

ANNEX 3

USE OF PROBABILITY CONCEPT

1 General

1.1 Absolute safety cannot be achieved in any human activity. Naturally, this fact shall be taken into account in developing safety requirements, which means that requirements shall 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 shall 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 standardized 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 shall 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 standardized 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;
- .3 independent failures in combinations involving more than one system, taking into account:
 - .3.1 any undetected failure that is already present;
 - .3.2 such further failures* as would be reasonably expected to follow the failure under consideration; and

* In assessing further failures which follow, account shall be taken of any resulting more severe operating conditions for items that have not up to that time failed.

- .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 shall be considered as being possible.

2.2.6 "Extremely improbable" is one which is so extremely remote that it shall 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 2.1.2, 2.1.3, 2.1.4, 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 shall 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 characterizing the relationship between craft performance represented as horizontal single-amplitude acceleration (g) 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 shall 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 shall 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 shall be substantially less than 10^{-9}

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

Table 1

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

¹ The accelerometers used shall have an accuracy of at least 5% full scale and shall have a frequency response bandwidth of at least 0.2 Hz to 20 Hz. Sampling frequency shall not be lower than 40 Hz. Filtering is recommended to eliminate any influence from machinery vibrations.

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

Table 2

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-25² PROBABILITY	← PROBABLE →		← IMPROBABLE →		← EXTREMELY IMPROBABLE →					
	← FREQUENT →		← REASONABLY PROBABLE →		← REMOTE →	← EXTREMELY REMOTE →				
	10 ⁻⁰	10 ⁻¹	10 ⁻²	10 ⁻³	10 ⁻⁴	10 ⁻⁵	10 ⁻⁶	10 ⁻⁷	10 ⁻⁸	10 ⁻⁹
CATEGORY OF EFFECT	← MINOR →			← MAJOR →		← HAZARDOUS →	CATASTROPHIC			

¹ United States Federal Aviation Regulations.
² European Joint Airworthiness Regulations.