COMMENT RESPONSE DOCUMENT

EASA CRD for Proposed Equivalent Safety Finding – Alternate Endurance Test Applicable to Turbine Engines
[Published on 08 June 2018, and officially closed for comments on 06 July 2018]

Commenter : GE Aviation (Paul Young) - 28/06/2018

Comment #1

Comment - In the ESF "Statement of Issue" it is stated: "CS-E 740 prescribes endurance test schedules and specifications for Turbine Engines, in order to demonstrate safe continued operation within and up to its declared operating limits."

The statement introduces a CS-E 740 intent that has not been previously stated by the Agency via the regulation or its AMC and is inconsistent with the endurance test specifications that are defined to achieve an accelerated deterioration (possibly to the level of operational abuse) of the engine and its components. In fact, for the modern high bypass turbofan engine, some of the test specifications found in CS-E 740, for example operating at multiple redlines for extended periods of time, are not indicative of a properly functioning in-service, type design engine.

Relative to safe continued operation, CS-E 740 states "After completion of the test, …The condition of the Engine must be satisfactory for safe continued operation." (Ref, CS-E 740(h)(1)). This is the appropriate context of "safe continued operation", because after the test an engine and its components need to show that they are suitable for continued in-service operation, i.e. per type design and operational intent. The engine and its components are not required to show capability/acceptability with respect to further exposure to the endurance test specifications, i.e. the ability to continue the regulatory test specification.

Recommendation - It is recommended that the ESF statement be modified from:

"CS-E 740 prescribes endurance test schedules and specifications for Turbine Engines, in order to demonstrate safe continued operation within and up to its declared operating limits.",

to:

"CS-E 740 prescribes endurance test schedules and specifications for Turbine Engines, in order to demonstrate the intended type design engine's ability to safely operate within and up to its declared operating limits."

Comment agreed.

The recommended change has been incorporated in the Final ESF, as follows:

CS-E 740 prescribes endurance test schedules and specifications for Turbine Engines, in order to demonstrate the intended type design engine's ability to safely operate within and up to its declared operating limits.

Comment #2

Comment - In the "EASA Position" it is stated that "Consequently, applicants have faced increased difficulties to run the endurance test schedules at the conditions prescribed by CS-E 740 (in particular the combined target speed and temperature redline conditions), resulting in the need to modify the tested vehicle in order to demonstrate the expected engine operating limitations."

The Agency states that the reason for significant and multiple modifications is to allow endurance test vehicles to achieve concurrent rotor speeds and turbine exhaust gas temperature redline levels. In fact, for a modern high bypass, multi-rotor, turbofan engine, multiple and significant component modifications are required to allow the machine to survive the extremely long, continuous time durations at redline conditions stipulated by the regulatory specification. Specifically, core (high-pressure compressor and high-pressure turbine) rotor redline speed is very difficult to achieve, while targeting concurrent low-pressure rotor redline speed and/or EGT redline exacerbates the difficulty.

A modern high bypass turbofan engine, designed to meet the latest governmental requirements, as well as airline operators and general population expectations, for lower carbon and acoustic footprints, is indeed able to achieve redline core rotor speed in a sea-level static test environment for short durations of time (minutes), even with concurrent EGT redline. Modifications being limited to minor control schedule alterations, along with minimal and temporary internal engine cooling circuit modifications. Coincidently, under most sea-level, static test conditions, 'pushing' the core rotor to its redline speed will result the engine's low-pressure rotor speed, along with thrust, meeting or exceeding the redline/rating values as well.

However, when elevated core rotor speed durations are extended from several minutes to several hours (as required by CS-E 740) these minor modifications are insufficient to maintain temperature/stress levels of high pressure turbine components within reasonable proximity to type design intent. This leads to the need for multiple, significant modifications to the endurance test vehicle.

Recommendation - Therefore, it is recommended that the ESF statement be amended from:

"Consequently, applicants have faced increased difficulties to run the endurance test schedules at the conditions prescribed by CS-E 740 (in particular the combined target speed and temperature redline conditions), resulting in the need to modify the tested vehicle in order to demonstrate the expected engine operating limitations.",

to:

"Consequently, applicants have faced increased difficulties to run the endurance test schedules at the conditions prescribed by CS-E 740 (in particular the combined target speed and temperature redline conditions for the extended time durations specified), resulting in the need to modify the tested vehicle in order to demonstrate the expected engine operating limitations for extended duration(s)."

Comment partially agreed.

The recommended change has been partially incorporated in the Final ESF. The word "extended" may be inadequately interpreted, and the repetition of the word "duration" is not deemed necessary. The sentence in the Final ESF as been modified as follows:

Consequently, applicants have faced increased difficulties to run the endurance test schedules at the conditions prescribed by CS-E 740 (in particular the combined target speed and temperature redline conditions for the time durations specified), resulting in the need to modify the tested vehicle in order to demonstrate the expected engine operating limitations.

Comment #3

Comment - Within the "EASA Position" it states that "… EASA considers that the proposed engine architecture and design are still in line with the technologies embedded in recent projects certified engines." However, the Agency provides no content (either directly or via reference materials) related to the circumstantial conditions and/or proposed type design definition under which application of the existing regulation versus ESF versus special condition is/will be considered.

Furthermore, the Agency provides no insights into how it has come upon its position that an engine design, presented to the Agency in 2018, does not contain any sufficiently modernized technologies, functions or features with respect to a regulatory specification (CS-E 740 and its direct FAA predecessor 14 CFR Part 33.87) that was developed and codified decades ago. This insight into the Agency's reasoning and application criteria is critical so as to allow the reviewer to determine if the proposed ESF is sufficiently comprehensive and appropriate for any immediate, or future, application.

Due to this lack of content, a cognizant and constructive review response cannot reasonably be expected. Therefore, the ESF proposal is deemed incomplete and insufficient for its stated, or implied, purpose.

Recommendation - It is recommended that the Agency provide additional content to address this shortcoming in the ESF proposal.

Comment partially agreed.

Regarding circumstantial conditions under which alternative regulatory approach is considered, the Agency works in accordance with 21.A.16B(a) for Special Conditions, and Part 21.A.17(a)(1)(i) / 21.A.21(c)(2) for Equivalent Safety Findings. The Agency considers that a Special Condition is used in case the applicable certification specification or equivalent does not cover at all or not comprehensively enough a subject incorporated in the type design and new or additional technical specifications need to be developed. Typically this is applied due to unusual design, unusual capabilities, new technologies, etc. An ESF is used in case the applicable requirement literally cannot be complied with, either in part or fully, but the safety intention of the requirement can be met using other means. An ESF can be used for example if the requirements contains not only objective but also prescriptive parts. An ESF would be used if the objective is met by a design or feature other than required in the specification, or for a different compliance demonstration than required.

Accordingly, the EASA assessment is clarified through the following modification of the sentence in the Final ESF:

However EASA has considered the architecture and design of the subject engine in view of Part 21.A.16B(a), and did not identify any novel or unusual design feature, nor any unconventional intended use that would justify a Special Condition.

Comment #4

Comment - Within the "EASA Position" it is stated that "All damage mechanisms for component and engine systems shall be exercised, to a level at least equivalent to the "intent of the current CS-E 740 tests". Furthermore, the phrase "intent of the current CS-E 740 tests" is utilized in the two subsequent bulleted paragraphs of the ESF proposal.

While the understanding of the "intent of the current CS-E 740 tests" appears to be a key to understanding how the Agency will establish and ultimately agree upon an acceptable level of equivalence for an alternate endurance test, the Agency has provided no information, directly or by reference, related to what this intent has been, is now, or will be in the future.

Neither the CS-E 740 specification nor its AMC material provide insight into the intent of the CS-E 740 test. Has the Agency published its perspective on the intent of the CS-E 740 testing anywhere?

Recommendation - It is recommended that this information be excerpted into the ESF proposal and/or referenced. The preference would be for this intent information to be preexisting, thereby lending legacy perspective to its use as a basis for an alternate test equivalence.

Furthermore, with respect to the statement that "All damage mechanisms for component and engine systems shall be exercised, to a level at least equivalent to the "intent of the current CS-E 740 tests", subsequently it is stated that "For all pertinent components, durability/severity criteria associated with these damage mechanisms shall be proposed and justified." It is unclear, and not explained, how an alternate endurance test proposal goes from needing to satisfying an equivalence to "all [CS-E 740 intended] damage mechanisms for engine components and systems" to an equivalence that focuses on "pertinent components…associated with these damage mechanisms".

Comment partially agreed.

EASA has used pre-existing information from an ARAC-EHWG group dedicated to the definition of an alternate endurance test. This group has reported its findings and recommendations, which include considerations of the regulatory objectives and also of the need for quantifiable and universally adaptable severity targets to ensure consistent safety margins and equitable application of the alternative approach. Its reference has been added in the Final ESF, and can be read as follows:

In determining the requirements of this ESF, EASA has considered the work performed by the Aviation Rulemaking Advisory Committee (ARAC), Engine Harmonization Working Group (EHWG) on Engine Endurance Testing Requirements. The EHWG released a recommendation report 'Alternate Test to

14CFR33.87, EHWG task from Federal Register Vol.79, #14 January 22, 2014', dated January 31, 2017. It has been published on December 21, 2017 on FAA website under Regulations & Policies > Rulemaking > Committees > Documents.

Considering the above recommendations, it is EASA intent that the severity of the existing test be retained in the alternate test. EASA therefore requires the Applicant to justify that this will be achieved through an analysis of damage mechanisms and associated levels. The wording of the relevant paragraphs has been revised to make the logical flow clearer, while also clarifying the definition of the "intent of the current CS-E 740 test". The modified paragraphs in the Final ESF can be read as follows:

In order to demonstrate the intended type design engine's ability to safely operate within and up to the declared engine operating limits, consistent with the level of demonstration intended by the current CS-E 740 requirement, it is expected that the Applicant addresses the following aspects:

1. The Applicant should identify from experience on previous testing and analysis the damage mechanisms exercised by the current test (CS-E 740, CS-E Amdt 4), and the associated affected engine systems and components.
2. Durability/severity criteria consistent with the "intent of the current CS-E 740 tests" associated with the damage mechanisms shall be established and justified. The proposed test shall be of sufficient severity and duration to exercise those damage mechanisms to a level at least equivalent to the established criteria.
    a. For these purposes the "intent of the current CS-E 740 test" should be understood as a theoretical set of conditions to which a particular component would be subjected to during a CS-E 740 test, if the practical limitations of engine testing did not apply. The assessment should therefore account for the current CS-E 740 schedules, maximum material temperatures or thermal severity, as applicable, of one, or more critically affected engine components associated with a type design engine running at the intended maximum Exhaust Gas Temperature (redline EGT) within its intended operational envelope, and combined with maximum physical rotor speeds (redlines).

Comment #5

Comment - Additionally, there is a level of impracticality to equivalencing to the all damage mechanisms. For example, an endurance test can cause component interface wear damage. Typically, this wear damage is deemed acceptable (i.e. serviceable) at the conclusion of the test. Wear is a difficult mechanism to quantify without a test being conducted and even more difficult to replicate (even when repeating the same test spec) or equivalence. However, the ESF indicates that this wear mechanism would need to be (at least) equivalenced between the regulatory test and an alternate test. This presumes that an analysis would need to be provided to predict wear that would occur during the regulatory test AND the proposed alternate test and equivalence shown. This appears to be an unreasonable and impractical approach for a damage mechanism that would likely result in a serviceable condition. Would this example be addressed by it being deemed not "pertinent"? If so, the current ESF wording does not make this clear.

Recommendation - It is recommended that more specifics and clarifications be applied to the "all damage mechanisms for components and engine systems" and the subsequent stipulation to address "all pertinent components, durability/severity criteria associated with these damage mechanisms".

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Comment #6

Comment - Although the two (2) sub-bulleted statements (i.e. those beginning with "The damage levels, and the key contributing parameters…" and "The conditions associated with the "intent of the current CS-E 740 test"…") may have been intended to clarify to the reader how to progress from the requirement to address "all damage mechanisms for components and engine systems" towards the specifics of determining that "all pertinent components, durability/severity criteria associated with these damage mechanisms", they do not.

Specifically, the first sub-bullet statement stipulates that "The damage levels, and the key contributing parameters, e.g. stresses and temperatures, shall be analysed and provided for the following conditions: The proposed alternate endurance test, the "intent of the current CS-E 740 test" and, when applicable, the actual most severe predicted in-service conditions." This does not clarify the alternate endurance test equivalence process because, as noted previous, there is no information provided regarding the "intent of the current CS-E 740 test". The process is further confused by the addition of analyzing for "the actual most severe predicted in-service conditions", as applicable.

It is not clear what conditions "actual most severe predicted in-service conditions" are intended to be. Is the Agency looking for actual in-service conditions or predicted in-service conditions to be represented in the subject analysis?

Additionally, it is not clear how including in-service condition (severe or otherwise) analysis adds to showing equivalence between a proposed alternate endurance test and the CS-E 740 test specifications. It is not clear when the addition of the in-service data could/would be applicable in the context of an equivalence substantiation discussion. As noted previously, some of the test specifications found in CS-E 740, for example operating at multiple redlines for extended periods of time, are not indicative of a properly functioning in-service, type design engine. It is difficult to understand how including any in-service condition analysis assists determining appropriate equivalence between the CS-E 740 test requirements and a proposed alternate test.

Recommendation - Therefore, it is recommended that the statement be changed from:

"The damage levels, and the key contributing parameters, e.g. stresses and temperatures, shall be analysed and provided for the following conditions: The proposed alternate endurance test, the "intent of the current CS-E 740 test" and, when applicable, the actual most severe predicted in-service conditions.",

to:

"The damage levels, and the key contributing parameters, e.g. stresses and temperatures, shall be analysed and provided for the following conditions: The proposed alternate endurance test and the "intent of the current CS-E 740 test".

With the intent of the current CS-E 740 testing addressed by additional Agency content in the ESF document (as noted above).

Alternate Recommendation - Alternatively, if in-service analysis conditions are to be included in an alternate endurance test assessment, the statement should be changed to read:

"The damage levels, and the key contributing parameters, e.g. stresses and temperatures, shall be analysed and provided for the following conditions: The proposed alternate endurance test, the "intent of the current CS-E 740 test" and, when applicable, the most severe predicted in-service conditions."

With the Agency providing guidance in the ESF regarding when and how most severe predicted in-service conditions should be incorporated into an equivalence assessment.

Comment partially agreed.

See EASA response to Comment #4 and associated modified paragraphs in the Final ESF.

In addition, the need for providing the damage levels for in-service conditions has been clarified as for benchmark puposes. The following sub-paragraph has been added in the Final ESF:

b. Damage levels for most severe predicted in-service conditions should also be analysed and provided for benchmark purposes.

Comment #7

Comment - In the ESF proposal, the statement that in-service conditions may, or will, be applied to the alternate endurance test durability/severity assessment "when applicable", there follows the this statement: "The conditions associated with the "intent of the current CS-E 740 test" should achieve maximum metal temperatures and representative thermal response of the pertinent components, associated with a fully deteriorated type design engine reaching Exhaust Gas Temperature (EGT) redline in service.". By this statement it appears that the Agency is incorporating an in-service assessment into the intent of the CS-E 740 test specification. This appears to contradict the prior statement that indicates that an in-service condition analysis is a possible (non-mandatory) additional assessment avenue outside of the regulatory test's intent equivalence assessment.

Recommendation – It is recommended that, should the use of in-service condition assessment remain part of the Agency's understanding of the intent of the CS-E 740 test for the ESF, Recommendation #6 (above) be incorporated, rather than Recommendation #6alt (above).

Also, this portion of the proposed ESF uses the phase "…should achieve maximum metal temperatures …". As engine technology progresses the use of metallic-based materials is being replaced by non-metallic compounds, such as ceramic composites, etc.

Additional Recommendation – It is recommended that the phrase be change from:

"… should achieve maximum metal temperatures …"

to:

"… should achieve maximum material temperatures …".

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Comment #8

Comment - Additionally, for all engine designs and/or components or systems, a fully deteriorated engine reaching EGT redline may not represent the most severe in-service condition, i.e. material temperature(s). Therefore, categorically stating that this is the condition that satisfies the intent of the CS-E 740 tests may not achieve what appears to be the desired equivalence result.

Furthermore, the incorporation of the phrase "… and representative thermal response of the pertinent component …" in the ESF provides an indefinite benchmark for equivalence. Is this meant to address bulk material temperature assuming indefinite time exposure to said conditions (i.e. steady state), peak surface temperature seen throughout any/all transient operations approaching or during the subject condition(s) or both. Any of which could produce multiple, possibly incompatible severity benchmarks, i.e. not a single set of definite thermal state benchmarks that can be achieved with a single engine test. Because of this complexity, it does not appear that the thermal response stipulation adds to the alternate endurance test -to- CS-E 740 test intent equivalence effort.

Also, in this sub-paragraph, it seems that it would be appropriate to direct the equivalence to a more manageable, focused scope. The current CS-E 740 test specification does not exercise all engine components and systems to the same severity level with respect to all potentially relevant (on a part-by-part or system-by-system basis) durability design/environment characteristics, i.e. temperatures, pressures, LCF, HCF, creep, wear, etc. Therefore, the ESF needs to provide an equivalence approach that allows for focusing in on a key component/system, along with a reasonable number of associated key design/environmental characteristics. This can be achieved via a high-level assessment survey of the engine system environmental exposures, relative severity(s) and characteristic(s) reviewed relative to the test equivalence benchmark(s). As a starting point, this high-level assessment can be directed towards high temperature/high pressure areas of the engine, new technologies and historically troublesome components/systems (directed by relevant test and/or in-service experience).

Finally, the proposed ESF in this sub-paragraph states that the maximum temperatures need to be combined "… with redline speeds, as prescribed by the current rule." As noted before, in a modern, high bypass, turbofan design redline rotor system speeds can be achieved with a minimum of modifications to type design, it is the extended durations at these condition that pose the issue. Therefore, by requiring that the metal temperature conditions at EGT redline be combined with rotor redline speed(s) as prescribed by CS-E 740 would drive the alternate test requirement to replicate, rather than equivalence, the CS-E 740 test specifications.

Recommendation – Change the ESF statement from : "The conditions associated with the "intent of the current CS-E 740 test" should achieve maximum metal temperatures and representative thermal response of the pertinent components, associated with a fully deteriorated type design engine reaching Exhaust Gas Temperature (EGT) redline in service.", to: "The conditions associated with the "intent of the current CS-E 740 test" should account for maximum material temperatures of one, or more, agreed upon engine components. In this assessment engine system conditions, such as flow path and internal cooling circuit temperatures and pressures (both transient and steady state), should take into consideration a fully deteriorated type design engine reaching Exhaust Gas Temperature (EGT) redline within its intended operational envelope, or any other in-service condition(s) under which maximum thermal severity would be predicted to be achieved. Predicted, typical and extreme, installed operating mission profiles over an agreed upon operational life-cycle mission mix shall also be defined and used in the equivalence assessment."

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Comment #9

Comment - The proposed ESF states that "The test times and conditions necessary to derive the proposed engine operating limitations (e.g. redlines) shall be proposed and justified. …" and "… will be declared in the EASA Type Certificate Data Sheet (TCDS)." It is unclear what this ESF stipulation is looking for or what value exists in providing this unprecedented certification test information on the engine TCDS.

Presumably the "test times and conditions" referred to here are those associated with the agreed upon alternate endurance test specification. If not, the Agency needs to define what test times and conditions are being referred to here.

If the alternate endurance test specification is the source of the test times and conditions the Agency is inaccurate in its stated association between the process used by an engine manufacturer to derive the intended redline levels for a high bypass turbofan engine intended for large commercial transport category aircraft installation and operations. These redlines are derived using extensive trade studies, long term discussions with airframe manufacturer(s) and expected customer base. This information is then translated into an engine specification that includes installed performance (thrust, SFC, etc.), design (weight, physical interface envelopes, reliability, etc.) and operational cost (on-wing maintenance, reliability, shop visit costs, etc.) requirements, among many others. All of these commercial and technical requirements are then vetted against the available technologies (both pre-existing, mature technologies and technologies whose emergence fits into the program's development and certification timeframes) and then installed engine performance prediction models are used to determine what basic engine operational parameters, including rotor speeds and turbine exhaust gas temperature redlines, are appropriate. These predictive performance models are based and vetted against relevant legacy engine program in-service data. Margins are included in the resulting model predictions, including redline levels, based on the confidence level that legacy experience provides. These models, and the resulting engine performance predictions, are refined as development engine data for the new engine design is

gathered. This process can, and has resulted in changes to one, or more, intended operational redline values as the program progresses through development.

Therefore, rather than a single test (such as the endurance test, CS-E 740 specified or an equivalent), providing the derivation basis for the engine redline levels, the combination of an entire certification showing and finding of compliance data set is used to validate/verify that the engine design is acceptably compatible with these declared redlines.

Including any single test, specific time(s) or condition(s) on the engine TCDS is unprecedented and could lead to confusion regarding how, specifically, declared rotor speed and EGT redlines are ultimately validated and approved by the Agency.

Recommendation – It is recommended that the statement "The test times and conditions necessary to derive the proposed engine operating limitations (e.g. redlines) shall be proposed and justified. Upon acceptance by the Agency, those will be declared in the EASA Type Certificate Data Sheet (TCDS)." be removed from the ESF.

Alternate Recommendation – Alternatively, it is recommended to remove the statement "The test times and conditions necessary to derive the proposed engine operating limitations (e.g. redlines) shall be proposed and justified. Upon acceptance by the Agency, those will be declared in the EASA Type Certificate Data Sheet (TCDS)." from the ESF and replace it with a requirement that documentation of pertinent, or essential, information related to the alternate endurance test equivalence assessment assumptions and condition(s), including specific test durations, be included as part of a CS-E 30 (Assumptions) compliance submittal to the Agency.

Comment disagreed.

CS-E 40 (d) and (e) require that operating limitations be established and listed in the Engine TCDS. See also AMC E 40 (d). Operating limitations are demonstrated through the Endurance Test, and CS-E 740 (f) Operating Limitations states that these are established under CS-E 40 (d).

Those limitations are also relevant for other tests required by CS-E to be run at or above those limits.

For consistency the word "redline" has been removed from the text, and the resulting paragraph has been modified as follows in the Final ESF:

8. Engine operating limitations shall be proposed and justified based on achieved test times and conditions. Note that EGT substantiation requires full demonstration of equivalent severity to the "intent of the current CS-E 740 test" as indicated in paragraph 2 above. Upon acceptance by the Agency, engine operating limitations will be declared in the EASA Type Certificate Data Sheet (TCDS) in accordance with CS-E 740 (f) and CS-E 40 (d) – See also AMC E 40 (d).

Comment #10

Comment - The ESF proposal states that "Any provisions of CS-E 740 that are not covered by the proposed alternate endurance test shall be demonstrated through additional testing or other evidence found acceptable by the Agency." This statement raises questions and possible confusion

regarding 1) the engine types intended that are eligible under the ESF proposal, 2) the Agency's intended ESF scope as it related to the provisions of CS-E 740.

CS-E 740 includes specifications to cover multiple engine types and intended application types, turbine engines for both rotorcraft and aeroplanes, as well as turbo-propeller engines. Is it the Agency's intention that all of these turbine engine types and application types would be eligible, with suitable equivalencing to the CS-E 740 test, for application of this ESF?

Recommendation – It is recommended that wording be added to the ESF that states that all turbine engine types and application types (rotorcraft and aeroplanes) addressed by CS-E 740 are eligible for consideration, or, conversely, stipulate in the ESF which engine and/or application types are specifically eligible, or ineligible, for consideration.

Comment agreed.

The following paragraph has been added in the Final ESF:

CS-E 740 includes specific provisions whether the engine is to be installed on aeroplanes or rotorcraft, and depending on selected ratings. Although this ESF may be applied in principle to any turbine engine, the Applicant should confirm its applicability to his project with the Agency.

Comment #11

Comment - As stated throughout the proposal, at least up to this final paragraph, the ESF is intended to address all provisions of CS-E 740. However, in this final paragraph it is stated that "… provisions of CS-E 740 that are not covered by the proposed alternate endurance test shall be demonstrated through additional testing or other evidence found acceptable by the Agency.". This appears to contradict the premise (setup by the remainder of the preceding ESF proposal) that the whole of CS-E 740 is to be equivalenced by an alternate test proposal. This premise is supported by the immediately preceding paragraph of the proposal that states that "The Applicant may propose additional compensating factors to contribute to the demonstration of the equivalent level of safety." Presumably any additional compensating factors could include "additional testing or other evidence" presented to and accepted by the Agency.

Therefore, it seems that what may be meant, at least in part, by the final paragraph is that the applicant may propose to execute one or more provisions of the CS-E 740 specification directly into an alternate endurance test proposal, thereby eliminating the need to show equivalence to the subject specification(s) test requirements. Additionally, it seems that what may be meant here, is that the applicant may be able to show that compliance to other CS-E specification requirements (or, in the case of an EASA engine validation effort, one or more of the certifying agency's requirements) can be used to show suitable direct, or equivalent, demonstration of a CS-E 740 specification provision.

Recommendation – It is recommended that the final two (2) paragraphs of the ESF be changed from:

"The Applicant may propose additional compensating factors to contribute to the demonstration of the equivalent level of safety.

Any provisions of CS-E 740 that are not covered by the proposed alternate endurance test shall be demonstrated through additional testing or other evidence found acceptable by the Agency.”,

to:

“The Applicant may propose additional compensating factors to contribute to the demonstration of the equivalent level of safety. Compensating factors may include additional (in form, extent and/or duration) test demonstrations or other evidence found acceptable by the Agency.

All provisions of CS-E 740 specification shall be addressed by the proposed alternate endurance test, directly or by acceptable equivalence.”

Comment partially agreed.

EASA agrees but some adjustments to the wording have been made for clarity. The following paragraphs have been modified as follows in the Final ESF:

The Applicant may propose additional compensating factors to contribute to the demonstration of the equivalent level of safety. Compensating factors may include additional test demonstrations (additional in form, extent and/or duration) or other evidence found acceptable by the Agency.

All provisions of CS-E 740 specification shall be addressed by the proposed alternate endurance test, directly or by equivalence found acceptable by the Agency.

Commenter : GE Aviation (Peter G Thompson) - 05/07/2018

Comment #12

GE is concerned that the proposed ESF lacks sufficient content related to the background, and explanation of regulatory intent to allow for a complete assessment, subsequent feedback and public comment.

However, we wish to point out the following:

- The ESF states that the subject engine may need to be modified to complete the prescriptive test defined in CS-E 740.[1] If the applicant must create an engine configuration that does not comply with the type design being approved to accomplish the test defined in CS-E 740, then one would naturally have to conclude this test is not a valid means of assessing the type design engine’s suitability to “demonstrate safe continued operation” as mentioned in the subject ESF.

As stated by EASA in the ESF, applicants have faced increased difficulties to run the endurance test schedule at the conditions prescribed by CS-E 740. Given this difficulty, it is appropriate for an applicant to define an alternate test which will exercise the engine in its type design rather than in a modified form, while still demonstrating operation at its limiting conditions as likely to be encountered in service. Such an alternate test would more

realistically simulate expected in service operational characteristics and levels of damage and thus better "demonstrate safe continued operation within and up to its declared operating limits" than the currently prescribed test.

- The ESF mentions the "intent of the current CS-E 740 tests" in several places as it relates to durability and severity criteria, yet nowhere is this intent described or defined in the ESF, CS-E 740 or relevant AMC material. It is recommended that EASA clarify the "intent of the current CS-E 740 tests" as it relates to durability and severity criteria.
- We agree that the alternate test should demonstrate limiting conditions (e.g. speeds & exhaust gas temperatures) to be declared on the EASA Type Certificate Data Sheet (TCDS) however achieving this in a type design configuration limits how this demonstration can be conducted
- Is the proposed ESF intended to apply to one applicant's specific engine design/model, or is it intended to be generic and applicable to any applicant's products if they propose an alternate to the prescribed CS-E 740 test? Clarification of this would be appropriate in our opinion for all manufacturers within the Engine Industry.

[1] The rule is based on the US rules which, were based on the technology in use at the time of its inception in the mid 1950's (and from the piston engine rules in place much earlier) and does not account for significant technology advances introduced in modern turbine engines including engine control architecture that inhibit the very conditions this test is required to assess. The current test requires engines to be run at off design conditions which significantly adversely affects the domestic cooling systems for turbine hardware, thus requiring non-type design modifications.

1st bullet : ***Comment noted.*** The comment justifies the need for an ESF.

2nd bullet : ***Comment partially agreed***. See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

3rd bullet : ***Comment partially agreed.*** See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

4th bullet : ***Comment agreed***. See EASA response to Comment #10 and resulting modified paragraphs in the Final ESF.

Comment #13

The proposed ESF states:

- "The conditions associated with the "intent of the current CS-E 740 test" should achieve maximum metal temperatures and representative thermal response of the pertinent components, associated with a fully deteriorated type design engine reaching Exhaust Gas Temperature (EGT) redline in service. Those should be combined with redline speeds, as prescribed by the current rule"

Because of the technology advancements (and resulting gains in efficiency, reliability and safety) in modern engines, the control architectures effectively preclude simultaneous redline (limiting) fan speed and Exhaust Gas Temperature (EGT).

Further, due to the deterioration mechanisms in place, reaching simultaneous redline core speed and Exhaust Gas Temperature (EGT) is extremely unlikely and should a service event occur, it may be accounted for by prescribed maintenance actions and operational limitations.

We suggest any proposed test should demonstrate the engine's capability to operate at individual redlines and only at two simultaneous redlines if such a condition is possible or likely to occur in service. (Additionally, should the engine have the capability to operate at two individual redlines simultaneously, recommended maintenance actions should be required within the Aircraft Maintenance Manual).

Comment partially agreed.

In consideration of the comment, and of the ARAC report referred above, EASA has :

- clarified the definition of the "intent of the current CS-E 740 test" and associated the durability/severity criteria for the alternate test proposal (See EASA response to Comment #4 and associated modified paragraphs in the Final ESF) and,
- included definition of the Critical Point Analysis (CPA) as well as requirements of minimum engine test time at maximum EGT and/or maximum/CPA rotor speed(s). The following paragraphs have been included in the Final ESF:

3. The applicant must determine through a validated Critical Point Analysis (CPA) the highest rotor shaft rotational speeds (CPA speeds) expected to occur for each rotor shaft system within the declared operating envelope. The CPA must be conducted and validated for the take-off and maximum continuous rated thrust and must consider the declared operating envelope, engine deterioration, engine-to-engine variability, and any other applicable variables that can cause the engine to operate at the extremes of its performance ratings.

4. In order to demonstrate maximum EGT limit for take-off (redline), the proposed test shall include testing at or above the rated take-off thrust/power and maximum take-off EGT for a minimum cumulated time of 18.75 hours. The associated average rotor speeds should not be lower than the maximum take-off CPA speeds.

5. In order to demonstrate maximum EGT limit for maximum continuous (redline), the proposed test shall include testing at or above the rated maximum continuous thrust/power and maximum continuous EGT for a minimum cumulated time of 45 hours. The associated average rotor speeds should not be lower than the maximum continuous CPA speeds. Testing shall include at least one continuous interval of a minimum of 30 minutes duration.

6. In order to demonstrate maximum rotor speed limits for take-off (redlines), the proposed test shall include testing for a minimum of 10 minutes duration at the maximum physical rotor speeds combined with the maximum take-off EGT, unless the CPA shows a longer period is required. If separate demonstration is proposed for each shaft, those shall be for a minimum of 10 minutes each.

7. In order to demonstrate maximum rotor speed limits for maximum continuous (redline), the proposed test shall include testing for a minimum of 10 minutes duration at the maximum continuous rotor speeds combined with maximum continuous EGT. This may be demonstrated by par. 6 above, unless the CPA shows a longer period is required, in which case testing would be extended at maximum continuous conditions. If separate demonstration is proposed for each shaft, those shall be for a minimum of 10 minutes each, plus extension if applicable.

Commenter : Honeywell (James Niessink) - 06/07/2018

Comment #14

- **Page 2, first major bullet - ESF states –** "All damage mechanisms for component and engine systems shall be exercised to a level at least equivalent to the intent of the current CS-E 740 tests."

Honeywell comment – Early engine designs had a significant portion of their cyclic life consumed during the current test, not due to extensive cyclic test requirements, but due to the limited capability of rotating components in those designs. It's unclear whether this ESF statement indicates an alternate test proposed by the applicant should consume a similar proportion of cyclic life in modern engine designs.

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Comment #15

- **Page 2, second minor bullet – ESF states –** "The conditions associated with the "intent of the current CS-E 740 test" should achieve maximum metal temperatures and representative thermal response of the pertinent components, associated with a fully deteriorated type design engine reaching Exhaust Gas Temperature (EGT) redline in service. Those should be combined with redline speeds, as prescribed by the current rule."

Honeywell comment – The second sentence in this statement seems to suggest an alternate test proposed by the Applicant must demonstrate maximum temperatures and speeds, concurrently. Given the current state of turbine engine design and operation, this likely will not be possible while also meeting the ESF requirement for the test article to be in type design configuration.

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Commenter : Rolls-Royce plc (Sharron Welch) - 06/07/2018

Comment #16

Rolls-Royce assume that this ESF is to allow an approach to the Endurance Test in accordance with that proposed in ARAC report "Proposed alternate test to 14 CFR33.87 – report in response to Engine Harmonisation Working Group (EHWG) task identified in the FAA Federal Register Vol 79, No. 14, January 22, 2014". It is Rolls-Royce opinion that the ESF should be clear and state that this is the case. EASA had a member on this working group on the basis that EASA would also adopt the recommendations. This ESF allows the EHWG recommended approach to be used prior to being formally adopted through future rule making. Making reference to the ARAC report would then imply that all the other requirements of the report are explicit (e.g. rated thrust, slam accels/ decels, bleed offtakes etc) including the derivation of the ETCDS declared redlines at the end of the test.

Comment agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Comment #17

Reference the following paragraph: *"The conditions associated with the "intent of the current CS-E 740 test" should achieve maximum metal temperatures and representative thermal response of the pertinent components, associated with a fully deteriorated type design engine reaching Exhaust Gas Temperature (EGT) redline in service. Those should be combined with redline speeds, as prescribed by the current rule. "*

1) The actual predicted most severe service conditions are derived from conducting a "Critical Point Analysis" of the engine operation and likely durations at limiting parameters This will define the maximum speeds and temperatures and if any occur simultaneously.
2) The ARAC report proposal allows for a severity equivalence based on metal temperatures, stresses (as a function of speed squared for rotating components) and time on condition. The report allows for speeds to vary by up to 3% on average and shortfalls are made up by more running time/ cycles. We therefore disagree with the wording that states the redline speeds need to be run as prescribed in the current rule unless max speeds and temperatures are determined to be concurrent from the "Critical Point Analysis".

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Commenter : Pratt & Whitney Canada (Peter Turyk) - 06/07/2018

Comment #18

Item 1

Page 2, first full para starting with "However, EASA considers…"

P&WC comment:

Understood, but did the "recent certified engines" themselves need to be significantly modified to demonstrate compliance to CS-E 740 as described in the "Statement of Issue" on page 1?

Comment partially agreed.

See EASA response to Comments #3 and #4, and resulting modified paragraphs in the Final ESF.

Comment #19

Item 2

Page 2, sub-sub-bullet starting with "The conditions associated with…"

P&WC comment:

The EASA position seems to indicate that, essentially, the "triple point" test (i.e. running with all proposed limiting temperature and speeds concurrently) is still to be carried out.

Is this what was intended?

This seems to be contrary to the approach provided in the FAA/AIA Alternate Endurance Test Working Group final report (31 January 2017) and the FAA SC 2017-24812 "GE alternate endurance test".

In particular, these references indicate that, if the applicant can show via a critical point analysis (CPA) that the intent of the endurance test can be demonstrated by means alternate to the triple point methodology, equivalent safety would thus be demonstrated.

Comment partially agreed.

See EASA response to Comment #4 and resulting modified paragraphs in the Final ESF.

Comment #20 **Item 3** Page 2, second first level bullet starting with “The test times and conditions…” **P&WC comment:** What does “those” refer to in the second clause? Presumably, it refers to the “operating limitations” and as such, clarification is suggested.
Comment agreed. See EASA response to Comments #4 and #13, and resulting modified paragraphs in the Final ESF.