Proposed Equivalent Safety Finding on CS 23.1305(a)(c)(d), CS23.1311 and CS23.1549 at Amdt 3

Powerplant System Indications

Introductory Note

The hereby presented Equivalent Safety Finding has been classified as an important Equivalent Safety Finding and as such shall be subject to public consultation, in accordance with EASA Management Board Decision 12/2007 dated 11 September 2007, Article 3 (2.), which states:

"*2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency.*"

Statement of Issue

The primary engine displays on turbine engine powered aircraft have traditionally displayed the required engine rotor speeds, oil temperature, oil pressure, EGT and fuel flow required by CS 23.1305 in an analog-only or an analog and digital format. Standby Engine Indicators (SEIs), when provided, have typically displayed these parameters in either analog-only or digital-only format. An increasing demand to conserve primary display space has led to digital-only primary displays for various engine parameters including those rotor speeds not normally used for power setting. This situation may result in a small, cluttered, low-resolution primary display.

EASA generally considers that digital-only displays are less effective than conventional analog displays at providing the flightcrew with discernible indication of the parameter during a rapid transient, and quick intuitive indication of the parameters approximate level, direction and rate of change, proximity to limits, and relationship to other parameters on the same engine or the same parameter on other engines. Normally it is found that "digital indicators are most valuable when integrated with an analog display."

While many of the referenced rules do not require an analog format, CS 23.1549 requires instrument markings which presumes an analog type display format. Therefore, EASA considers that features of the digital format must at least provide a level of safety equivalent to that intended by compliance with CS 23.1549 and CS23.1311.

Some of the relevant requirements, such as the “redline” limit marking requirements of CS 23.1549, presume the flightcrew has the primary responsibility for assuring continued safe engine operation (e.g. operation within the safe operating limits). With the advent of full authority digital engine controls (FADEC), the primary means of assuring operation within some engine safe operating limits has been taken over by automated protection features within these engine controls. Hence the FADEC may provide compensating features that EASA can consider when determining whether or not a digital-only display can provide an equivalent level of safety.

For example, if the applicant demonstrates and EASA finds that the FADEC will prevent exceedance of an engine operating limit, then the flightcrew would no longer need to be the primary means of doing so. This diminishes the need for flightcrew awareness of proximity to the limit value, which is normally provided by redline markings required by CS23.1549. The design should still provide a means for flightcrew awareness, to the extent practicable, via markings, placards and/or at least

airplane flight manual (AFM) information and training. In case the FADEC fails to keep engine operating limits, the design must still make the flightcrew aware of that condition via appropriate flightcrew alerting features (e.g. background or digital color changes, flashing display, aurals, associated messaging, procedures, etc.). Such modern alerting may even be found superior to the colored “arc” or background type markings required by CS 23.1549.

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The Applicant must demonstrate compliance with, or demonstrate compensating factors that provide an equivalent level of safety to, the marking requirements of CS 23.1549 and CS 23.1311. When an applicant proposes a digital-only format for primary display of any rotor speed, oil temperature, oil pressure or fuel flow parameter required by CS 23.1305, EASA will review the visibility, relative location, criticality, and functionality of this display. The design must effectively and safely compensate for any of the explicit or implicit benefits of a traditional analog display . Lastly, the applicant must show that the availability of the display is commensurate with its criticality. However, since this aspect is not unique to the digital-only format it will not be discussed further here.
Applicant shall demonstrate that, given the noted shortcomings of a digital-only display format, the proposed digital-only high-pressure turbine speed (N2), engine oil temperature, oil pressure and fuel flow displays on the Model airplane still meets or provide an equivalent level of safety with all applicable regulations including:

1. Verify the engine instrument design supports compliance with CRI F-51 (Equipment, systems and installations) to collectively limit the acceptable effects of foreseeable failures and malfunctions, whenever flightcrew awareness and possibly intervention are required.
2. Verify the engine instrument design supports compliance with CRI B-152 (Human Factors) to collectively limit the acceptable effects of foreseeable failures and malfunctions, whenever flightcrew awareness and possibly intervention are required.
3. CS 23.903(b)(2) requires the engine control devices, systems, and instrumentation must be designed to provide reasonable assurance that those engine operating limitations that adversely affect turbine rotor structural integrity will not be exceeded in service.
4. The design must be shown to effectively provide any intended functions, including those related to flight manual procedures, normal engine monitoring functions, and failure intervention. CS 23.1309(b) requires that the displays “perform their intended functions under any foreseeable operating condition.”
5. Since a digital only display provides meager cues of the trend and proximity to limits, the applicant must identify supplemental compensating design features to assure flightcrew awareness prior to a limit (redline) being reached if flightcrew intervention is required. 23.1309(b)(3) requires that “warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action;” and “monitoring and warning means must be designed to minimize crew errors which could create additional hazards”. The CS-E engine type certificate, supplemented by the CS 23 type certificate as required, will establish appropriate limits for some engine parameters such as rotor speed, oil pressure, and oil temperature. The engine installation manual may also identify a “precautionary range” for these parameters. CS 23.1549 restricts how this warning (limit/redline) and caution (precautionary/yellow band) information can be presented. Therefore, in complying with CS 23.1309(b) and 23.1549, even if the engine installation manual does not specify a “precautionary range,” Applicant should implement a yellow precautionary range or equivalent that would enable a timely and effective flightcrew intervention to prevent any foreseeable gradual limit exceedance.

6. CS 23.1321(a) requires that “Each flight, navigation and powerplant instrument for use by any required pilot during take-off, initial climb, final approach, and landing must be located so that any pilot seated at the controls can monitor the aeroplane’s flight path and these instruments with minimum head and eye movement.” Applicant should specifically show this for all intended safety-related display functions.
7. Applicant should reference CS 23.1322 to show an ELOS to compliance with the sections of CS 23.1549 that pertain to alerting.°CS 23.1322 provides standards addressing alerting definitions, prioritization, color requirements, and performance for flightcrew alerting. This rule updates, consolidates and standardizes regulations for warning, caution, and advisory alerting systems.
8. CS 23.1549 restricts how required powerplant instruments may indicate the safe operating limits, normal operating range, and takeoff and precautionary ranges. The intent of these requirements is more difficult to meet with a digital-only display and typically require a finding of equivalent safety. EASA has accepted the following as meeting the intent of, and hence providing a level of safety equivalent to, compliance with certain of these requirements:

a) Lack of limit “redline” type markings may be effectively compensated for by autonomous engine controls which employ sufficiently reliable and effective "topping loops" that act in place of the flightcrew to prevent a limit exceedance under any foreseeable operating and environmental conditions

b) Lack of range “arc” type markings may be effectively compensated for by display digits/background that change color based on the range in which the parameter is currently operating.

The applicant current practice for powerplant system indications is to have colored coding of the normal, precautionary and exceedance values/ranges, combined with CAS messages and aural alerts when engine parameters are beyond limit.

To support the Equivalent Safety Finding, the applicant presented the following comments:

- the applicant verifies the engine instrument design and demonstrates compliance with CRI F-51 & CRI B-152.

- The engine parameters are sensed by the engine-mounted sensors and transmitted to the UMS and FADEC. The operating limits of engine parameters such as N1/N2 rotor speeds, ITT, oil pressure and oil temperature are also monitored by the FADEC.

- The normal range/exceedance information is transmitted from the FADEC to the APEX avionics, triggering green, amber or red colors on display, as well as CAS messages and aural alerts (chimes).

- The crew is then alerted to abnormal engine operating conditions, thereby being able to take corrective action(s) and avoid overstressing the engine. This implementation reduces the crew workload by relieving them from monitoring those parameters, and aids in minimizing crew errors.

- The fuel flow has no operating limits and, therefore, its value is displayed as white numeral, with no colour changes to amber or red, no CAS messages and no aural alerts.

- The flight deck has been developed in compliance with the own Flight Deck Philosophy Document, which includes anthropometric requirements. Compliance with the CS 23.1321(a) has been shown through HF evaluations in ground/flight tests as presented in Human Factors Certification Programme report.

In conclusion, the applicant believes that the engine system indications implemented, are equal or superior to analogue displays compliant with the marking requirements of CS 23.1549. The color coding of the normal, precautionary and exceedance values/ranges, combined with CAS messages and aural alerts improve the level of safety by alerting the pilot sooner than if the pilot relied on an instrument panel scan.

In addition, due to the automated engine protections assured by the FADEC, the level of safety compared to an all analogue format is further improved as a result of pilot workload reduction, especially in single pilot operations, and in presence of failures.