Proposed Special Condition for Installation of Flutter Suppression System

Applicable to Boeing B 747-8F/-8

Introductory note:

The hereby presented Special Condition to the EASA Certification Basis shall be subject to public consultation, in accordance with EASA Management Board decision 02/04 dated 30 March 2004, 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

The mandatory EASA airworthiness standards for the B747-8/-8F are determined as CS 25 Amendment 2, effective October 02, 2006.
The Boeing 747-8F aeroplane exhibits an aeroelastic mode of oscillation that is self-excited and does not completely damp out after an external disturbance. The sustained oscillation, also known as a limit cycle oscillation (LCO) or limit cycle flutter, exists for a limited set of fuselage payload and fuel combinations within the operational and design flight envelope of the aeroplane. The limit cycle flutter mode is primarily symmetric, manifesting itself as a 2.3 Hz sustained oscillation of the wings, engine pylons and fuselage.

It has been established that compliance with CS 25.251 and CS 25.629 can not be shown with this amount of LCO present. Boeing is therefore adding an Outboard Aileron Modal Suppression System (OAMS) to the fly-by-wire roll flight control system to reduce the amplitude of the sustained oscillation and to control the aeroelastic instability.

This would be the first time the use of an active flight control system to control flutter is approved on a commercial transport aeroplane. The OAMS system is considered to be a novel and unusual design feature that the existing airworthiness requirements do not adequately address. Therefore Boeing is requested to show compliance with the Special Condition C-18.

Boeing 747-8 / -8F – Special Condition C-18

- Installation of Flutter Suppression System -

Special Condition

In general, this Special Condition applies to fly-by-wire active flutter suppression systems that are intended to operate on a certain type of aeroelastic instability. This type of instability is characterized by a low frequency, self-excited, sustained oscillation of an aeroelastic vibration mode that is shown to be a stable limit cycle oscillation, with the system inoperative and operative. (An LCO is considered “stable” if it maintains the same frequency and amplitude for a

given excitation input and flight condition.) In addition, the type of sustained oscillation covered by this Special Condition cannot be a hazard to the aeroplane nor its occupants with the active system failed. These systems must be shown to reduce the amplitude of the sustained oscillation to acceptable levels and effectively control the aeroelastic instability.

More specifically, the following criteria address the existence of such sustained oscillation on the B747-8F aeroplane and the Outboard Aileron Modal Suppression System (OAMS) that will be used to control it.

In lieu of the requirements contained in CS 25.629, the existence of a sustained, or limit cycle, oscillation that is controlled by an active flight control system is acceptable, provided that the following requirements are met:

1) OAMS System Inoperative:

The sustained, or limit cycle, oscillation must be shown by test and analysis to be stable throughout the nominal aeroelastic stability envelope specified in CS 25.629(b)(1) and throughout the flight envelope with the OAMS system inoperative. This should include the consideration of disturbances above the sustained amplitude of oscillation.

2) Nominal Conditions:

a) With the OAMS system operative it must be shown that the aeroplane remains safe, stable, and controllable throughout the nominal aeroelastic stability envelope specified in CS 25.629(b)(1) and throughout the flight envelope by providing adequate suppression of the aeroelastic modes being controlled. All applicable airworthiness and environmental requirements should continue to be complied with. Additionally, loads imposed on the aeroplane due to any amplitude of oscillation must be shown to have a negligible impact on structure and systems, including wear, fatigue and damage tolerance. The OAMS system must function properly in environments that may be encountered.

b) The applicant must establish by test and analysis that the OAMS system can be relied upon to control and limit the sustained amplitude of the oscillation to acceptable levels (per CS 25.251) and control the stability of the aeroelastic mode. This should include the consideration of disturbances above the sustained amplitude of oscillation, maneuvering flight, icing conditions, manufacturing variations, Master Minimum Equipment List (MMEL) items, spare engine carriage, engine removed or inoperative ferry flights, and wear, repairs, and modifications throughout the service life of the aeroplane by:

1) Analysis to the nominal aeroelastic stability envelope specified in CS 25.629(b)(1) and to the flight envelope, and

2) Flight flutter test to the Vdf/Mdf boundary. These tests must demonstrate that the aeroplane has a proper margin of damping for disturbances above the sustained amplitude of oscillation at all speed up to Vdf/Mdf, and that there is no large and rapid reduction in damping as Vdf/Mdf is approached.

c) The structural modes must have sufficient stability margins for any OAMS flight control system feedback loop at speeds up to the fail-safe aeroelastic stability envelope described in CS 25.629(b)(2).

3) Failures, Malfunctions, and Adverse Conditions:

a) For the OAMS system operative and failed, for any failure, or combination of failures, addressed by CS 25.629(d), CS 25.571, CS 25.631, CS 25.671, CS 25.672, CS 25.901(c) or CS 25.1309 that results in LCO, it must be established by test or analysis up to the aeroelastic stability envelope described in CS-25 Appendix K25.2(c)(2)(v) that the LCO:

1) is stable and decays to an acceptable limited amplitude once an external perturbing force is removed;

2) does not result in loads that would cause static, dynamic, or fatigue failure of structure during the expected exposure period;

3) does not result in repeated loads that would cause (due to wear) an additional failure during the expected exposure period that precludes safe flight and landing;

4) has, if necessary, sufficient indication of OAMS failure(s) and crew procedures to properly address the failure(s);

5) does not result in a vibration condition on the flight deck that is severe enough to interfere with control of the aeroplane, ability of the crew to read the flight instruments, performance of vital functions like reading and accomplishing checklist procedures, or to cause excessive fatigue to the crew;

6) does not result in adverse effects on the flight control system or on aeroplane stability, controllability, or handling characteristics (including aeroplane-pilot coupling (APC) per CS 25.143) that would prevent safe flight and landing; and
7) does not interfere with the flight crew’s ability to correctly distinguish vibration from buffeting associated with the recognition of stalls or high speed buffet.

b) The applicant must show those particular risks such as engine failure, uncontained engine or APU rotor burst, or other failures not shown to be extremely improbable, will not adversely or significantly change the aeroelastic stability characteristics of the aeroplane.

c) No MMEL dispatch is allowed with the OAMS system inoperative.