# Proposed Equivalent Safety Finding to CS 23.1305, 23.1311, 23.1321 and 23.1549: Powerplant instruments

## Introductory note:

The hereby presented Equivalent Safety Finding (ESF) to the EASA Certification Basis shall be subject to public consultation, in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) of 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

On the Primary Garmin 3000 display, the powerplant indication of gas generator speed (NG) and fuel flow are in a digital reading alphanumeric-only format. Use of a digital reading alphanumeric-only presentation of powerplant 'indicators' required by §23.1305 and §23.1549 requires an Equivalent Safety Finding.

The digital-only presentation of the gas generator speed (NG) and fuel flow might unacceptably limit the flight crew's ability to properly monitor and operate the engines.
The primary engine displays on turbine engine powered aircraft have traditionally displayed the required engine rotor speeds, ITT and fuel flow required by FAR(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 flight crew 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, FAR(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 FAR(CS) 23.1549 and FAR(CS) 23.1311.

Some of the relevant requirements, such as the "redline" limit marking requirements of FAR(CS) 23.1549, presume the flight crew has the primary responsibility for assuring continued safe engine operation (e.g. operation within the safe operating limits).

## EASA Safety Equivalency Demonstration proposal

Aircraft Industries must demonstrate compliance with, or demonstrate compensating factors that provide an equivalent level of safety to, the marking requirements of FAR(CS) 23.1549 and FAR(CS) 23.1311. When an applicant proposes a digital-only format for primary display of any rotor speed, or fuel flow parameter required by FAR(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, Aircraft Industries 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.

Aircraft Industries shall demonstrate that, given the noted shortcomings of a digital-only display format, the proposed digital-only fuel flow displays on the Model L-410NG airplane still meets or provide an equivalent level of safety with all applicable regulations including:

1. Verify the engine instrument design supports compliance with FAR(CS) 23.1309 to collectively limit the acceptable effects of foreseeable failures and malfunctions, whenever flight crew awareness and possibly intervention are required.

2. Verify the engine instrument design supports addresses all Human Factors to collectively limit the acceptable effects of foreseeable failures and malfunctions, whenever flight crew awareness and possibly intervention are required.

3. FAR(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. FAR(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, Aircraft Industries must identify supplemental compensating design features to assure flight crew awareness prior to a limit (redline) being reached if flight crew 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 FAR(CS) 23 type certificate as required, will establish appropriate limits for engine parameters. The engine installation manual may also identify a "precautionary range" for these parameters. FAR(CS) 23.1549 restricts how this warning (limit/redline) and caution (precautionary/yellow band) information can be presented. Therefore, in complying with FAR(CS) 23.1309(b) and 23.1549, even if the engine installation manual does not specify a "precautionary range," Aircraft Industries should implement a yellow precautionary range or equivalent that would enable a timely and effective flight crew intervention to prevent any foreseeable gradual limit exceedance.

6. FAR(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.” Aircraft Industries should specifically show this for all intended safety-related display functions.

7. For digital reading alphanumeric-only presentation of powerplant instrument indications, which require trend or rate-of-change information, an ESF must be requested. Aircraft Industries must provide an applicant’s position for this CRI, which includes a description of the digital reading alphanumeric-only powerplant indications, compensating features that will allow the granting of the ESF along with a detailed explanation of how the features provide equivalent safety to literal compliance with the applicable §23.1305 and §23.1549 requirements. Any digital reading alphanumeric-only powerplant indication should meet the criteria established in Advisory Circular 23.1311-1C, paragraph 9.4.c and be shown compliant with the applicable requirements of §23.1311 and §23.1321.

Aircraft Industries should reference FAR(CS) 23.1322 to show an ESF to be compliant with the sections of FAR(CS) 23.1549 that pertain to alerting.

FAR(CS) 23.1322 provides standards addressing alerting definitions, prioritization, colour requirements, and performance for flight crew alerting. This rule updates, consolidates and standardizes regulations for warning, caution, and advisory alerting systems.

8. FAR(CS) 23.1549 restricts how required powerplant instruments may indicate the safe operating limits, normal operating range, and take-off 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 flight crew 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 colour based on the range in which the parameter is currently operating.

The objective is to obtain a design with a minimum number of significant latent failures.
Each significant latent failure will be highlighted in the system safety assessment,
subject to review by the Authorities.

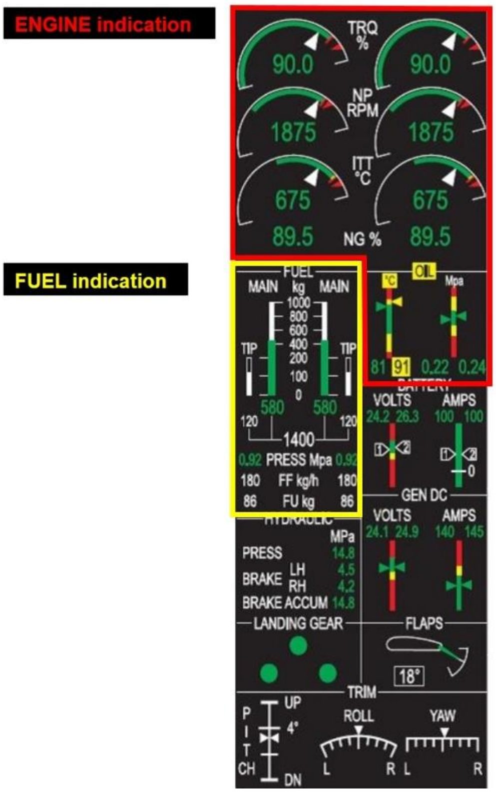
**<u>Description of compensating features, which allow the granting of the ESF:</u>**

All the engine parameters primary indications including gas generators speed (NG) and fuel flow indications are displayed on multifunction display (MFD) located on the central instrument panel of the flight deck.

The engine parameters can be also displayed on dedicated window of PFD. The indicators are sufficiently visible to the pilot and co-pilot. Any negative effect of vibrations was not observed.

On secondary page of EIS, which can be displayed on either MFD or PFD, the NG together with all other engine parameters are displayed in the way of conventional gage with scale and pointer accompanied with alphanumeric presentation.

**Primary EIS indication on the MFD or on the PFD in reverse mode**




**Secondary EIS indication on the MFD or PFD**


On the primary EIS indicator, where the NG are displayed in only alphanumeric format, the gas generators speed trend can be derived from analog torque indicators and ITT indicators located on EIS just above the NG indications since both torque and ITT are related to gas generator speed. For ground engine starting and in flight starting the use of secondary EIS page with full information about engine parameters is recommended in AFM.

There is a color change of alphanumeric indication when gas generator approaches to its limiting values. There is a caution range in which the alphanumeric indication is provided by yellow color and over-speed range in which the alphanumeric indication is done by red color. Furthermore in case of the gas generator speed limit overrun the CAS notification is displayed on the MFD similarly as in case of other engine parameters exceeding.

The engine power setting is carried out by means of torque primarily since the torque and propeller speed gives the engine power or power unit thrust respectively, which is important for flight symmetry. The gas generator speed of each engine may differ at the same torque setting depending on engine production tolerances and accumulated hours.
The gas generator speed digital indication forewarning is ensured by color indication similarly as used for analog indicator.

The fuel flow is considered as informative, noncritical parameter, with no strict limits defined. Therefore, a digital alphanumeric-only format without any caution range, forewarning etc. is believed as adequate for fuel flow indication.
Since the fuel flow is proportional to the engine power i.e. torque the fuel flow trend copies the torque trend.

Beside this, if considering the engine production tolerances and accumulated hours the actual fuel flow of each engine similarly as gas generator speed may differ at the same torque setting.

**Explanation of how features provide equivalent safety:**

Engine overspeed protection:
In the normal FCU operation, the gas generator speed is limited by the value of 101.5 %, which is set by means of the hard stop on the FCU.

Concerning the FCU failures, following four FCU failure modes are identified in the FCU FMEA resulting to the FCU setting to the maximum fuel supply.

These failures are:
1) Failure of FCU drive shaft
2) Jamming of drive shaft bearings
3) Jamming of FCU knife valve
4) Failure of the membrane of pressure governor

All these failure modes are extremely remote with failure probability 5.9x10-8.

The overspeed effect of first three failure modes can be rectified by retarding the power control lever to a lower fuel supply. In case of the forth failure mode, the function of the FCU speed governor is maintained and the FCU fuel supply will be reduced by engagement of the speed governor.

Besides, a switching to emergency fuel control circuit is possible. According to AFM:
The emergency fuel control circuit is used for the engine control in case of normal fuel control system failure which is indicated by NG hang-up, or a spontaneous increase in NG or a spontaneous drop of engine power, when the engine does not respond to movements of the TCL, or responds abnormally.

Engaging the emergency fuel control circuit (according to AFM):

TCL ...................................................................... ………………IDLE
Fuel stop cock/Emergency throttle lever .................... ………………Check OPEN position
ISOL. VALVE circuit breaker……………………………………………ON
ISOLATION VALVE amber cell on the CWD of the affected engine…Check ON
Fuel stop cock/Emergency throttle lever…….Move slowly forward from OPEN position to emergency circuit area to set minimum $N_G$
Set required power rating by slow displacement (min. 6 sec) of the FUEL STOP COCK / EMERGENCY THROTTLE LEVER in the range from OPEN position to MAX. POWER position.