise certification costs" as intended by the NPA (see final assessment of option 3 on page 11), further guidance on when "it is not necessary to implement VHM" would be useful.

response | *Noted*

Paragraph (b)(6) of the AMC is amended to clarify that VHM will always be required in meeting an Operational rule, irrespective of other compensating features introduced to protect against the risk of premature failures. However, it is not always necessary for a VHM system to cover the complete capability (defined in Table 1 of the AMC), unless other means of health monitoring can be substantiated.

comment | *48* comment by: *UK CAA*

Paragraph No:
4(b)(1)(iii)

Comment:

Typographical error in the single line of text

Proposed Text:
Change "requirements" to "requirement"

response *Accepted*

comment *49* comment by: *UK CAA*

Paragraph No:
4(b)(3)

The first sentence (taken from the draft rule) states that VHM must be provided, *when it can increase the likelihood of early detection* while the second sentence effectively says that it does not, if other compensating provisions are available. The second sentence in this AMC paragraph does not seem to be consistent with what is in the proposed rule. From the text in the rule, it is the possible increased likelihood of detection which should be assessed, not whether other provisions are available. (i.e. if it can add to detection capability, then it should be fitted).

Justification:
The AMC material and the rule should be consistent.

response *Accepted*

CS 29.1465(b)(3) has been amended to state "*unless other means of health monitoring can be substantiated*". In addition, the AMC paragraph (now) (b)(6) is also amended for clarification and states that "...*it will not be necessary to implement VHM for a given failure mode if no safety benefit can be established*".

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - c. Definitions p. 14

comment *33* comment by: *FAA Rotorcraft Directorate*

Reference page 14, paragraph c.: Add ***"Warning"*** to definitions.

response *Partially accepted*

"Warning" has a specific meaning requiring immediate flight crew recognition and immediate flight crew action. Warning has been replaced by "indication" in the definition of Alert and elsewhere throughout the AMC.

comment *50* comment by: *UK CAA*

Paragraph No:
c. Definitions

Comment:
Add definition of 'Close Monitoring'

Justification:
This is a key process within the post alert diagnostic stage between operator and TCH/ 3rd party specialist diagnostic support provider; and has implications

for MEL use. Text taken from CAA publication, CAP 753.

Proposed Text:
Add new paragraph:

"(13) <u>Close Monitoring</u>: This may be required when a VHM component or indicator requires focused and increased monitoring, e.g. in the event that an indicator value exceeds a "maintenance action" threshold or shows other signs which warrant increased attention. The close monitoring procedure typically reduces the maximum period between successive indicator downloads to no more than 10 hours. Note that close monitoring is not intended to be a long-term solution, but a period of heightened monitoring, diagnostic support and assessment to ensure that determinations of serviceability are made using all the data available."

response *Not accepted*

The term is not used in the NPA. It is a basic principle of VHM that any warning should be timely and allow for corrective maintenance to take place. The AMC is deliberately not prescriptive about particular download periods and provides generic guidance. Accordingly, the frequency of normal monitoring or "close" monitoring will be for the TCH/VHM supplier to determine.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - e. System Design Considerations p. 14-17

comment *11* comment by: *Eurocopter*

According to Explanatory Note Section IV Background item 13., engines are excluded from the proposals. The row addressing the engine in Table 1 should be deleted.

response *Accepted*

comment *19* comment by: *CAA-NL*

AMC 29.1465 e(1): Suggests that sensor calibration is required, In the current practice usually uncalibrated sensors are used because of the cost. The spectrum shift in G-level is then analysed and appraised by a VHM specialist to be acceptable or not. The AMC should make clear whether there is room for such a procedure within certified VHM systems.

response *Noted*

The AMC is not specific on this point and allows flexibility in the design of the VHM system. Where calibration is required by the design, this will need to be stipulated in the maintenance instructions and adequately controlled (See AMC 29.1465(e.)(1) Sensors)

comment *44* comment by: *Eurocopter*

"A prescriptive scope for monitoring rotor and rotor drive system components" is provided. This unduly dictates design by AMC. The applicant must keep his freedom of design, without having to substantiate the non-use of design features not specified in the airworthiness code.

response | *Not accepted*

The list in Table 1 is for typical VHM applications. The intent is to identify the scope of VHM monitoring required, which is not defined in operational rules. The substantiation of the absence of monitoring of any components, as identified in Table 1, is not considered to be an undue burden as it falls within the design assessment process. If alternative methods are proposed, which can be shown to be as effective and reliable as those prescribed and which are to the satisfaction of the Agency, then these can also be accepted.

comment | *51* comment by: *UK CAA*

Paragraph No:
(i), (ii) below Table 1.

Comment:
Paragraphs (i) and (ii) both contain the comment in brackets "does not meet the criteria for gear monitoring". The comment is therefore highlighting a limitation of the technique, and is not in keeping with the rest of the paragraph, which highlights the particular advantages of each technique described.

Justification:
To be consistent with the other sub-paragraphs, an indication of the strengths of particular techniques would be useful, rather than what they are not useful for.

response | *Accepted*

The text "does not meet the criteria for gear monitoring" is removed.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - h. Pilot Interface p. 17

comment | *52* comment by: *UK CAA*

Paragraph No:
h. Pilot Interface

Comment:
Clarify that cockpit warnings to aircrew are not recommended.

Justification:
VHM by nature is based on identifiable trends over the medium to long term period (typically 30-300 hours) and the warning may indeed be transient. Cockpit in-flight warnings may lead crew to take inappropriate ditching action, leading to reduced occupant safety.

Proposed Text:
Amend paragraph:
"h. Pilot Interface
Pilot interaction with the VHM system, if any, should be specified and should not adversely impact on pilot workload. ***The use of in-flight cockpit VHM alerts is not recommended.***"

response	*Partially accepted* Note added to the AMC.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - i. Maintenance Personnel Interface p. 17

comment	*53* comment by: *UK CAA* **Paragraph No:** (i) Maintenance Personnel Interface **Comment:** The paragraph as written describes the responsibilities of maintenance personnel in the process. This is not appropriate for a product certification code. It is not clear what the intent of the paragraph is; if it is to ensure that the applicant provides the necessary information to allow maintenance personnel to carry out the task effectively, then the paragraph should be reworded to make it clear what the applicant should provide. **Justification:** The guidance material supplied should be aimed at the applicant for the approval, not maintenance personnel, whose duties are covered by other EASA codes. **Proposed Text:** Amend paragraph: **"**Information should be provided by the applicant to ensure that personnel responsible for releasing …" etc.
response	*Partially accepted* Text has been changed to clarify that VHM data should be made available to maintenance personnel.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - l. Ground-Based System Architecture p. 18

comment	*45* comment by: *Eurocopter* What is acceptable to the Agency for COTS as regards data integrity assurance and reliabillity of processes needs to be clarified .
response	*Noted* DO 278 Assurance Level 5 (AL5) provides an acceptable method for acceptance of ground based systems, which include COTS. Reference is now made to this standard in paragraph (m)(1) for ground based systems.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - m. Software p. 18

comment	*35* comment by: *FAA Rotorcraft Directorate* Reference page 18, paragraph m.(1): Change the first paragraph as follows: **" *All software that makes up the VHM processing, whether airborne or ground-based, is to be produced to the software quality standard required to achieve the necessary level of system integrity commensurate with the criticality determined from the functional hazard assessment.*** Change the third paragraph as follows: ***"All software specifically developed for VHM should be developed to EUROCAE ED 12B/RTCA DO 178B level D, or higher, commensurate with the criticality determined from the functional hazard assessment.***
response	*Partially accepted* Text has been changed to clarify the rationale for level D software.

comment	*40* comment by: *FAA Rotorcraft Directorate* Reference page 18, paragraph m.(2): Change the paragraph to read as follows: ***"The software for these systems should ensure that supplied data meets VHM system integrity requirements and should not be less than EUROCAE ED 12B/RTCA DO 178B level D, and commensurate with the highest level of criticality as determined for each function of the integrated system."***
response	*Partially accepted* Issue addressed by the addition of a note in paragraph (m)(1).

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - n. Performance Criteria p. 18-19

comment	*20* comment by: *CAA-NL* AMC 29.1465(n)(1): To make clear that the 25 hours is the fall back option we would like to suggest the following addition to this paragrapph: For operations which do not contain periods of stabilised operation of greater than 30 minutes, alternative procedures need to be incorporated to ensure that the total data set is recorded within a specified number of flying hours "related to the minimum adequate frequency of data collection determined under AMC 29.1465(e)(2)" and in any case no longer than 25 flying hours.
response	*Accepted* Text added to paragraph (n)(1).

comment	*54* comment by: *UK CAA* **Paragraph No:** n. (2) Data transfer and storage capability **Comment:** Add additional requirement for Groundstation to alert maintenance personnel when the VHM has not generated a 'Maintenance Log' due to download medium 'lock up' on shutdown.

Justification:
Potential AAIB recommendation from G-REDL Fatal accident. If no Maintenance log is processed then the system may show 'all green ' icons on ground station when in fact an alert may be present

Proposed Text:
Add paragraph:
"The data transfer process should be capable of downloading partial data sets to the Ground-Based System if for any reason a complete data set for every monitored component has not occurred. The ground station should alert maintenance personnel/aircrew when during post flight actions the creation of a 'Maintenance log' has not been possible due to download medium 'lock-up' "

response *Partially accepted*

Proposed wording is further developed.

comment *55* comment by: *UK CAA*

Paragraph No:
n. (3) VHM Alert generation and fault detection performance

Comment:
Though reference is made to a claimed probability of detection, there is no definition of what an acceptable rate would be. It is presumed that this was discussed within the group but it was decided against including any numerical levels. As a minimum there should be some reference to a rate of detection that is acceptable to the Agency.

Justification:
As written, it appears that there is nothing to prevent an applicant declaring their own criteria for an acceptable rate, and this rate varying considerably between applicants. As stated in the explanatory note (Page 8, 4 a ii, Option 1) one aim of the NPA is to avoid varying standards being presented to the agency.

Proposed Text:
Amend first sentence:
"The Alert and Alarm generation processing should be designed to achieve a claimed probability of detection ***that is acceptable to the Agency*** for each component defect being monitored.

response *Accepted*

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - o. Performance Validation p. 19-20

comment *56* comment by: *UK CAA*

Paragraph No:
o) Performance Validation, Note under 1(C)

Comment:
It is stated that *it is recommended that* a mechanism be established for

requesting maintenance feedback with respect to component monitoring failure/degradation. This does not place sufficient emphasis on this important aspect of a CSI.

Justification:
It has become clear from experience that feedback from investigations into removals from service is a fundamental element of understanding the performance of the VHM system, to aid in the determination of false alert rates, detection system successes etc., both during and after the CSI phase. It is therefore important that the feedback system for removals and other relevant investigations is formally declared to EASA at the start of the CSI, to allow EASA to monitor during the CSI. A separate section under this paragraph should be introduced in place of the note to give this aspect sufficient emphasis.

Proposed Text:
Delete the note and add text under a separate sub paragraph of this section:
"D) information from module strips**,** component removals, inspections and other investigations which is relevant to the review of VHM system performance."

response *Partially accepted*

The text proposed has been added to "A)". EASA do not consider that this negates the need for the note, as this relates to establishment of a method for obtaining information from overhauled equipment.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - p. VHM System Criticality p. 20-21

comment *36* comment by: *FAA Rotorcraft Directorate*

Reference page 20, paragraph p.(3)(ii): Change the sentence to the following: "***When an onboard VHM system is used to replace existing portable test equipment, and is performing an identical function, this is considered to be a Minor criticality level.***"

response *Not accepted*

The criticality level stated here does not relate to a loss of function of the VHM system. It is simply a comparison between the relative safety level achieved using carry-on equipment to perform a maintenance task as compared to performing this task with on-board VHM equipment certified in accordance with this Regulation.

To emphasise the need to show equivalent reliability and accuracy with equipment being replaced, additional AMC has been added to paragraph (p)(3).

comment *37* comment by: *FAA Rotorcraft Directorate*

Reference page 21, paragraph p.(4)(ii): Change the paragraph as follows: "***A Minor criticality is where the VHM System provides vibration monitoring to replace functions conducted by portable test equipment without requiring the mitigation of a maintenance verification test flight for standard vibration reduction checks and/or adjustments (rotor track and balance, balancing, absorber tuning, etc.). These***

functions require validation (see paragraph o.), such as seeded fault testing (bench) or operational experience to show the system (airborne and ground components) is capable of detecting monitored faults with at least the same level of performance as the method it is replacing.

Paragraph (A): Delete

Paragraph (B): Delete, or Change to the following: "***(A) VHM system monitoring of grease packed bearings and replacing a manual inspection, if there is no change to other means of mitigation – MG15 applies since there is a change to a maintenance practice and the failure condition category is greater than Minor.***"

Paragraph (C): Delete, or Change to the following: "***(B) VHM system monitoring of swash-plate bearings to extend a manual inspection period – MG15 applies since there is a change to an inspection interval and the failure condition category is greater than Minor.***"

response *Not Accepted*

Minor criticality can be established where the validated detection capability and integrity of a VHM function is equal to or better than the process it replaces. This will require verification in accordance with paragraph (o).

comment *46* comment by: *Eurocopter*

Subparagraph (3):
Manual maintenance tasks may generally be expected to be accomplished successfully in a timely manner. Additional guidance should be provided to address criticality of VHM functions replacing such manual maintenance tasks.

response *Noted*

Subparagraph (p) has been amended to clarify the criticality of VHM functions. The overriding intent is that the reliability and accuracy of any VHM functions that replace a maintenance task must be equal to or better than that of the process it replaces.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - q. Technical Publications p. 21-22

comment *21* comment by: *CAA-NL*

AMC 29.1465 (q)(6): For some of the on-board VHM system equipment it may be impossible for the pilot to assess serviceability. Inclusion in the MMEL would then be inappropriate.

response *Not accepted*

It is envisaged that any unserviceability of a VHM system will be brought to the attention of maintenance. This would later be available to the pilot via the tech-log. Accordingly, determination of compliance with the MMEL could then be made by the pilot.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - t. Minimum Equipment List (MEL) Recommendation p. 23

comment *38* comment by: *FAA Rotorcraft Directorate*

Reference page 23, paragraph t: 25 hours seems excessive for allowable absence of an assessment of any VHM indicator to which Alert criteria are applied. Delete the following from the second sentence: "***and should not exceed 25 hours.***" Add the following sentence to the end of the first paragraph: "***During the absence of any VHM data, revert back to the standard procedures used to ensure component integrity.***"

response *Partially accepted*

It is not the intention that unserviceability of a VHM system should ground a rotorcraft. Text has been added to paragraph (t) to consider situations where 25 hours is too long.

comment *57* comment by: *UK CAA*

Paragraph No:
t. MEL Recommendation

Comment:
There should be provision for a reduced MEL limit, 10 hours where a VHM alert is being monitored through a 'Close Monitoring' phase. (CAA policy item 45-1).

Justification:
With an active alert being monitored, a 25 hour rectification interval will reduce the level of safety for what may be a developing fault

Proposed Text:
Amend paragraph:
"The MEL should address the Airborne Element of the VHM system. The maximum period for absence of an assessment of any VHM indicator, to which Alert criteria are applied, should be limited to a suitable period and should not exceed 25 hours **or 10 hours for a component which is subject to 'close monitoring**'"

response *Partially accepted*

Defining a specific MMEL rectification period during close monitoring will be dependent on the failure mode being monitored, its failure severity and the prognostic period. A note is added to highlight this issue and it is left to the applicant as to what, if any, time is appropriate. A reference to (e)(2) has been added to (n)(1), which also addresses this subject.

B. Draft Decisions - I. Draft Decision CS-29 - Proposal 4: Add a new AMC 29.1465 - u. Controlled Service Introduction p. 23

comment *39* comment by: *FAA Rotorcraft Directorate*

Reference page 23, paragraph u.(1): Replace with the following: "***For some VHM applications, when validation is required for a Minor criticality level, a plan for a Controlled Service Introduction (CSI) phase may be***

	necessary to fully validate system performance."
response	*Not accepted* Most VHM applications can result in false alarms and consequent unnecessary maintenance on a rotorcraft. Therefore, a CSI period would be necessary to verify satisfactory performance of the whole system.

comment	*58* comment by: *UK CAA* **Paragraph No:** u. (2) (iii) **Comment:** This paragraph highlights the need to check that, in the event of failures or defects in monitored components, then the VHM should provide a timely alarm. Information concerning the nature of the defect or failure may be required to allow the type of alarm which should have triggered to be determined. This would only come from the investigation findings. **Proposed Text:** Add a sentence: "The information from the investigation findings of such failures and defects should be made available to enable a review of the system effectiveness."
response	*Not accepted* In order to meet (u.)(2)(iii), it will be necessary to have a full understanding of the failure mode. The proposed additional paragraph is, therefore, unnecessary. Also feedback of information from defect investigations is addressed elsewhere in the NPA.

Final draft text

CS 29.1465 Vibration Health Monitoring

(a) If certification of a rotorcraft with vibration health monitoring of the rotors and/or rotor drive systems is requested by the applicant, then the design and performance of an installed system must provide a reliable means of early detection for the identified failure modes being monitored.

(b) If a vibration health monitoring system of the rotors and/or rotor drive systems is required by the applicable operating rules, then the design and performance of the vibration health monitoring system must, in addition, meet the requirements of this paragraph.

(1) A safety analysis must be used to identify all component failure modes that could prevent continued safe flight or safe landing, for which vibration health monitoring could provide a reliable means of early detection;

(2) All typical VHM indicators and signal processing techniques should be considered in the VHM System design;

(3) Vibration health monitoring must be provided as identified in subparagraph (1) and (2), unless other means of health monitoring can be substantiated.

AMC 29.547 Main Rotor And Tail Rotor Structure

Where Vibration Health Monitoring is used as a compensating provision to meet CS 29.547(b), the design and performance of the vibration health monitoring system should be approved by requesting compliance with CS 29.1465(a).

AMC 29.917 Rotor Drive System Design

Where Vibration Health Monitoring is used as a compensating provision to meet CS 29.917(b), the design and performance of the vibration health monitoring system should be approved by requesting compliance with CS 29.1465(a).

AMC 29.1465
Vibration health monitoring

a. Explanation

(1) The purpose of this AMC is to provide an Acceptable Means of Compliance and Guidance Material for the design and certification of Vibration Health Monitoring (VHM) applications. VHM is used to increase the likelihood of detection of dynamic component incipient faults in the rotors and rotor drive systems that could prevent continued safe flight or safe landing, by providing timely indications of potential failures to maintenance personnel.

(2) Designing a VHM system in accordance with this AMC is expected to achieve the required performance together with acceptable levels of system integrity and reliability for compliance with type certification and/or operational regulations that require VHM of rotor and/or rotor drive systems.

(3) This AMC defines terms, processes, performance and standards that a VHM system should meet and also the support that a VHM approval holder should provide after the system has entered into service.

(4) VHM systems which satisfy this AMC and that perform functions, the failure of which are categorised as Minor or No Safety Effect (see paragraph p.), can be accepted without the need for additional compliance with AC 29-2C MG15.

Note 1: FAA AC 29-2C Miscellaneous Guidance (MG)15, which addresses the use of HUMS in Maintenance, is complementary to this AMC.

Note 2: If an applicant wishes to install a VHM system that is not compliant with CS 29.1465(a), it may still be accepted for installation on a "No hazard/No credit" basis. However, it cannot replace any existing type-design maintenance instructions or change the established methods of complying with CS-29.

b. Procedures

(1) CS 29.1465 does not mandate the fitment of VHM systems. However, if a VHM system is installed on the rotorcraft to meet a type-certification or operational rule, then compliance is required. Three typical scenarios are foreseen as to when compliance by the applicant may be requested. The three scenarios in question are:

(i) as a means of demonstrating compliance with an operational rule requiring helicopters be fitted with a VHM system and that operators of such helicopters implement procedures covering data collection, analysis and determination of serviceability;

(ii) as a selected compensating provision to mitigate the probability of a failure condition, identified from the design assessments of CS 29.547(b) and/or CS 29.917(b), from arising;

(iii) on a voluntary basis to meet a customer requirement or company objective.

(2) CS 29.1465(a) allows non-required and/or partial VHM applications with limited capability to monitor specific failure modes to be approved. Such systems can offer safety benefits and it is not the intention here to discourage their installation and use. However, any installed system must meet CS 29.1301 and be of a kind and design appropriate to its intended function and function properly when installed. The guidance given in this AMC is therefore considered to be applicable to these types of VHM systems.

(3) Where an operating rule mandates installation of a VHM system, CS 29.1465(b) aims to provide a VHM system capability that maximises the safety benefit. All typical VHM indicators and signal processing techniques should be considered in the VHM design and a system safety assessment undertaken to identify failure modes where VHM could provide early detection of incipient failures. VHM must be provided for all potential failure modes unless other means of health monitoring can be substantiated.

(4) The safety analysis required by CS 29.1465(b)(1) is limited to rotors and rotor drive systems. The existing design assessments of CS 29.547 and CS 29.917 can be used for this purpose. All component failure modes that could prevent continued safe flight or safe landing (Catastrophic and Hazardous failure conditions) and for which vibration health monitoring could provide a reliable means of early detection must be identified. Previous experience together with the guidance in this AMC can be used to determine failure modes that could benefit from VHM and the applicable techniques that can produce reliable indications of incipient failures.

(5) CS 29.1465(b)(2) requires the design and performance of the VHM system to consider indicators and processing techniques used on typical existing VHM installations. A non-exhaustive list is provided in Table 1 of this AMC.

(6) CS 29.1465(b)(3) states that VHM must be provided as identified in subparagraph (b)(1) and (b)(2), unless other means of health monitoring can be substantiated. For many failure modes, there may be other compensating provisions which are capable of providing protection against the risk of premature failure. In such cases, the added benefit of VHM in increasing the likelihood of early detection should be assessed. It will not be necessary to implement VHM for a given failure mode if no safety benefit can be established.

c. Definitions

(1) **Alarm**: An Alert that, following additional processing or investigation, has resulted in a maintenance action being required.
(2) **Alert**: An indication produced by the VHM system that requires further processing or investigation by the operator to determine if corrective maintenance action is required.
(3) **Commercial Off-the-Shelf (COTS)**: This term defines equipment hardware and software that is not qualified to aircraft standards.
(4) **Controlled Service Introduction (CSI)**: A period in-service where capabilities and functions that could not be verified prior to entry into service (including support functions) are evaluated.
(5) **False Alarm**: An Alert that after further processing or investigation has resulted in unnecessary maintenance action.
(6) **False Alert**: This is an Alert that after further processing or investigation has been determined to not require any further action.
(7) **Ground-Based System**: A means of access to VHM data, including Alerts, for immediate post-flight fault diagnosis by the responsible maintenance staff.
(8) **Prognostic Interval**: The predicted time between an Alarm and the component becoming unairworthy.
(9) **Vibration Health Monitoring (VHM)**: Use of data generated by processing vibration signals to detect incipient failure or degradation of mechanical integrity.
(10) **VHM Application**: A VHM function implemented for a defined purpose.
(11) **VHM Indicator**: A VHM Indicator is the result of processing sampled data by applying an algorithm to achieve a single value, which relates to the health of a component with respect to a particular failure mode.
(12) **VHM System**: Typically comprises vibration sensors and associated wiring, data acquisition and processing hardware, the means of downloading data from the rotorcraft, the Ground-Based System and all associated instructions for operation of the system.

d. Component Monitoring Capability

The scope of the VHM capability is determined by the range of components monitored and their incipient failures which can be detected. For each component to be monitored the range of potential damage being diagnosed should be declared and the principles of the monitoring techniques applied should be described. The health monitoring effectiveness should be demonstrable (see paragraph o).

e. System Design Considerations

(1) **Sensors**: They are the hardware that measures vibration. They should provide a reliable signal with an appropriate and defined performance. The position and installation of a vibration sensor is as critical as its performance. Sensor selection, positioning and installation should be designed to enable analysis of the processed signals to discriminate the vibration characteristics of the declared monitored

component failure modes. Built-In Test capability is necessary to determine the correct functioning of the sensor. Maintenance instructions should ensure that the correct function, and any calibration, of sensors and their installation are adequately controlled.

(2) **Signal Acquisition**: It is likely that processed VHM data will be sensitive to the flight regime of the rotorcraft. For this reason it is desirable to focus data acquisition to particular operating conditions or phases of flight. Consideration should be given to the likely operation of rotorcraft that may utilise the VHM system and the practicality of acquiring adequate data from each flight to permit the Alert and Alarm processing to be performed to the required standard. The method of vibration signal acquisition should be designed so that:

(i) The vibration signal sampling rate is sufficient for the required bandwidth and to avoid aliasing with an adequate dynamic range and sensitivity.

(ii) The data acquired from the vibration signal should be automatically gathered in specifically defined regimes at an appropriate rate and quantity for the VHM signal processing to produce robust data for defect detection.

(iii) If the mission profile does not allow regular acquisition of complete data sets, then the data acquisition regimes should be capable of reconfiguration appropriate to particular flight operations.

(iv) The acquisition cycle should be designed in such a way that all selected components and their defects are monitored with an adequate frequency irrespective of any interruptions in the cycle due to the operational profile.

(3) **Signal Processing**: The helicopter's rotor and rotor drive systems are a mixture of complex and simple mechanical elements. Therefore, the signal processing or the analysis techniques utilised should reflect the complexity of the mechanical elements being monitored as well as the transmission path of the signal and should be demonstrated as being appropriate to the failure modes to be detected. The objective of processing the sampled data should be to produce VHM Indicators that clearly relate to vibration characteristics of the monitored components, from which the health of these components can be determined. A key part of the success of in-service VHM is the signal-to-noise enhancement techniques such as vibration signal averaging for gears and signal band-pass filtering and enveloping for bearings. These techniques are used to generate enhanced component vibration signatures prior to the calculation of the VHM Indicators. Accordingly, the method of signal enhancement should be shown to be effective. The method of signal processing and the analysis techniques utilised to generate the data used for defect detection should be defined for the claimed defect detection capability (see Table 1 below).

Table 1: Typical Vibration Health Monitoring Indicators & Signal Processing Techniques

Assembly	Component Type	Types of VHM indicators used
Engine to main gearbox input drive shafts	Shafts	Fundamental shaft order and harmonics
Gearboxes	Shafts	Fundamental shaft order and harmonics
	Gears	Gear meshing frequency and harmonics, modulation of meshing waveform, impulse detection and energy measurement, non-mesh-related energy content
	Bearings	High frequency energy content, impulse detection, signal envelope modulation patterns and energies correlated with bearing defect frequencies
Tail rotor drive shaft	Shafts	Fundamental shaft order and harmonics
	Hanger Bearings	As for gearbox bearings, but can utilise simple band-passed signal energy measurements
Oil cooler	Oil Cooler Blower and Drive Shaft	Fundamental shaft order and harmonics, blade pass frequency
Main and Tail rotor	Rotors	Fundamental shaft order and harmonics up to blade pass frequency, plus multiples of this.

Recording and storing of some raw vibration data and the processed vibration signal, from which the Indicators are derived, may also be of significant diagnostic value. Typical signal processing techniques include;

(i) Asynchronous Power Spectrum where phase information or frequency tracking is not required.

(ii) Synchronous Spectrum where phase information or frequency tracking is required.

(iii) Band-pass filtered signal Envelope Power Spectrum Analysis (a recommended technique for gearbox bearings).

(iv) Synchronous Averaging for time and frequency domain signal analysis (a recommended technique for gearbox gears).

(v) Band-pass filtering and the measurement of filtered signal statistics, including crest factor (can be used for bearings not within engines or gearboxes).

(vi) Further signal enhancement techniques are typically required in the calculation of certain VHM indicators targeted at detecting specific defect-related features (e.g. localised signal distortion associated with a gear tooth crack).

Note 1: When showing compliance to CS 29.1465(a), for non-required and/or partial VHM applications with limited capability to monitor specific failure modes, it is not necessary to address the scope of VHM capability stated in Table 1.

Note 2: When showing compliance to CS 29.1465(b), it is not always necessary for the VHM system to cover the complete capability defined in Table 1. However, absence of any of these areas, and/or techniques, should be substantiated. It is acknowledged that the above provides a prescriptive scope for monitoring rotor and rotor drive system components. If alternative methods are proposed, which can be shown to be as effective and reliable as those prescribed and which are to the satisfaction of the Agency, then these can also be accepted.

f. Data Management

The data transfer process from the rotorcraft to the maintenance personnel interface should be sufficient to determine all the VHM Indicators post flight. The upload/download should have minimal impact on flight operations. VHM data should be accessible in order to permit alternative analysis and comparison. The following should be specified:

(1) Data transfer, processing, networking, data integrity assurance.

(2) Methods to ensure the reliability of this process.

(3) The time for upload/download and retrieval of data and/or health report.

(4) Facilities for the warehousing of all of the data downloaded from the VHM systems and to permit timely access to the data.

g. Alert Management

(1) **VHM Alert Generation**: VHM Alert criteria should be applied to every monitored component. VHM Alerts are produced to indicate possible anomalous behaviour or a specific defect.

(2) **VHM Alert Management**: Diagnostic processes are required to determine if VHM driven maintenance of the rotorcraft is necessary.

h. Pilot Interface

Pilot interaction with the VHM system, if any, should be specified and should not adversely impact on pilot workload.

Note: The level of system integrity for VHM provided under this AMC is not sufficient to support the provision of in-flight cockpit VHM alerts.

i. Maintenance Personnel Interface

The person responsible for releasing a rotorcraft into service should be provided with VHM data, maintenance recommendations and VHM system Built-In Test data necessary to release that rotorcraft. This should include the ability to view VHM Indicators, trend data and detection criteria, including thresholds, for relevant VHM parameters from that rotorcraft. These capabilities should be available locally to maintenance personnel for immediate post flight fault diagnosis.

j. Fleet Diagnostic Support Interface

Where an operator has multiple rotorcraft of the same type, facilities should be made available to the operator to support the analysis of all data acquired by the VHM systems in the operator's fleet. The operator and all parties supporting the operator should have remote, multi-user and timely access to the data and the diagnostic processes in order to assist in determining the continued airworthiness of their fleet.

k. VHM system installation

The VHM system installation must comply with CS-29, as applicable to the specific rotorcraft type.

l. Ground-Based System Architecture

Any Ground-Based System Architecture requirements should be specified (see paragraph q. Technical Publications). The Ground-Based System may include COTS hardware, software and services, compatible with the Data Management objectives of paragraph (f) above.

m. Software

(1) **For the case where the VHM system is stand alone**

All software that makes up the VHM processing, whether airborne or ground-based, is to be produced to the software quality standard required to achieve the necessary level of system integrity.

All COTS software should be identified and should be of a quality standard that does not compromise the overall system's integrity.

All ground-based system software (specifically developed for VHM processing and COTS) should be developed to EUROCAE ED-109A/RTCA DO-278A Assurance Level 5 (AL5). DO 278 Assurance Level 5 (AL5) provides an acceptable method for acceptance of ground-based systems which include COTS.

VHM applications with hazard severity level Major or higher are addressed by MG15 and not AMC 29.1465.

Note: EUROCAE ED-12C/RTCA DO-178C Level D software for airborne systems and EUROCAE ED-109A/RTCA DO-278A Assurance Level 5 for non-airborne systems can be applied where VHM is utilised in addition to traditional helicopter design provisions. This will not require certification to a level any higher than Minor, based on the required reliability for these VHM applications. Should a design be proposed where greater reliance was placed solely on VHM, this would not be in compliance with the "minimise" target of CS 29.917(b) and CS 29.547(b).

(2) **For the case where the VHM is integrated into a system with other functions**

Software partitioning is addressed in both EUROCAE ED-12C/RTCA DO-178C and EUROCAE ED-109A/RTCA DO-278A.

n. Performance Criteria

(1) **Signal Acquisition**

The applicant for VHM system certification should specify the rate of acquisition of data sets for defect diagnostics in consistent flight regimes.

As a target, the total data set acquired in a flight should be sufficient for complete and reliable diagnostics to be produced for every flight above a defined duration in stabilised conditions. As a minimum, at least the data set for all components should be automatically obtained on each flight of greater than 30 minutes in stabilised conditions without the need for in-flight pilot action. For operations which do not contain periods of stabilised operation of greater than 30 minutes, alternative procedures need to be incorporated to ensure that the total data set is recorded within a specified number of flying hours related to the minimum adequate frequency of data collection determined under AMC 29.1465(e)(2), and in any case no longer than 25 flying hours.

Where subsystem performance is critical or relied upon to achieve the quoted defect probability of detection or False Alert rate, such as sensor accuracy, dynamic range or bandwidth, then this should be quoted.

(2) **Data transfer and Storage Capability**

The VHM defect status data should be capable of being downloaded during rotors running turnarounds.

All the data sets acquired should be stored until successfully transferred to the Ground-Based System. The storage capacity should not be less than 25 flying hours.

The applicant should describe the maximum interval between data downloads for which the system memory capacity is not exceeded.

In the event that a complete data set is not recorded, the data transfer process should be capable of downloading a partial data set to the Ground-Based System. In such a case, the ground station should alert maintenance personnel of a missing maintenance log or that the data set provided is incomplete.

(3) **VHM Alert generation and fault detection performance**

The Alert and Alarm generation processing should be designed to achieve a claimed probability of detection that is acceptable to the Agency for each component defect being monitored. Processing to isolate False Alerts and False Alarms should not result in an unacceptable workload. Also this processing should not compromise the verification and validating evidence of claimed defect detection performance. This workload should be assessed prior to completion of the Controlled Service Introduction (CSI) phase.

o. Performance Validation

The applicant should demonstrate how the VHM system provides an acceptable defect detection performance. Experiences gained during the CSI phase should be reviewed to confirm that this is the case.

(1) **Validation methodology**

It is not practical to verify predicted component defect detection performance for all failure modes by in-service experience or by trials. Therefore it is necessary that the methodology employed can be clearly substantiated from an understanding of how the failure mechanisms affect vibration and how the diagnostic processing will generate appropriate Alarms. Direct or indirect evidence should be provided as follows:

(i) Direct evidence includes:

(A) Actual service experience on VHM equipped rotorcraft of the same or of similar type and configuration, including information from module strips, component removals, inspections and other investigations which is relevant to the review of VHM system performance.

(B) Test rig results.

(C) Rotorcraft trials, investigating cause and effect (for example, introducing degrees of imbalance or mal-alignment and calibrating the techniques response). This should be supported by flight experience to demonstrate that the False Alert criterion can be met and that all the diagnostic indicators lie within reasonable ranges.

Note: A mechanism should be established for requesting maintenance feedback with respect to component failure/degradation and VHM indication. The cases are as follows:

- to verify component condition following rejection after an Alarm, in order to establish the diagnostic accuracy, probability of detection and the False Alarm rate.
- to inform the TC holder in the event that a failure occurs which is monitored by VHM, where the VHM fails to provide an Alarm. This will provide the missed Alarm rate.

(ii) Indirect evidence includes:

(A) Evidence as to the provenance of the technology and its suitability for application to rotorcraft.

(B) Reference to adequate performance in other applications.

(C) Modelling of the processes

The types of evidence stated in (i) and (ii) above can be used to substantiate:

(A) That the Alert processing methodology can deliver an adequate False Alarm rate, Prognostic Interval and probability of detection.

(B) Data acquired in a flight is sufficient for complete and reliable diagnostics to be produced for every flight above a minimum duration in stabilised conditions.

(C) The sensitivity, dynamic range and bandwidth of the signal acquisition are adequate.

(D) That the processed vibration signal-to-noise ratio is acceptable and that it is capable of discriminating the features required to identify potential incipient defects for the monitored components.

Typically, the False Alarm Rate and Alert Management performance will be validated during the CSI phase.

p. VHM System Criticality

(1) It is necessary to understand the criticality of a VHM function in order to determine the appropriate level of integrity required. Criticality describes the severity of the end result of a VHM application failure/malfunction and is determined by an assessment that considers the safety effect that the VHM application can have on the rotorcraft.

Note: The criticality of the VHM function relates only to its contribution to the overall integrity of the component being monitored.

(2) The criticality categories are defined in FAA AC 29.1309. In order to determine the appropriate level of criticality of the VHM function, it will be necessary to perform a safety assessment or functional hazard analysis on the rotorcraft systems affected. This should be carried out in accordance with standard safety assessment requirements such as CS 29.1309. In performing this assessment it will be necessary to consider the possibility of dormant and common mode failures and the possibility of the VHM system introducing additional risks, e.g. due to the False Alarm rate.

(3) Different VHM Systems have functions that can have different levels of criticality, such as those described below:

(i) Many VHM applications provide a method of enhanced health monitoring which adds to traditional techniques that have been used to establish an acceptable level of component integrity. Where a VHM application is not necessary for compliance with CS 29.547(b) and/or CS 29.917(b), the failure effect of these

functions is considered to be 'No Safety Effect' when there have been no changes to the traditional techniques.

(ii) Where a VHM application is identified as a compensating provision in order to comply with CS 29.547(b) and/or CS 29.917(b), then the failure criticality is considered to be 'Minor'. A proposed design that places greater reliance on VHM would not be deemed compliant with the "minimise" target of CS 29.547(b) and CS 29.917(b).

(iii) When an on-board VHM system is used to replace existing portable test equipment, and is performing an identical function, (though not necessarily utilising the same method of detection), this can be classified as 'No Safety Effect', providing that in such cases there will be no reduction in scheduled component inspection, or extension of overhaul or replacement intervals. A level of system integrity related to Minor criticality supports the reduction or elimination of check flights after standard vibration reduction checks and/or adjustments (rotor track and balance, balancing, absorber tuning, etc.).

As this equipment is airborne equipment, it is considered that a quality standard for the software used is necessary. For this reason software to EUROCAE ED-12C/RTCA DO-178C Level D is necessary.

Note: As there should be no effect on safety of the helicopter as a result of utilising the airborne system, it will not be necessary to carry out recurring independent verification means.

(iv) When a validated on-board VHM system is used to replace an existing maintenance task, this can be considered to be minor if the validated detection capability and integrity is better than the maintenance task being replaced. For example, VHM system monitoring of grease packed bearings which results in modification to manual inspection intervals.

For use of EUROCAE ED-12C/RTCA DO-178C level D software, it will be necessary to carry out periodic functional verification of the VHM system for dormant hardware or software failure or following a hardware or software change. An alternative approach to periodic functional verification is the retention of the original inspection at an increased interval. These instructions will need to be specified in the ICA.

Note: In cases (iii) and (iv), it is essential that the reliability and accuracy of the VHM must be equal to or better than that of the process it is replacing. This will require direct or indirect verification such as seeded fault testing (bench) or operational experience in accordance with paragraph (o) of this AMC. Compliance with paragraph (o) may require access to the design data and MSG3 analysis (or equivalent) used during substantiation of the original maintenance task.

q. Technical Publications

Appropriate Instructions for Continued Airworthiness (ICA) are required by CS 29.1529 and Appendix A. ICA and other supporting data should be available to operators and maintenance organisations before entry into service and should be updated whenever necessary during the service life of the system.

ICA should include the following:

(1) Guidance for the interpretation of the diagnostic information produced by the VHM system for all components monitored, to include Alert and Alarm management, a description of the indicators, and Alert generation methods.

(2) Maintenance instructions defining the actions to be taken in the event of all Alarms, including the appropriate rotorcraft inspections (or other maintenance) necessary for fault-finding to verify the Alarm.

(3) Scheduled maintenance to be carried out on the VHM system itself, including inspections to confirm sensor performance and system functionality.

(4) Instructions for all maintenance of the VHM System, including Illustrated Parts Catalogue/Illustrated Parts Breakdown and wiring diagrams.

(5) Installation instructions for retrofit VHM systems addressing all aspects of VHM system integration with the rotorcraft.

(6) A recommendation of the maximum period of unavailability of VHM functions for inclusion in the rotorcraft Master Minimum Equipment List (MMEL) or maintenance instructions, as required.

(7) Operating Instructions detailing the operation of the VHM system including any ground-based elements or functions.

(8) Required Flight Manual instructions.

r. Training

Suitable training should be made available with respect to operation and maintenance of the VHM system. This training should be made available prior to initial delivery of the VHM system. Training material and training courses should evolve to include lessons learned from service experience and appropriate diagnostic case studies. Training material and training courses should cover:

(1) Installation of the VHM system.

(2) Line maintenance of the VHM system (including VHM system fault-finding, any calibration necessary).

(3) Use of the VHM System during Line maintenance to monitor the rotorcraft, including the data transfer, interface with data analysis, response to Alerts and Alarm processing, rotorcraft fault-finding and other Line diagnostic actions.

(4) Necessary system administration functions, covering operational procedures relating to data transfer and storage, recovery from failed down loads and the introduction of hardware and software modifications.

(5) Any data analysis and reporting functions that are expected to be performed by the operator.

s. Product Support — System Data and Diagnostic Support

The necessary support should be provided to operators to ensure that the VHM system remains effective and compliant with any applicable requirements throughout its service life. The support provided should cover both the VHM system itself (i.e. system support), and the data generated (data and diagnostic support).

The data and diagnostic support provided should ensure that:

(1) The operator has timely access to approved external data interpretation and diagnostic advice. It is the responsibility of the approval holder to provide this information; however, this may also involve the rotorcraft TC holder, or through formal agreement, from another suitably qualified organisation.

(2) There is a defined protocol for requesting and providing diagnostic support, including response times that meet VHM system operational requirements, with traceability of all communications.

(3) The organisation providing diagnostic support to an operator has a defined process for training and approving all personnel providing that support.

(4) VHM performance is periodically assessed, with an evaluation of Alert criteria, and a controlled process for modifying those criteria if necessary.

(5) Sufficient historical VHM data is retained and collated to facilitate the identification of trends on in-service components, the characterisation of rotorcraft fleet behaviour, and VHM performance assessment.

t. Minimum Equipment List (MEL) Recommendation

The MEL should address the Airborne Element of the VHM system. The maximum period for absence of an assessment of any VHM indicator, to which Alert criteria are applied, should be limited to a suitable period and should not exceed 25 hours.

Note: If the VHM data is subject to close monitoring due to an increased likelihood of a developing mechanical problem, the maximum alleviation of 25 hours provided by the MMEL should be reduced or removed.

It is recommended that the VHM system automatically generates an indication to the operator if no VHM data has been gathered for a particular component for longer than a certain number of hours.

In the absence of any VHM data, reversion to the standard procedures used to ensure component integrity should be made.

u. Controlled Service Introduction

(1) When a VHM system initially enters into service or it is adapted to a new application on a different rotorcraft type, then a Controlled Service Introduction (CSI) phase is usually necessary in order to fully validate the system performance.

(2) If a CSI phase is considered to be necessary, then this activity should be detailed in a CSI plan to be approved prior to release to service, detailing the VHM applications being developed and the criteria for the successful completion of the CSI. Such criteria should address:

(i) The number of rotorcraft, number of operators, calendar time and flying hours.

(ii) Validation of specific sensor performance.

(iii) If targeted failures or defects occur during the CSI phase, it should be verified that the applicable VHM system applications provide an accurate timely Alarm.

(iv) Validate the False Alarm rate.

(v) Evolution of Alert criteria.

(vi) Validate the timeliness and integrity of the end-to-end data transfer and analysis process.

(vii) Demonstration of specific support processes.

(viii) System hardware reliability.

(ix) System maintainability.

(x) System usability (including rotorcraft and ground based man-machine interfaces).

(xi) ICA usability.

(xii) Effectiveness of training.

(xiii) Effectiveness and timeliness of diagnostic support.

(3) A CSI Plan should be agreed between the applicant for VHM system certification and the Agency prior to initial approval of the VHM system. This plan should then be implemented by the VHM approval holder and the operator(s) and monitored periodically by the Agency. Prior to any VHM function replacing an existing maintenance task, it may be necessary to complete a period of in-service operation. The validation and improvement activities should be detailed in this plan which should also detail the objectives that must be achieved before the CSI can be considered to be completed.

(4) Formal CSI meetings should take place in order to review service experience against the CSI criteria. They should involve the VHM system approval holder, the Agency (as applicable), and the operators.

(5) Once all parties agree that the intent of the CSI has been satisfied, the CSI phase will be considered closed. The process of review and closure should be recorded.

v. Related documents

(1) Federal Aviation Administration (FAA) AC 29-2C MG 15 'Airworthiness Approval of Rotorcraft Health Usage Monitoring Systems (HUMS)'

http://www.faa.gov/regulations_policies/advisory_circulars/

(2) CAP 753: Helicopter Vibration Health Monitoring (VHM) — Guidance Material for Operators Utilising VHM in Rotor and Rotor Drive Systems of Helicopters

http://www.caa.co.uk/docs/33/CAP753.pdf