

Annex 3

Use of probability concept

1 General

1.1 Absolute safety cannot be achieved in any human activity. Naturally, this fact should be taken into account in developing safety requirements, which means that requirements should not imply that safety is absolute. In the case of traditional craft, it has frequently been possible to specify certain aspects of design or construction in some detail, in a way which was consistent with some level of risk which had over the years been intuitively accepted without having to be defined.

1.2 For high speed craft, however, it would often be too restrictive to include engineering specifications into the Code. Requirements therefore need to be written (where this question arises) in the sense of ". . .the Administration should be satisfied on the basis of tests, investigations and past experience that the probability of . . . is (acceptably low)". Since different undesirable events may be regarded as having different general orders of acceptable probability (e.g. temporary impairment of propulsion as compared with an uncontrollable fire), it is convenient to agree on a series of standardised expressions which can be used to convey the relative acceptable probabilities of various incidents, i.e. to perform a qualitative ranking process. A vocabulary is given below which is intended to ensure consistency between various requirements, where it is necessary to describe the level of risk which should not be exceeded.

2 Terms associated with probabilities

Different undesirable events may have different orders of acceptable probability. In connection with this, it is convenient to agree on standardised expressions to be used to convey the relatively acceptable probabilities of various occurrences, i.e. to perform a qualitative ranking process.

2.1 Occurrences

2.1.1 "Occurrence" is a condition involving a potential lowering of the level of safety.

2.1.2 "Failure" is an occurrence in which a part, or parts, of the craft fail or malfunction, e.g. runaway. A failure includes:

- .1 a single failure;
- .2 independent failures in combination within a system; and
- .3 independent failures in combinations involving more than one system, taking into account;
 - .1 any undetected failure that is already present;

.2 such further failures as would be reasonably expected to follow the failure under consideration; and

.4 common cause failure (failure of more than one component or system due to the same cause).

2.1.3 "Event" is an occurrence which has its origin outside the craft (e.g. waves).

2.1.4 "Error" is an occurrence arising as a result of incorrect action by the operating crew or maintenance personnel.

2.2 Probability of occurrences

2.2.1 "Frequent" is one which is likely to occur often during the operational life of a particular craft.

2.2.2 "Reasonably probable" is one which is unlikely to occur often but which may occur several times during the total operational life of a particular craft.

2.2.3 "Recurrent" is a term embracing the total range of frequent and reasonably probable.

2.2.4 "Remote" is one which is unlikely to occur to every craft but may occur to a few craft of a type over the total operational life of a number of craft of the same type.

2.2.5 "Extremely remote" is one which is unlikely to occur when considering the total operational life of a number of craft of the type, but nevertheless should be considered as being possible.

2.2.6 "Extremely improbable" is one which is so extremely remote that it should not be considered as possible to occur.

2.3 Effects

2.3.1 "Effect" is a situation arising as a result of an occurrence.

2.3.2 "Minor effect" is an effect which may arise from a failure, an event, or an error (as defined in 2.1.1, 2.1.2, 2.1.3 of this annex) which can be readily compensated for by the operating crew; it may involve:

.1 a small increase in the operational duties of the crew or in their difficulty in performing their duties; or

.2 a moderate degradation in handling characteristics; or

.3 slight modification of the permissible operating conditions.

2.3.3 "Major effect" is an effect which produces:

- .1 a significant increase in the operational duties of the crew or in their difficulty in performing their duties which by itself should not be outside the capability of a competent crew provided that another major effect does not occur at the same time; or,
- .2 significant degradation in handling characteristics; or
- .3 significant modification of the permissible operating conditions, but will not remove the capability to complete a safe journey without demanding more than normal skill on the part of the operating crew.

2.3.4 "Hazardous effect" is an effect which produces:

- .1 a dangerous increase in the operational duties of the crew or in their difficulty in performing their duties of such magnitude that they cannot reasonably be expected to cope with them and will probably require outside assistance; or
- .2 dangerous degradation of handling characteristics; or
- .3 dangerous degradation of the strength of the craft; or
- .4 marginal conditions for, or injury to, occupants; or
- .5 an essential need for outside rescue operations.

2.3.5 "Catastrophic effect" is an effect which results in the loss of the craft and/or in fatalities.

2.4 Safety Level

Safety level is a numerical value characterising the relationship between craft performance represented as horizontal single amplitude acceleration (g) and rate of acceleration (g/s) and the severity of acceleration-load effects on standing and sitting humans.

The safety levels and the corresponding severity of effects on passengers and safety criteria for craft performance should be as defined in Table 1.

3 Numerical values

Where numerical probabilities are used in assessing compliance with requirements using the terms similar to those given above, the following approximate values may be used as guidelines to assist in providing a common point of reference. The probabilities quoted should be on an hourly or per journey basis, depending on which is more appropriate to the assessment in question;

Frequent	More than 10^{-3}
Reasonably probable	10^{-3} to 10^{-5}

Remote	10^{-5} to 10^{-7}
Extremely remote	10^{-7} to 10^{-9}
Extremely improbable	Whilst no approximate numerical probability is given for this, the figures used should be substantially less than 10^{-10}

Note: Different occurrences may have different acceptable probabilities, according to the severity of their consequences (See Table 2).

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TABLE 1

EFFECT	CRITERIA NOT TO BE EXCEEDED		COMMENTS
	Type of load	Value	
LEVEL 1 MINOR EFFECT Moderate degradation of safety	Maximum acceleration measured horizontally ¹	0.20g ²	0.08g and 0.20g/s ³ : Elderly person will keep balance when holding. 0.15g and 0.20g/s : Mean person will keep balance when holding. 0.15g and 0.80g/s : Sitting person will start holding
LEVEL 2 MAJOR EFFECT Significant degrading of safety	Maximum acceleration measured horizontally	0.35g	0.25g and 2.0g/s: Maximum load for mean person keeping balance when holding. 0.45g and 10g/s : Mean person falls out of seat when not wearing seat belts.
LEVEL 3 HAZARDOUS EFFECT Major degradation of safety	Collision design load, based on vertical acceleration at centre of gravity	Ref. 4.3.3 Ref. 4.3.1	Risk of injury to passengers; safe emergency operation after collision. 1.0g: Degradation of passenger safety.
LEVEL 4 CATASTROPHIC EFFECT			Loss of craft or/and fatalities

1/ The recording instruments used should be such that acceleration accuracy is better than 5% of the real value and frequency response should be minimum 20 Hz. Antialiasing filters with maximum passband attenuation 100 + 5% should be used.

2/ g= gravity acceleration (9.81 m/s²).

3/ g-rate or jerk may be evaluated from acceleration/time curves.

TABLE 2

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SAFETY LEVEL	1	1	1	2	3	4				
EFFECT ON CRAFT AND OCCUPANTS	Normal	Nuisance	Operating limitations	Emergency procedures; significant reduction in safety margins; difficult for crew to cope with adverse conditions; passenger injuries.	Large reduction in safety margins; crew over-burden because of workload or environmental conditions; serious injury to a small number of occupants.	Deaths, usually with loss of craft.				
F.A.R. ¹ PROBABILITY (reference only)	← PROBABLE →			← IMPROBABLE →		← EXTREMELY IMPROBABLE →				
JAR-25 ² PROBABILITY	← FREQUENT →		← REASONABLY PROBABLE →	← REMOTE →	← EXTREMELY REMOTE →	← EXTREMELY IMPROBABLE →				
CATEGORY OF EFFECT	← MINOR →			← MAJOR →	← HAZARDOUS →	CATASTROPHIC				
	10 ⁻⁰	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴	10 ⁻⁵	10 ⁻⁶	10 ⁻⁷	10 ⁻⁸	10 ⁻⁹

- 1/ The United States Federal Aviation Regulations
- 2/ European Joint Airworthiness Regulations