Federal Aviation Administration

Memorandum

Date: June 13, 2008

To: Manager, Small Airplane Directorate, ACE-100

From: Manager, Project Support Branch, ACE-112

Prepared by: Peter L. Rouse, Aerospace Engineer, Regulations & Policy, ACE-111

Subject: Equivalent Level of Safety (ELOS) to §§ 23.1305, 23.1309, 23.1321 and 23.1549; Embraer S.A., EMB 500; Finding No. ACE-08-10

This memorandum requests your office to review and provide concurrence with the proposed finding of equivalent level of safety (ELOS) for the digital-only display of high-pressure rotor speed (N2), to the display requirements of 14 CFR, part 23, §§ 23.1305, 23.1309, 23.1321 and 25.1549.

BACKGROUND:

The Embraer S.A. Model EMB-500 is a normal category, low-winged monoplane with "T" tailed vertical and horizontal stabilizers, retractable tricycle type landing gear and twin turbofan engines mounted on the aircraft fuselage. Its design characteristics include a predominance of metallic construction. The maximum takeoff weight is 9,965 pounds, the VMO/MMO is 275 KIAS/M 0.70 and maximum altitude is 41,000 feet.

The primary engine displays on turbine powered aircraft have traditionally displayed the engine rotor speed required by § 23.1305(c)(5), in an analog-only or an analog and digital format. Standby engine indicators (SEI), 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 those rotor speeds not normally used for power setting. This situation may result in a small cluttered, low-resolution primary display. In addition, it is generally accepted that digital-only displays are often less effective than conventional analog displays at providing the 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 engine. This is why Federal Aviation Administration (FAA) AC 20-88A, paragraph 4(c), states that: "digital indicators are most valuable when integrated with an analog display".

Embraer S.A. requests the FAA to give them credit for the digital-only display of N2 by accepting it as equivalent to the display requirements of 14 CFR, part 23, §§ 23.1305, 23.1309, 23.1321 and 25.1549.

APPLICABLE REGULATIONS:

14 CFR, part 23, §§ 23.1305, 23.1309, 23.1321 and 25.1549.

REGULATIONS REQUIRING AN ELOS:

In general, if the primary display of any rotor speed required by 14 CFR part 23, § 23.1305(c)(5), is being proposed in a digital-only format, then the visibility, relative location, criticality, and functionality of this display will be stringently reviewed during certification to assure that the proposed design does not require any of the explicit, or implicit benefits of a traditional analog display.

Consequently, it must be clearly demonstrated that the proposed Embraer EMB-500 digital-only N2 display still meets the intent of all applicable 14 CFR part 23 regulations, including:

- 14 CFR part 23, § 23.1309(b)(1): This rule requires that the displays "perform its intended function under any foreseeable operating condition". Therefore, 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.
- 14 CFR part 23, § 23.1309(b)(2): This rule limits the acceptable effects of foreseeable failures and malfunctions. Where compliance with these regulations is reliant on the effective use of the subject rotor speed display, then that assumed capability must be verified.
- 14 CFR part 23, § 23.1309(b)(3): This rule 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 that could create additional hazards". The 14 CFR part 33 approved engine type certificate, supplemented by the 14 CFR part 23 type certificate as required, will establish rotor speed limits. The engine installation manual may also identify a "precautionary range". The 14 CFR part 23, § 23.1549 restricts how this warning (limit/redline) and caution (precautionary/yellow band) information can be presented. Given the meager trend and proximity to limits information provided by a digital-only display, supplemental compensating features must be identified that will assure crew awareness prior to a limit (redline) being reached if crew intervention is required. Therefore, in complying with this rule and 14 CFR part 23, § 23.1549, even if a "precautionary range" is not specified in the engine installation manual, a yellow precautionary range or equivalent should be implemented that would enable the crew to effectively intervene and prevent any foreseeable gradual engine overspeed.
- 14 CFR part 23, § 23.1321(a): Each flight, navigation, and powerplant instrument for use by any required pilot during takeoff, initial climb, final approach, and landing must be

- located so that any pilot seated at the controls can monitor the airplane's flight path and these instruments with minimum head and eye movement.
- 14 CFR part 23, § 23.1549: This rule 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. However, it has been accepted the following as meeting the intent of these requirements:

    1. A visible placard, stating the operating limits of the subject parameter, located is such that it is clearly associated with that parameter; and
    2. Display digits/background that change color based on the range in which the parameter is currently operating.

In considering the current design, the applicant has requested an ELOS for the digital-only display of N2 that the FAA has determined that an appropriate level of safety can be provided by the issuance of an ELOS, in accordance with the provisions of 14 CFR, part 21, § 21.21(b)(1).

DESCRIPTION OF COMPENSATING FEATURES:

The design provides a digital-only display of N2 that displays the appropriate color commensurate with operations in the normal, precautionary and exceedance range. Additionally, the following mitigations also contribute to the equivalent level of safety of the digital-only display of N2:

- N2 is not used in the thrust setting process.
- Engine starting and fuel-on selection is automatic.
- Automatic FADEC monitoring of N2 to prevent limit exceedance.
- High Rotor Overspeed Protection.
- Verification of N2 condition.

EXPLANATION OF COMPENSATING FEATURES:

1. N2 is not used in the thrust setting process.

    The primary thrust setting parameter is fan speed (N1). The engine control system (one dual channel FADEC per engine) sets the fan speed (N1) (and the associated engine thrust) for given ambient/operating conditions and built-in corrected fan speed look-up tables. The selected fan speed is requested by the FADEC through metered fuel supply to the engine single spool gas generator. The gas generator spool speed (N2) will vary as required by closed loop control to maintain the selected fan speed. Therefore, the

information about level, direction and rate of change of a parameter, typically provided by analog displays, is not applicable in the thrust setting process.

2. Engine starting and fuel-on selection is automatic.

   Fuel-on selection during engine starts is automatically commanded by the FADEC, ensuring consistent engine start procedures. All engine control parameters that are relevant for engine starting such as fuel flow rate, turbine temperature and compressor bleed schedules are set and limited as required by the FADEC. During the engine start procedure the crew will monitor the high-pressure rotor speed but this is simply to detect engine abnormalities during the start sequence (hung start). There is no requirement for the crew to monitor the high-pressure rotor speed indication to detect the appropriate fuel-on selection conditions (as would have previously been required on past installations equipped with hydromechanical fuel controls) since this is automatically commanded by the FADEC.

   Crew visual monitoring of N2 to prevent limit exceedance is not practical or effective.

   During high thrust operation (take-off, climb, cruise), when exceeding the gas generator speed limit could be considered to be more probable, the typical observed values of N2 are within 10 percent of the redline, which makes visual detection of proximity to limits impractical.

   Hence, even with expanded scales at the high end close to the speed limit, analog indication of a parameter that maintains such proximity to the redline does not lead to continuous effective monitoring by the crew.

3. Automatic FADEC monitoring of N2 to prevent limit exceedance.

   The most probable scenario for an N2 overspeed would be a rapid rate event and even with active limit exceedance (such as flashing red display), crew intervention before the threshold is reached is highly unlikely due to the required recognition-reaction time.

   Continuous monitoring of N2 by the FADEC ensures a prompt fuel flow cutback if the FADEC software governor limit is reached. If, for any reason, the N2 speed is allowed to reach or exceed either amber (steady state limit) or redline limit (transient limit), the N2 digital indication for the affected engine will be changed accordingly: digital indication will be boxed amber/red, the digits will be amber/red and the amber/red box will flash, thus providing active limit exceedance information to the crew.

4. High Rotor Overspeed Protection.

   In addition to the N2 speed limit protection provided by the FADEC software, the engine will be certified on Part 33 to meet high rotor overspeed protection. The PW617 High Pressure Turbine is designed to reach blade melting in case an overspeed event occurs limiting rotor speed to a safe value. Consequently, there is no need to take credit of crew

recognition-reaction time for either preventive or corrective action for this particular failure mode.

5. Verification of N2 condition.

   Cross comparison of N2 values between the two engines and verification that N2 is in the expected range can effectively be performed by the crew with digital-only N2 indication. The crew usually performs these tasks as routine actions, when cockpit workload permits."

ACE-112 RECOMMENDATION:

The Project Support Branch, ACE-112, Small Airplane Directorate concurs with the Embraer S.A. that the digital-only display of N2 provides an ELOS to the display requirements of 14 CFR, part 23, §§ 23.1305, 23.1309, 23.1321 and 25.1549.

RECOMMENDATION:

The Small Airplane Directorate concurs with and grants ELOS ACE-08-10 for the Embraer S.A. Model EMB-500.

Concurred by:

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Manager, Project Support Branch, ACE-112	Date
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Manager, Standards Office, ACE-110	Date
David R. Showers for	*6-13-08*
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