**NOTICE OF PROPOSED AMENDMENT (NPA) No 02/2005**
**DRAFT DECISION OF THE EXECUTIVE DIRECTOR OF THE AGENCY,**
**on certification specifications for large aeroplanes (CS-25)**

# Flight Load Validation

## Contents

This Notice of Proposed Amendment is made up of four different parts:

**A. Explanatory Note**
Describing the development process and explaining the contents of the proposal.

**B. Proposals**
The actual proposed amendments.

**C. Original JAA NPA 25C-343 proposals justification**
The proposals were already circulated for comments as a JAA NPA. This part contains the justification for the JAA NPA.

**D. JAA NPA 25C-343 Comment-Response Document**
This part summarizes the comments made on the JAA NPA and the responses to those comments.

# A. EXPLANATORY NOTE

## I. General

1. The purpose of this Notice of Proposed Amendment (NPA) is to propose changes to the certifications specifications for large aeroplanes (CS-25). The reason for this proposal is outlined further below. This measure is included in the Agency's 2004 Rulemaking programme.

2. The text of this NPA was developed by the ARAC Loads and Dynamics Harmonisation Working Group (LDHWG). It was adapted to the EASA regulatory context by the Agency. It is now submitted for consultation of all interested parties in accordance with Article 5(3) of the EASA rulemaking procedure[1].
The review of comments will be made by the Agency unless the comments are of such nature that they necessitate the establishment of a group.

## II. Consultation

3. Because the content of this NPA was already the subject of a full worldwide consultation, the transitional arrangements of article 15 of the EASA rulemaking procedure apply. They allow for a shorter consultation period of six weeks instead of the standard three months and also exempt from the requirement to produce a full Regulatory Impact Assessment.

4. To achieve optimal consultation, the Agency is publishing the draft decision on its internet site in order to reach its widest audience and collect the related comments.

Comments *(preferably in WORD format)* on this proposal may be forwarded (*by e-mail),* using the attached comment form, to:

**By e-mail:** **NPA@easa.eu.int**

**By correspondence:** Ms. Inge van Opzeeland
Postfach 10 12 53
D-50452 Köln, Germany
Tel: +49 221 89990 5008

Comments should be received by the Agency before **15 March 2005** and if received after this deadline they might not be treated. Comments may not be considered if the form provided for this purpose is not used.

## III. Comment response document

5. All comments received will be responded to and incorporated in a Comment Response Document (CRD). This will contain a list of all persons and/or organisations that have

[1] Decision of the Management Board concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material ("rulemaking procedure"), EASA MB/7/03, 27.6.2003.

provided comments. The CRD will be widely available ultimately before the Agency adopts its final decision.

## IV. Content of the draft Decision

6. The initial issue of CS-25 was based upon JAR-25 at amendment 16. During the transposition of airworthiness JARs into certification specifications the rulemaking activities under the JAA system were not stopped. In order to assure a smooth transition from JAA to EASA the Agency has committed itself to continue as much as possible of the JAA rulemaking activities. Therefore it has included most of it in its own rulemaking programme for 2004 and planning for 2005-2007. This NPA is a result of this commitment and a transposed version of the JAA NPA 25C-343 which was circulated for comments from 1st January 2003 till 1st March 2003, the proposed final rule being modified to take into account the conclusions of the JAA comment / response document provided under section D.

## B. PROPOSALS

The proposal for each paragraph is identified as follows: Text to be deleted is crossed out and new text is underlined, except for the completely new AMC No. 2 to CS 25.301(b).
"* * *" means that the text of that (sub-)paragraph is unchanged.

*The following amendments should be included in Decision No. 2003/2/RM of the Executive Director of the Agency of 17 October 2003:*

**BOOK 1** **CS 25**

**Proposal 1**

**To amend CS 25.301(b) to include references to AMC's No. 1 and No. 2 to CS 25.301(b):**

**CS 25.301 Loads**
(a) * * *
(b) Unless otherwise provided the specified air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the aeroplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. (See AMC No. 1 to CS 25.301(b).) Methods used to determine load intensities and distribution must be validated by flight load measurement unless the methods used for determining those loading conditions are shown to be reliable. (See AMC No. 2 to CS 25.301(b).)
(c) * * *

**BOOK 2** **CS 25**

**Proposal 2**

**To renumber the existing AMC 25.301(b) as AMC No. 1 to CS 25.301(b), and to delete subparagraph (b):**

**AMC No. 1 to CS 25.301(b)**
**Loads (Interpretative Material)**

~~(a)~~ The engine and its mounting structure are to be stressed to the loading cases for the aeroplane as a whole.
~~(b) Notwithstanding the advancements in analytical methods used in predicting loads on aeroplane structures, accurate prediction of loads on wing leading edge and trailing edge high lift devices continues to be a problem. It is, therefore, advisable to verify the loads on these surfaces by conducting flight loads surveys regardless of the level of confidence in the overall loads program.~~

**Proposal 3**

**To add a new AMC No. 2 to CS 25.301(b) to read as follows:**

**AMC No. 2 to CS 25.301(b)**
**Flight Load Validation (Interpretative Material)**

1. PURPOSE

This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the validation, by flight load measurements, of the methods used for determination of flight load intensities and distributions, for large aeroplanes.

2. RELATED CS PARAGRAPHS

CS 25.301(b) “Loads”
CS 25.459 “Special Devices”

3. BACKGROUND

(a) CS-25 stipulates a number of load conditions, such as flight loads, ground loads, pressurisation loads, inertia loads and engine/APU loads. CS 25.301 requires methods used to determine load intensities and distributions to be validated by flight load measurements unless the methods used for determining those loading conditions are shown to be reliable. Although this applies to all load conditions of CS-25, the scope of this AMC is limited to flight loads.

(b) The sizing of the structure of the aircraft generally involves a number of steps and requires detailed knowledge of air loads, mass, stiffness, damping, flight control system characteristics, etc. Each of these steps and items may involve its own validation. The scope of this AMC however is limited to validation of methods used for determination of loads intensities and distributions by flight load measurements.

(c) By reference to validation of “methods”, CS 25.301(b) and this AMC are intended to convey a validation of the complete package of elements involved in the accurate representation of loads, including input data and analytical process. The aim is to demonstrate that the complete package delivers reliable or conservative calculated loads for scenarios relevant to CS-25 flight loads requirements.

(d) Some measurements may complement (or sometimes even replace) the results from theoretical methods and models. Some flight loads development methods such as those used to develop buffeting loads have very little theoretical foundation, or are methods based directly on flight loads measurements extrapolated to represent limit conditions.

## 4. NEED FOR AND EXTENT OF FLIGHT LOAD MEASUREMENTS

### 4.1. *General*

(a) The need for and extent of the flight load measurements has to be discussed and agreed between the Agency and Applicant on a case by case basis. Such an assessment should be based on:

(i) a comparison of the design features of the aeroplane under investigation with previously developed (by the Applicant) and approved aeroplanes. New or significantly different design features should be identified and assessed.

(ii) the Applicant's previous experience in validating load intensities and distributions derived from analytical methods and/or wind tunnel tests. This experience should have been accumulated on previously developed (by the Applicant) and approved types and models of aeroplanes. The validation should have been by a flight load measurement program that was conducted by the Applicant and found acceptable to the Agency for showing compliance.

(iii) the sensitivity to parametric variation and continued applicability of the analytical methods and/or wind tunnel test data.

(b) Products requiring a new type certificate will in general require flight-test validation of flight loads methods unless the Applicant can demonstrate to the Agency that this is unnecessary.
If the configuration under investigation is a similar configuration and size as a previously developed and approved design, the use of analytical methods, such as computational fluid dynamics validated on wind tunnel test results and supported by previous load validation flight test experience, may be sufficient to determine flight loads without further flight test validation.

(c) Applicants who are making a change to a Type Certificated airplane, but who do not have access to the Type certification flight loads substantiation for that airplane, will be required to develop flight loads analyses, as necessary, to substantiate the change.
In general, the loads analyses will require validation and may require flight test loads measurements, as specified in this AMC.

(d) The Applicant is encouraged to submit supporting data or test plans for demonstrating the reliability of the flight loads methods early in the certification planning process.

### 4.2. *New or significantly different design features*.

Examples of new or significantly different design features include, but are not limited to:

- Wing mounted versus fuselage mounted engines;
- Two versus three or more engines;
- Low versus high wing;
- Conventional versus T-tail empennage;

- First use of significant sweep;
- Significant expansion of flight envelope;
- Addition of winglets;
- Significant modification of control surface configuration;
- Significant differences in airfoil shape, size (span, area);
- Significant changes in high lift configurations;
- Significant changes in power plant installation/configuration;
- Large change in the size of the aeroplane.

4.3. *Other considerations*

(a) Notwithstanding the similarity of the aeroplane or previous load validation flight test experience of the Applicant, the local loads on the following elements are typically unreliably predicted and may require a measurement during flight tests:

- Loads on high lift devices;
- Hinge moments on control surfaces;
- Loads on the empennage due to buffeting;
- Loads on any unusual device.

(b) For non-deterministic loading conditions, such as stall buffet, the applicant should compile a sufficient number of applicable flight loads measurements to develop a reliable method to predict the appropriate design load.

## 5. FLIGHT LOAD MEASUREMENTS

5.1. *Measurements.*

Flight load measurements (for example, through application of strain gauges, pressure belts, accelerometers) may include:

- Pressures / air loads /net shear, bending and torque on primary aerodynamic surfaces;
- Flight mechanics parameters necessary to correlate the analytical model with flight test results;
- High lift devices loads and positions;
- Primary control surface hinge moments and positions;
- Unsymmetric loads on the empennage (due to roll/yaw manoeuvres and buffeting);
- Local strains or response measurements in cases where load calculations or measurements are indeterminate or unreliable.

5.2. *Variation of parameters.*

The test points for the flight loads measurements should consider the variation of the main parameters affecting the loads under validation. Examples of these parameters include: load factor, speeds, altitude, c.g., weight, power settings (thrust, for wing mounted engines), fuel loading, speed brake settings, flap settings and gear conditions (up/down) within the design limits of the aeroplane. The range of variation of these parameters must be sufficient to allow the extrapolation to the design loads conditions. In general, the flight test conditions need not exceed approximately 80% of limit load.

5.3. *Conditions.*

In the conduct of flight load measurements, conditions used to obtain flight loads may include:

- Pitch manoeuvres including wind-up turns, pull-ups and push-downs (e.g. for wing and horizontal stabiliser manoeuvring loads);
- Stall entry or buffet onset boundary conditions (e.g. for horizontal stabiliser buffet loads);
- Yaw manoeuvres including rudder inputs and steady sideslips;
- Roll manoeuvres.

Some flight load conditions are difficult to validate by flight load measurements, simply because the required input (e.g. gust velocity) cannot be accurately controlled or generated. Therefore, these type of conditions need not be flight tested. Also, in general, failures, malfunctions or adverse conditions are not subject to flight tests for the purpose of flight loads validation.

5.4. *Load alleviation.*

When credit has been taken for an active load alleviation function by a particular control system, the effectiveness of this function should be demonstrated as far as practicable by an appropriate flight test program.

## 6. RESULTS OF FLIGHT LOAD MEASUREMENTS

6.1. *Comparison / Correlation.*

Flight loads are not directly measured, but are determined through correlation with measured strains, pressures or accelerations. The load intensities and distributions derived from flight testing should be compared with those obtained from analytical methods. The uncertainties in both the flight testing measurements and subsequent correlation should be carefully considered and compared with the inherent assumptions and capabilities of the process used in analytic derivation of flight loads. Since in most cases the flight test points are not the limit design load conditions, new analytical load cases need to be generated to match the actual flight test data points.

6.2. *Quality of measurements.*

Factors which can affect the uncertainty of flight loads resulting from calibrated strain gauges include the effects of temperature, structural non-linearities, establishment of flight/ground zero reference, and large local loads, such as those resulting from the propulsion system installation, landing gear, flap tracks or actuators. The static or dynamic nature of the loading can also affect both strain gauge and pressure measurements.

6.3. *Quality of correlation.*

A given correlation can provide a more or less reliable estimate of the actual loading condition depending on the "static" or "flexible dynamic" character of the loading action, or on the presence and level of large local loads. The quality of the achieved correlation

depends also on the skills and experience of the Applicant in the choice of strain gauge locations and conduct of the calibration test programme.

Useful guidance on the calibration and selection of strain gauge installations in aircraft structures for flight loads measurements can be found, but not exclusively, in the following references:

1. Skopinski, T.H., William S. Aiken, Jr., and Wilbur B. Huston,
"Calibration of Strain-Gage Installations in Aircraft Structures for Measurement of Flight Loads", NACA Report 1178, 1954.

2. Sigurd A. Nelson II, "Strain Gage Selection in Loads Equations Using a Genetic Algorithm", NASA Contractor Report 4597 (NASA-13445), October 1994.

6.4. *Outcome of comparison / correlation.*

Whatever the degree of correlation obtained, the Applicant is expected to be able to justify the elements of the correlation process, including the effects of extrapolation of the actual test conditions to the design load conditions.

If the correlation is poor, and especially if the analysis underpredicts the loads, then the Applicant should review and assess all of the components of the analysis, rather than applying blanket correction factors.

For example:
(a) If the level of discrepancy varies with the Mach number of the condition, then the Mach corrections need to be evaluated and amended.
(b) If conditions with speed brakes extended show poorer correlation than clean wing, then the speed brake aerodynamic derivatives and/or spanwise distribution need to be evaluated and amended.

## C. ORIGINAL JAA NPA 25C-343 PROPOSALS JUSTIFICATION

1. Explanatory note

The Aviation Rulemaking Advisory Committee (ARAC) was established in 1991, with the purpose of providing information, advice, and recommendations to be considered in rulemaking activities. The FAA and JAA are continuing to work toward the harmonisation of JAR-25 and FAR 25 by assigning ARAC specific tasks. One of the tasks assigned to the ARAC Loads and Dynamics Harmonisation Working Group (LDHWG) concerned the interpretative material for flight load measurements.

The LDHWG has now finished this task. The Working Group report has been sent to, and accepted by the ARAC Transport Airplanes and Engines Issues Group (TAEIG) in their June 2002 meeting. This NPA therefore contains the proposals necessary to achieve harmonisation of the interpretative material for flight load measurements by adopting the LDHWG (and TAEIG) agreed text.

2. Safety justification / explanation

The determination of load intensities and distributions is fundamental to the structural substantiation of any aeroplane. Validation of the methods to determine these load intensities and distribution therefore plays an important role in the assessment of the proposed means of compliance to the loads requirements of JAR-25.

In the past recent years, the JAA has raised several Certification Review Items (CRI's), when validating American products, on the subject of flight load validation. This highlighted a difference in interpretation between FAA and JAA on this subject. Historically the FAA has been more focused on the *methods* used to determine load intensities and distributions, whereas the JAA has been more focused on the flight load *measurements*. In addition, the FAA focused more on flight load measurements related to horizontal tail buffeting and high lift devices (ref. AC 25-22, section 25.699), whereas the JAA CRI's addressed the whole airplane.

The proposed new ACJ No. 2 to JAR 25.301(b) will provide guidance to Applicants on the subject of flight load validation such as to enhance consistent application of the applicable requirements and hence increase safety in general. The current ACJ 25.301(b) as per NPA 25C-312 will be renumbered as ACJ No. 1 to JAR 25.301(b). Subparagraph (b) of this ACJ 25.301(b) is proposed to be deleted, since it is adequately covered in the proposed ACJ No. 2 to JAR 25.301(b).

After review of the JAR-25 requirements related to this harmonisation activity, the LDHWG decided (and the JAA concurs) that the rule text of the existing FAR/JAR 25.301 and FAR/JAR 25.459 are adequate and necessary, so no amendments or deletions are proposed.

The LDHWG also decided (and the JAA concurs) to limit the scope of the proposed advisory material to validation of flight loads by flight load measurements, although the need to validate methods to determine other load conditions by other means is recognized. However, this was felt to be beyond the scope of the current tasking.

3. Cost / Safety Benefit Assessment

The proposals contained in this NPA are intended to achieve common interpretation related to flight load measurements, without reducing the safety provided by the regulations below the level that is acceptable to Authorities and Industry.
Harmonisation of JAR-25 and FAR 25 on this subject would yield cost savings by eliminating duplicate certification activities.

## D. JAA NPA 25G-334 COMMENT-RESPONSE DOCUMENT

1. Introduction

NPA 25C-343 was published for comment on January 1, 2003. This NPA is a result of a harmonisation activity between JAA and FAA.
For more details on the background of this NPA is referred to the NPA itself.

2. Comments & Responses

The following (five) organisations have commented on this NPA:
CAA/Czech Republic
Cessna/USA
DGAC/France
CAA/UK
Saab/Sweden

The first three commenters (CAA/Czech Republic, Cessna/USA, DGAC/France) either offered no comments or stated to support the NPA as published.

The comments from the last two commenters (CAA/UK, Saab/Sweden) are addressed as follows:

CAA/UK
*Comment:*
" Throughout the proposal the word "gauge" is spelt incorrectly as "gage". This should be corrected. Example of its incorrect spelling may be found in:

- Para 5.1 Measurements
- Para 6.2 Quality of measurements, first and last sentence
- Para 6.3 Quality of correlation, final sentence
- Reference introduction
- Reference 1 Title
- Reference 2 Title"

*Response:*
Comment accepted. The incorrect spelling ("gage") of the word "gauge" will be corrected (except for References 1 and 2, since the word "gage" appears in the (American) titles).

Saab/Sweden
*Comment:*
"ACJ's No. 1 and 2 to JAR 25.301(b) should be referenced in the requirement. It is therefore proposed to amend JAR 25.301(b) as follows:
2nd sentence: ... actual conditions. (See ACJ No. 1 to JAR 25.301(b)).
3rd sentence: ... to be reliable. (See ACJ No. 2 to JAR 25.301(b)).")
*Response:*
Comment accepted. The corresponding change(s) will be made to the NPA.

*Comment:*
"The following change to the 4th paragraph of section 2. SAFETY JUSTIFICATION / EXPLANATION is proposed:
After review ... existing FAR/JAR25.301, apart from a change regarding references to ACJ's in JAR 25.301(b), and FAR/JAR 25.459 ... are proposed beyond the aforementioned change of references."
*Response:*
Comment accepted. The corresponding change(s) will be made to the NPA.

*Comment:*
"In section 4. PROPOSALS it is proposed to add a Proposal 1 (and to renumber Proposals 1 and 2 as Proposals 2 and 3) as follows:
1. To amend JAR 25.301 as follows:
JAR 25.301 Loads
(a) ***
(b) (see proposal for change of references above)
(c) ***"
*Response:*
Comment accepted. The corresponding change(s) will be made to the NPA.

*Comment:*
"In Proposals 2 and 3 ("old" Proposals 1 and 2): Replace "ACJ No. X to 25.301(b)" by "ACJ No. X to JAR 25.301(b)" (4 times)"
*Response:*
Comment accepted. The corresponding change(s) will be made to the NPA.

*Comment:*
"Proposed changes to NPA No. 2 to JAR 25.301(b):
- section 4.3, 2nd item: - Hinge moments on control surfaces;
- sections 5 and 6: replace "strain gage" and "strain-gage" by "strain gauge" (at least 5 times)"
*Response:*
Comment accepted. The corresponding change(s) will be made to the NPA.