Federal Aviation Administration

Memorandum

Date: July 25, 2016

To: Manager, Military Certification Office, ACE-100M

From: Manager, Transport Airplane Directorate, ANM-100

Prepared by: Bob Klein, ACE-100M

Subject: INFORMATION: Equivalent Level of Safety (ELOS) Finding for Vibration/Buffeting Compliance Criteria, Radome installed on a Boeing Model 737-700 airplane, FAA Project # ST00376MC-T

ELOS Memo #: ST00376MC-T-F-1

Regulatory Ref: §§ 25.251(b) Amendment 25-77

This memorandum informs the certificate management aircraft certification office of an evaluation made by the Transport Airplane Directorate (TAD) on the establishment of an equivalent level of safety (ELOS) finding for the Model 737-700 airplane.

Background

Section 25.251(b) requires "each part of the airplane must be **demonstrated in flight** to be free from excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}." Therefore, a flight demonstration out to V_{DF}/M_{DF} is required to demonstrate compliance with the rule. When external modifications are made to an existing type design, compliance with § 25.251(b) must be addressed. The applicant requests the use of an ELOS finding to show by means other than flight testing that the installation of this upper fuselage mounted radome would not cause excessive vibration under any appropriate speed and power conditions up to V_{DF}/M_{DF}. The FAA determined that if the applicant can show an acceptable method that the original compliance finding for this rule remains valid (i.e., no vibration/buffet issues exist due to the change), an ELOS has been shown. However, if the original certification for this rule does not remain valid due to potential effects of the external modification, the applicant must re-demonstrate direct compliance with the rule.

Applicable regulation(s)

Regulation(s) requiring an ELOS finding

§§ 25.251(b) Amendment 25-77

Description of compensating design features or alternative standards which allow the granting of the ELOS finding (including design changes, limitations or equipment need for equivalency)

For an external modification to an existing approved design, such as the one proposed, the applicant must do an evaluation to determine whether or not the modification could affect compliance with § 25.251(b). If so, then the applicant must re-demonstrate compliance, and the only means for accomplishing this is by an in-flight demonstration at speeds up to V_{DF}/M_{DF}.

The FAA considers that the extent of the airplane modifications proposed by the applicant, particularly the size and location of the antenna with respect to the unmodified airplane, may cause significant changes in the aerodynamic flow field around the airplane at high speed, which may lead to excessive vibration. Potential vibration sources include unsteady flow conditions on the antenna, fuselage, tail assembly, or control surfaces arising from shocks, flow separation or other unsteadiness in the flow. Because of these potential effects, the FAA determined that the original demonstration of compliance for § 25.251(b) may not be valid for the modified airplanes. Therefore, unless the applicant can show that the modification would not affect the original § 25.251(b) compliance demonstration, the applicant must re-demonstrate compliance by flight testing at speeds up to V_{DF}/M_{DF}.

Currently, there are no valid analytical methods of substantiating that there is no excessive vibration at V_{DF}/M_{DF} other than flight testing to V_{DF}/M_{DF}. Analysis tools may be helpful, however, in determining whether a given modification may affect the original § 25.251(b) compliance finding.

To evaluate whether the modification could affect the original compliance finding, the applicant may propose to use any suitable combination of the following:

1. Similarity to other approved designs. (Consider the size, shape, and location of the respective modification, the airplanes they are installed on, the respective V_{DF}/M_{DF} speeds, and the method of compliance used for the approved designs.)
2. Flowfield analysis using an acceptable computational fluid dynamics tool. The applicant must show that the tool is valid for its intended use. For example, the tool must be capable of accurately assessing whether a shock is present, including its strength and location, and the area of separated flow. Generally, a full Navier-Stokes code with robust turbulence modeling is needed for such an analysis. Validation using flight test data is preferred, but suitable wind tunnel data may be acceptable. The applicant should also address other known limitations and characteristics of the code to be used, such as:
    a. Grid sizes and spacing.
    b. Geometric fidelity of the airplane model – the effect of simplifications of the model (e.g., ignoring flap track fairings, vortex generators, small gaps, etc., how

the engines are modeled, aeroelastic effects, other differences between the actual airplane and the digital model used in the analysis).

c. CFD modeling errors, particularly in turbulence modeling.
d. Location of the trip point from laminar to turbulent flow.
e. Boundary conditions (e.g., ensuring that far field conditions are applied sufficiently far away).

3. A vibration analysis, usually based on the results of the flowfield analysis addressed in (2).
4. Flight testing to a speed from which the analyses described in this paragraph can be used to extrapolate the findings to V_{DF}/M_{DF}. As a minimum, flight testing must be conducted to at least V_{MO}/M_{MO}.

CFD Code Validation

To use a CFD tool in showing that the modification does not affect compliance with § 25.251(b), the tool, the applicant should show that the tool is valid for its intended use. The CFD tool needs to be capable of accurately assessing whether a shock is present, including its strength and location, and the area of separated flow. Generally, a full Navier-Stokes code with robust turbulence modeling is needed for such an analysis. Validation using flight test data is preferred, but suitable wind tunnel data may be acceptable.

Code validation includes:

- Showing that the code accurately models flow phenomena of interest (e.g. transonic shocks, shock induced flow separation, shock-boundary layer interaction and separated flows) that may result from the modification.
- Showing that the person/organization performing the analysis is experienced and qualified to properly run the code and interpret the results.

The applicant should demonstrate accuracy of the modeling of the flow field phenomena of interest by comparing flow field characteristics (e.g., pressure distributions, shock strength/location, etc.) predicted by the model to flight test or wind tunnel data for a configuration (including shape, location, and airframe) similar to the modification being evaluated at airspeeds up to V_{DF}/M_{DF}. In addition, if there are no significant flow field phenomena of interest (e.g. transonic shocks, shock induced flow separation, shock-boundary layer interaction and separated flows) shown with the configuration being evaluated, a comparison should be made to another configuration that does exhibit such phenomena. (Validation depends on the flow phenomena of interest being present to show that the code will accurately model such flow phenomena.) The applicant should address known limitations and characteristics of the model, such as grid sizes and spacing, geometric fidelity of the airplane model, turbulence modeling fidelity, boundary conditions, and strength and location of shocks/ recovery.

The FAA should agree in advance the test cases used to validate the code.

Aerodynamic Analysis

An aerodynamic analysis using the validated code may be used to show that compliance with § 25.251(b) will not be affected by the modification provided the FAA accepted the code validation.

The aerodynamic analysis need not cover all flight conditions. The critical flight conditions should be identified and those that need to be analyzed in detail selected. The applicant should document how these critical flight conditions have been identified.

The applicant should analyze the effects of all simplifications or assumptions applied to the aerodynamic model (i.e., the analytical representation of the modified and unmodified airplanes) and show that these simplifications would not lead to an inappropriate conclusion.

After FAA acceptance of both the code validation and the results of the aerodynamic analysis, it is not required to perform a flight test to V_{DF}/M_{DF} to show that the modification did not affect compliance with § 25.251(b). However, a flight test to V_{MO}/M_{MO} should be performed with a qualitative assessment that no buffeting condition exists up to that speed to show compliance with § 25.251(d).

Explanation of how design features or alternative standards provide an ELOS to that intended by the regulation

The compensating factor(s) raise the level of safety to that required by § 25.251(b) by using a combination of CFD analysis to V_{DF}/M_{DF} and flight verification to V_{MO}/M_{MO} for the Commercial Wideband System (CWS) radome. The antenna will be modeled in its correct location on the aircraft upper fuselage in order to capture any interaction between the wing and antenna. The CFD model will consist of the aircraft wing, wing-to-body fairing, empennage, fuselage and the CWS radome. The CWS radome and flow field will be modeled using the CFD software package AVUS, which solves the turbulent Navier-Stokes equations coupled with the Spalart-Allmaras turbulence model. The flow field downstream of the CWS radome will be determined acceptable when the CFD-determined wake recovery region ends forward of any airplane structure or other external modification. If the wake extends over an existing or new protuberance, then a dynamic structural response analysis will be performed to ensure that the structure does not respond to the wake.

FAA approval and documentation of the ELOS finding

The FAA has approved the aforementioned ELOS finding in project Issue Paper F-1, titled Vibration/Buffeting Compliance Criteria, Radome installed on 737-700. This memorandum provides standardized documentation of the ELOS finding that is non-proprietary and can be made available to the public. The TAD has assigned a unique ELOS memorandum number (see front page) to facilitate archiving and retrieval of this ELOS finding. This ELOS memorandum number should be listed in the Limitations and Conditions section of the supplemental type certificate (STC) in accordance with the statement below:

Equivalent Level of Safety Findings have been made for the following regulation(s):
§ 25.251(b) Vibration and buffeting.

ELOS Memo No. ST00376MC-T-F-1
(documented in TAD ELOS Memorandum ST00376MC-T-F-1)]

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Transport Airplane Directorate,
Aircraft Certification Service

Date

ELOS Originated by ACO: Military Certification Office	ACO Manager: Derek Morgan	Routing Symbol: ACE-100M