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## Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
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| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/Figure/ Table/Note | Type of comment | Commend (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |



**56/2029/CD**

COMMITTEE DRAFT (CD)

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|-----------------------------------------------------------|-------------------------------------------------|
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|                                                                                                                                                                                                       |                                                                                                                                                          |
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| IEC TC 56 : DEPENDABILITY                                                                                                                                                                             |                                                                                                                                                          |
| SECRETARIAT:<br>United Kingdom                                                                                                                                                                        | SECRETARY:<br>Ms Stephanie Lavy                                                                                                                          |
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|                                                                                      |
|--------------------------------------------------------------------------------------|
| TITLE:<br><b>Dependability Management - Application guide - Guide on Reliability</b> |
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| NOTE FROM TC/SC OFFICERS: |
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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## DEPENDABILITY MANAGEMENT –

Application guide –  
Guide on Reliability

## FOREWORD

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| XX/XX/FDIS | XX/XX/RVD        |

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

250 The committee has decided that the contents of this document will remain unchanged until the  
251 stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to  
252 the specific document. At this date, the document will be

- 253 • reconfirmed,
- 254 • withdrawn,
- 255 • replaced by a revised edition, or
- 256 • amended.

257

258 The National Committees are requested to note that for this document the stability date  
259 is 20XX..

260 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED  
261 AT THE PUBLICATION STAGE.

262

## INTRODUCTION

This document provides guidance on how to identify and apply appropriate analysis and assurance techniques for reliability.

Reliability is an inherent characteristic of a design solution and expresses the ability to provide a required function for a given interval (time, operating cycles, distance etc.) under given conditions. The requirements for this characteristic are ideally be identified as early in the design process as possible, when other performance criteria are also being set. If it is not considered at this stage, it is likely that the item will not deliver the desired balance and assurance of intended performance, cost, and risk.

When an item fails there is loss of value to the user; this can result from direct costs involved in restoring the item to a functional state and/or loss of service or increased risk exposure. In the case of systems with a safety implication, unexpected failure can have far more serious consequences. The outcome of failures can range from loss of reputation through to direct and indirect financial penalties and ultimately to legal action.

A reliability program takes into account the life cycle implications by formally assessing and mitigating design-associated risks and delivery of the reliability requirements. Such risks can adversely impact the ability of items to deliver value through unacceptable item down time caused by poor design for reliability.

Guidance in this standard can be used at any time during the lifecycle of an item or project to guide the planning and implementation of a reliability program with a balance of safety, performance, cost, and their associated levels of assurance. These capabilities can be explicit in contractual agreements and statutory obligations or implicit in commitments to all stakeholders.

The activities described within this standard normally form part of an organization's asset management strategy and should therefore be aligned to, and consistent with, the organizational objectives.

This document is one of a suite of "top level" interrelated IEC dependability standards that provide managers and technical personnel, with guidance on how to effectively plan and implement dependability activities. Other documents in the suite are:

- IEC 60300-1 which highlights the importance and benefits of managing dependability. It gives guidance on dependability activities and how to integrate them into an existing management system and life cycle processes;
- IEC 60300-3-4 which provides guidance for writing dependability requirements in specifications, together with a means of assuring the achievement of those requirements;
- IEC 60300-3-10 and IEC 60300-3-14 which provide guidance on how to identify and apply appropriate analysis and assurance techniques for maintainability (and maintenance) and supportability (and support) respectively;
- A standard to cover availability, which is planned.

## DEPENDABILITY MANAGEMENT –

### Application guide – Guide on reliability

## 1 Scope

This document gives guidance on managing reliability and reliability activities that are applicable throughout the life cycle and to any organization.

This part of IEC 60300 provides guidance to managers and technical personnel involved with the specification, design, development, manufacture, acceptance, use and support of systems, products and services.

This document describes:

- principles and benefits of reliability;
- the elements of reliability programmes;
- specifying reliability;
- measurement, analysis and assurance of reliability;
- reliability information and its control.

The ability to retain the reliability of an item is not only dependent upon the design itself but also design and management of its associated maintenance (IEC 60300-3-10) and support (IEC 60300-3-14) programmes. The interaction between reliability, maintainability and supportability activities is discussed within this document.

## 2 Normative references

The following documents are referred to in the text such that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

There are no normative references.

## 3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

### 3.1 Terms and definitions

#### 3.1.1

#### **reliability**

ability to perform as required, without failure, for a given interval, under given conditions

Note 1 to entry: The interval can be expressed in units appropriate to the item concerned, e.g. calendar time, operating cycles, distance run, etc., and the units should always be clearly stated

Note 2 to entry: Given conditions include aspects that affect reliability, such as: mode of operation, stress levels, environmental conditions, and maintenance.

Note 3 to entry: Reliability can be quantified using measures defined in Section 192-05, Reliability related concepts: measures

#### 3.1.2

#### **reliability <measure>**

probability of performing as required for given interval, under given conditions

Note 1 to entry: Given conditions include aspects that affect reliability, such as: mode of operation; stress levels; environmental conditions; and maintenance, where applicable.

Note 2 to entry: It is usually assumed that the item is in a state to perform as required at the beginning of the time interval.

### 3.1.3

#### **obsolescence**

transition of an item from available to unavailable from the manufacturer in accordance with the original specification

Note 1 to entry: Transition of an item from available to unavailable from the manufacturer in accordance with the original specification

Note 2 to entry: Obsolescence might be because production has ended or because of the lack of availability of service provision, support of software or processed material.

Note 3 to entry: Obsolescence might be because production has ended or because of the lack of availability of service provision, support of software or processed material.

[SOURCE: IEC 62402:2019]

### 3.1.4

#### **availability <of an item>**

ability to be in a state to perform as required

Note 1 to entry: Availability depends upon the combined characteristics of the reliability, recoverability, and maintainability of the item, and in some cases, on the maintenance support performance.

Note 2 to entry: Availability can be quantified using appropriate performance measures.

[SOURCE: IEC 60050-192:2014, definition 192-01-23]

### 3.1.5

#### **dependability**

ability to perform as and when required

Note 1 to entry: Dependability includes availability, reliability, recoverability, maintainability, and maintenance support performance, and, in some cases, other characteristics such as durability, safety and security.

Note 2 to entry: Dependability is used as a collective term for the time-related quality characteristics of an item.

[SOURCE: IEC 60050-192:2014, definition 192-01-22]

### 3.1.6

#### **item**

subject being considered

Note 1 to entry: The item can be an individual part, component, device, functional unit, equipment, subsystem, or system.

Note 2 to entry: The item can consist of hardware, software, people or any combination thereof.

Note 3 to entry: The item is often comprised of elements that can each be individually considered.

[SOURCE: IEC 60050-192:2014, definition 192-01-01]

### 3.1.7

#### **maintainability <of an item>**

ability to be retained in, or restored to a state in which it can perform as required, under given conditions

Note 1 to entry: Given conditions include aspects that affect maintainability, such as: location for maintenance, accessibility, maintenance procedures and maintenance resources.

Note 2 to entry: Maintainability can be quantified using appropriate performance measures.

[SOURCE: IEC 60050-192:2014, definition 192-01-27]

### 3.1.8

#### **supportability, <of an item>**

ability to be supported to sustain the required availability with a defined operational profile and given logistic and maintenance resource

Note 1 to entry: Supportability of an item results from the inherent maintainability (192-01-27), combined with factors external to the item that affect the relative ease of providing the required maintenance and logistic support.

[SOURCE: IEC 60050-192:2014, definition 192-01-31]

### 3.1.9

#### verification

confirmation, through the provision of objective evidence, which specified requirements have been fulfilled

Note 1 to entry: The term “verified” is used to designate the corresponding status.

Note 2 to entry: The term “verified” is used to designate the corresponding status.

Note 3 to entry: The term “verified” is used to designate the corresponding status.

[SOURCE: IEC 60050-192:2014, definition 192-01-17]

### 3.1.10

#### validation

confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

Note 1 to entry: The term “validated” is used to designate the corresponding status.

Note 2 to entry: The use conditions for validation can be real or simulated.

Note 3 to entry: to entry: In design and development, validation concerns the process of examining a product to determine conformity with user needs.

Note 4 to entry: Validation is normally performed on the final product under defined operating conditions, although it can also be performed in earlier stages.

Note 5 to entry: Multiple validations can be carried out if there are different intended uses.

[SOURCE: ISO 9000:2005, 3.8.5]

## 3.2 Abbreviated terms

|               |                                                |
|---------------|------------------------------------------------|
| <b>ADT</b>    | Abstract data types                            |
| <b>CTL</b>    | Computational Tree Logic                       |
| <b>DRACAS</b> | Data reporting and Corrective Action System    |
| <b>FDSC</b>   | Failure definition and scoring criteria        |
| <b>FMEA</b>   | Failure Modes and Effects analysis             |
| <b>FMECA</b>  | Failure Modes Effects and Criticality analysis |
| <b>FRACAS</b> | Failure reporting and Corrective Action System |
| <b>HAZOP</b>  | Hazard and Operability Study                   |
| <b>LTL</b>    | Linear Temporal Logic                          |
| <b>MTTF</b>   | Mean operating Time to Failure                 |
| <b>NFF</b>    | No Fault found                                 |
| <b>OTS</b>    | Off-the-Shelf [item]                           |
| <b>PoF</b>    | Physics of Failure                             |
| <b>RBD</b>    | Reliability Block Diagram                      |
| <b>SRE</b>    | Software Reliability Engineering               |
| <b>SPC</b>    | Statistical Process Control                    |

## 4 Reliability overview

### 4.1 Description of reliability

Reliability is an inherent characteristic of a design solution and expresses the ability to provide a required function for a given interval (time, operating cycles, distance etc.) under given conditions. It is assured through performing a number of activities which can or can not result in a quantification of the reliability which is expressed as a probability. Reliability, as a probability, is not an attribute that can be assigned or measured for a single item. It is a stochastic or probabilistic parameter and therefore it cannot be measured exactly and repeatedly. However, other reliability characteristics such as failure intensity or Mean operating Time to Failure (MTTF) can be measured.

The objective of a reliability programme is to establish the likelihood and provide assurance that an item will meet stakeholder requirements in this respect. The reliability programme is used to influence the design, material selection, usage or environment of an item in order to achieve desired outcomes and hence should be tailored to stakeholder needs.

EXAMPLE 1: Reliability analysis can indicate that additional measures are required in order to avoid the unacceptable losses associated with failure. Such measures can include: additional hardware, additional software, and adjustments based on the environment and human factors, such as a need for more training.

When quantified as a measure, reliability is defined as the probability of operating for a specified interval without failure.

NOTE the specified interval can be expressed in terms of (mission) time, cycles or other parameter, e.g. mission reliability. It can also be expressed as an instantaneous reliability i.e. probability of failure 'on demand'.

When reliability is to be quantified, probability models can be used to support estimation of the reliability expressed as a probability, as well as relevant alternative measures such as failure intensity or MTTF.

In order to evaluate reliability, it is necessary to clearly define the item functions and associated performance levels which are required. Function loss can be total or partial and each function can have separate reliability requirements. Functions are normally derived from stakeholder requirements: functions being the actions or behaviours of the item needed to achieve one or more of such requirements. Such requirements can vary throughout the life of an item.

EXAMPLE 2: An engine can be designed to produce an output torque of 800 Nm. However to perform its function in a specified application only 750 Nm are required to achieve its required function. It is only considered to have failed, therefore, when output is below 750 Nm. However, if an output of 500 Nm allows the application to perform in an acceptable reduced performance state, an output below 750 Nm and above 500 Nm is regarded as a partial failure and below 500 Nm as a total failure. Partial failure can be acceptable with a higher frequency than total failure.

The analysis of reliability can occur in all stages within the lifecycle of an item, although the objective and means of analysis can differ between stages. The methods employed and the timing of their execution will be determined by stakeholder requirements and the scale of the project undertaken.

EXAMPLE 3: During a concept and design stages reliability can be predicted based upon analysis of data from similar equipment or testing of prototypes. This can be followed by testing of production versions and ultimately measurement during operation to demonstrate reliability with a stated confidence.

Measurement of reliability will normally take place in the realization and operational stages based on monitoring, diagnostic schemes, incidents reporting and data collected during testing and operation. In design and development reliability can only be estimated based on an appropriate model and using any samples of data from test and analysis. If data are collected in operation, the reliability can be estimated directly from the population data without need for a model.

Reliability growth methods (see IEC 61014) can be applied to assist in improving the reliability through the whole lifecycle and predict future reliability based on the activities planned.

In applications where formal presentation of reliability activities and results is specified, a dependability case (IEC 62741) can be used during design and development stages to give structured arguments and evidence of meeting reliability requirements.

## 4.2 Principles

Analysis and control of item reliability is founded on a set of principles. These principles should influence an organization's intent as well as its approach to design and delivery of reliability of: hardware, software and processes. Maximum benefit will be obtained from the reliability activities if all of these principles are applied.

The reliability principles are as follows.

- 1) The functions of the item and a definition of function loss should be clearly identified.

NOTE 1 It is often the case that some functions are regarded as critical to task success, whereas others might only be desirable.

A clear and unambiguous statement of the intended functions of that item and which functional failures (failure modes) are of interest is required to establish a representation of reliability. The level of knowledge about the item configuration (functional and physical) and its context of use will therefore determine the extent to which reliability can be evaluated. This principle requires that when undertaking reliability activities:

- the capability of the item and intent is known;
- the boundary conditions are clearly stated;
- the uncertainties in the delivery of the function are understood;
- the uncertainties in identification of failure modes are understood.

In addressing this principle Open or Information Systems present a number of challenges which require careful management. Item boundaries and requirements should be given particular attention as their specification might be complex and potentially change with time. Such changes might also result in alteration of function definitions. Thus, it is essential that all factors which can affect reliability over time are clearly documented together with the uncertainties as creation of a complete model of the item can not be possible. In such systems it can also not be possible to foresee all factors, so that they can need to be dealt with as they occur.

- 2) The item configuration, operating characteristics and operating environment should be defined sufficiently for the specified purpose.

NOTE 2 The specified purpose in this context means the lifecycle stage at which reliability is being evaluated and the stakeholder requirements for the analysis.

A full understanding of the physical configuration of an item is required together with a clear specification of operating scenarios (missions) in order to evaluate its reliability. Operating scenarios are the combinations of item performance (such as: speed, flow rate) and environmental conditions in which it will operate (such as: temperature, altitude, water depth). This principle requires that when undertaking reliability activities:

- item configuration is known;
- operating characteristics are known;
- operating environment is clearly defined.

The environmental conditions (temperature, pressure, chemical, dust, etc.) in which an item is used, stored and transported, as well as how it is operated and maintained, can have a major influence on its reliability.

NOTE 3 For example, a standard car could not be expected to achieve the same reliability when driven on desert tracks as it would in European road use; cars intended for such desert use are especially designed for the conditions.

The period of usage in which an item is expected to function should be determined as part of the development of requirements.

NOTE 4 For example, the typical flight pattern for an aircraft, a typical day for a transport vehicle, the period between major shutdowns for an industrial plant, or a 12 month period for an eCommerce system.

Reliability of items might vary with their age (covering calendar time, usage time, distance travelled, number of cycles or whatever metric is appropriate). Separate requirements for reliability under different conditions or for different periods of time (for instance summer or winter use, or periods of continuous use versus intermittent usage) should be identified and related to the relevant functions.

- 3) Reliability data for all items should be obtained or derived with justified and sufficient confidence to achieve requirements.

NOTE 5 This data can be qualitative or quantitative or a combination thereof

Ideally, when designing for, or analysing, reliability quantification of failure characteristics is required. Such characteristics always have uncertainty associated

with them which can be evaluated. This principle requires that when undertaking reliability activities:

- the necessary failure and / or survival information is defined;
- collection methods are determined;
- the quality of data is determined.

In the case of open or information systems, where external influences can be difficult to define or unknown, these principles can be met through an assurance process rather than explicit quantification.

#### 4) Reliability activities should influence item design.

The analysis of reliability is only of value if it is able to influence the design of the item itself, the subsequent operation and maintenance of the item and its support requirements. The activities undertaken and their timing are therefore tailored to the ability of the organization to obtain value from the results. This principle requires that when undertaking reliability activities:

- sufficient authority exists to influence the design, maintenance or support of the item;
- the activities are performed at a time when outcomes can be applied in both a practical and cost-effective manner;
- the activities are integral to all processes of the organization which affect design and use of the item.

#### 5) Reliability should be balanced with other relevant factors to achieve stakeholder objectives.

The reliability required will be determined by its relative importance with respect to other organizational and dependability objectives in order to deliver value. These objectives, relating to issues such as life cycle cost, maintainability and supportability, can also impose constraints on the activities undertaken and implementation of results. This principle requires that when undertaking reliability activities:

- there is an understanding of other dependability and organizational objectives;
- analyses and studies are tailored to context;
- an understanding exists of the desired balance and how this is to be evaluated.

#### 6) Reliability activities continue during use to assure that the item continues to meet stakeholder requirements.

During the use of an item the environment, stakeholder requirements and other factors might change and thus necessitate review of reliability requirements.

When applying these principles to develop a reliability programme, activities should be tailored taking into account the market conditions, item complexity and stakeholder requirements together with the size and experience of the organization.

### 4.3 Benefits

Expected benefits from reliability activities include, but are not limited to:

- providing justified confidence that the reliability of items will be as required, when required;
- understanding and managing the risks of failure or degraded performance in an effective way to achieve a balance of cost, risk and performance;
- enabling reliability design weaknesses to be identified and improved in line with performance, risk and through life cost requirements or goals;
- providing information and data that enable continual improvement;

- providing justification for the cost of reliability activities and demonstrating affordable levels of reliability performance;
- verification of contract requirements;
- fewer disruptions that make the item unusable and effective;
- increasing the understanding of the reliability performance so that failure can be managed more effectively;
- affordable levels of performance ensuring sustainability;
- fewer delays in test programmes and product development as a result of failures;
- provision of data for logistics planning
- input to other activities such as supportability or safety.

#### **4.4 Interfaces**

##### **4.4.1 Introduction**

Reliability is an attribute of dependability (see IEC 60300-1) The other main attributes are maintainability supportability and availability. The interfaces between these attributes are explained in more detail below.

##### **4.4.2 Effect of reliability on maintainability and maintenance**

Maintenance is intended to manage the consequences of failure either by avoiding the consequences or mitigating their effect. Although maintenance of an item will not influence its inherent reliability characteristics, it can influence its operational reliability if not executed as expected and poor quality maintenance can reduce reliability below its inherent value. Therefore, when designing for reliability, the maintainability of the item should always be taken into account (see IEC 60300-3-10).

In performing maintenance, improvements in the design of the item might be identified; this should be fed back to developers so changes can be made to the design to increase the reliability. Conversely, any changes proposed in maintenance activities or frequency should be evaluated for potential negative impact on reliability.

##### **4.4.3 Effect of reliability on supportability and support**

Support of an item is the combination of the integrated set of defined resources, such as personnel, spares, information, training, tools, facilities, communication systems, and transport logistics that are necessary to deliver desired organizational objectives. Supportability is concerned with identifying and quantifying the support required for a defined item in a given context of use, time to provide that support, resourcing, cost and quality of that support and the quality of the delivered support.

Both support and supportability can affect the reliability of an item through the inability of the organization to effectively or correctly deliver the required maintenance. Therefore, during the development stage supportability and support aspects should always be carefully assessed and suitable provision put in place to achieve the desired reliability.

##### **4.4.4 Effect of reliability on availability**

Reliability is a primary determinant of availability: every failure places a demand on maintenance and support resources and hence the item downtime or potential for downtime. System configuration will determine if a single failure results directly in lost availability but, even where redundancy is employed, lower reliability results in loss of availability through increased probability of multiple failures.

##### **4.4.5 Effect of manufacturing on reliability**

The expected reliability of an item can only be achieved if the manufacturing processes are executed as required. Failure to do so could be a result of poor manufacturability or lack of the specified materials and components. Processes to combat these issues should include but not be limited to:

- ensuring item design processes include evaluation of manufacturability;
- controlling any manufacturing process or material change through a strict design change approval system, in which the design team reviews the potential impact on reliability.

Often, the early manufacturing processes for components and assemblies need to be “run in” and be adjusted to ensure correct item quality. This can cause early failures that should be screened out (see IEC 61163-1 and IEC 61163-2) until the process problems have been solved. Statistical process control is an important tool to support these activities. Intermediate tests and inspections can be needed, such as visual inspection (by eye or by picture analysis) or X-ray inspection of solder joints. Intermediate tests and final acceptance testing are also important (see ISO 9001).

Manufacturing processes can also include a period of operation of every item prior to shipping in order to reduce the probability of early life failures in service; this is often referred to as ‘burn-in’ or ‘infant mortality’.

#### 4.5 Effect of operation on reliability

The environmental conditions at operation influence the reliability (IEC 61709 and IEC 60721 series). In particular, extreme temperature or humidity levels outside those specified can adversely affect the achieved reliability.

EXAMPLE 1 High humidity is often associated with high ambient temperature and can reduce reliability while the product is not operated (e.g. “Off” or “Standby”).

EXAMPLE 2 Low temperature can reduce the reliability of the start of operation due to freezing or increased viscosity in fluids.

EXAMPLE 3 Electrostatic discharge can influence reliability during low humidity (winter conditions).

The normal operating load can influence the reliability through high constant operating temperature, temperature or load variation due to frequent or intermittent ‘on-off’ cycling.

The effect of operation on reliability might not only be due to its environment but also on how it is operated with respect to its performance (i.e. operating at reduced performance can increase reliability but use beyond its design performance can reduce it).

#### 4.6 Effect of handling and storage on reliability

Before installation or use, an item has often been stored for some time and potentially transported. These circumstances might reduce the reliability of the item as a result of environmental conditions outside specified operational conditions; for example: high or low temperature, humidity, contamination, mechanical shock and vibrations (see the IEC 60721 series). Appropriate specification of packaging, handling, storage and transportation should form part of the reliability programme, see IEC 60300-3-14.

If an item is to be installed into a larger item it might be damaged during installation; for example: bearings damage, misalignment or, for electronics, Electrostatic Discharge. Similarly, damage can occur during disassembly to preform maintenance and reassembly following maintenance. The conditions at the installation / repair location can also be different from those specified for item operation. Reliability programmes should therefore include design of correct procedures to avoid these issues

In some circumstances, ad-hoc modifications are made to items to facilitate installation if unforeseen problems are encountered. This should be controlled through “as built” drawings and part lists and reviewed to identify any potential adverse effects on operational reliability.

#### 4.7 Input for Life Cycle Cost analysis

During development, the decisions concerning system configuration, choice of components, rating/derating and possible redundancy is based on the predicted reliability and informs the data for Life Cycle Cost (LCC) analysis (see IEC 60300-3-3). Test e.g. accelerated tests (see IEC 62506 and IEC 61649) give data to update the LCC estimates. During operation, the actual costs due to failures (e.g. corrective maintenance and reduced availability) can be collected to give input for future LCC estimates (closing the feed back loop).

Generally, the LCC is dominated by maintenance and support costs which in turn are driven by item reliability. In meeting stakeholder requirements, trade-offs might be required to balance between low reliability items that are expensive and resource intensive to maintain and high reliability items that are expensive to design or acquire. Thus reliability assessment is an essential part within any programme that addresses maintenance and support requirements. The reliability programme should also be tailored to ensure that it is appropriate for the LCC limitations.

## **5 Specifying for reliability**

### **5.1 Overview**

In order to select the activities which achieve the reliability programme outcomes, the measures of reliability relevant to the context should be chosen. Quantitative or qualitative measures of reliability, provide a means of assessing programme success. IEC 60300-3-4 provides detailed guidance on the principles of writing dependability requirements in specifications, together with a means of assuring the achievement of those requirements. It also contains a high-level approach to determine what information is required, the decisions that could be made and what the output of the decision making process might be.

Reliability is the ability for an item to continue to function without failure and is predicted or measured with regards to relevant units of usage (operating hours, cycles, miles, demands, calendar time etc), it can also be predicted or measured at various levels of indenture:

- fleet of items;
- system level;
- sub system level;
- component level;

Failure at a lower level of indenture might not cause a failure at a higher level, but can still be important as it can potentially involve:

- costs associated with fixing the fault;
- opportunity costs associated with stopping the operation of the higher-level indenture, even if it is at a less inconvenient time;
- increased risk as redundancy is reduced or probability of failure at a higher-level indenture is increased.

Some items, with elements of redundancy, might have a level of reliability associated with the ability to start operating, where the item could require redundant elements to be in a working condition – in the aerospace environment this is known as dispatch reliability.

Reliability can be expressed as a probability of life of similar items or the probability of an individual item surviving a given usage.

Reliability requirements will have a direct impact on maintainability, supportability and availability requirements; similarly requirements for these elements of dependability will impact reliability requirements. All such requirements should therefore be developed together as part of any design development or modification programme.

The specification of each reliability requirement as a quantitative or qualitative measure should detail the life cycle stages at which conformity will be assured and the means and procedures (analytical methods, simulations, tests, etc.) by which this will be carried out. The interdependence between requirements should be clearly described.

The required confidence in the assessed measure determines the amount of resources (people, cost, time) which are necessary to demonstrate achievement of programme outcomes.

## 5.2 Principal elements of reliability requirements

When defining reliability requirements, the following aspects affecting design should be taken into account and expressed as part of the requirement:

- a) The intended usage cycle: this should identify not only how the user will use the item, but also which characteristics of usage will impact the reliability of the item.

EXAMPLE 1 The reliability of a traditional filament light bulb is a combination of both operating hours and the number of on/off cycles. Therefore the usage cycle would have to include expected operating hours but also the required number of changes of state.

- b) Required function: many items have more than one function, when specifying reliability it is necessary to identify which functions are of importance.

EXAMPLE 2 A mobile phone which is only used for voice communication could be considered to be in working state even if the 5G capability is lost.

- c) Hidden functions: if an item has functions which are not visible to the user then the impact of failures of these have to be taken into account when specifying the reliability.

Example 3 A user would only realize that a background backup system on a computer had failed when the user has need of the backed-up data.

## 5.3 Quantitative measures of reliability

### 5.3.1 General

Reliability performance requirements should preferably be quantitative and specified before design of the item begins. As with any statistic, quantitative reliability requirements or measures should also specify the confidence with which the requirement is to be demonstrated or stated (see IEC 60605-4).

There are several alternative ways in which reliability may be measured. Some of the more common measures are shown in Table 1. These can relate to either a probability that an item will survive a given usage or a probability that greater than x% of items will survive a given usage. They can also relate to mean values over a given time period. The mathematical relationship between some of these measures are explained in Table B.1 of IEC 61703.

Clauses 5.3.2 to 5.3.7 give high-level guidance on where each measure might be appropriately applied, but the user must tailor this to the specific item and context of use. The values used in the examples are given only to illustrate how they may be stated in a specification: they should not be used as standardized values.

| Reliability performance measure                                                                                                                   | Symbol/ abbreviation                           | Example requirement*        |
|---------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------|
| Mean failure rate                                                                                                                                 | $\bar{\lambda}(t_1, t_2)$                      | $\leq 27 \cdot 10^{-6} / h$ |
| Mean time to failure                                                                                                                              | <i>MTTF</i>                                    | $\geq 37000h$               |
| Mean failure intensity                                                                                                                            | $\bar{z}(t_1, t_2)$                            | $\leq 1.5 / h$              |
| Mean time between failures                                                                                                                        | <i>MTBF</i>                                    | $\geq 6000h$                |
| Useful life / Remaining Useful Life                                                                                                               | <i>RUL</i>                                     | $\geq 8 \text{ years}$      |
| Reliability                                                                                                                                       | $R(t_1, t_2)$<br>$t_1 = 100h$<br>$t_2 = 1100h$ | $\geq 0.9$                  |
| * The requirement states the acceptable value (contract value) which should be used to calculate the acceptance criterion for a statistical test. |                                                |                             |

**Table 1 – Reliability measures**

One early consideration should be the failure mechanisms likely to be experienced by the item, as this influences which of the reliability measures is appropriate and relevant. For example: items such as motor vehicle engines show wear-out so that use of the constant failure rate assumption is not valid. The exact meaning of a unit of time, such as in Table 1, should be given as it is not necessarily chronological time.

EXAMPLE 1 A motor vehicle engine will fail according to how far it is driven rather than age since new, so that miles driven would be the appropriate unit.

EXAMPLE 2 Household electric light bulbs primarily fail relative to the number of times they are switched on and off, and to a lesser extent the number of hours they are lit, so operations or operational hours are the appropriate units and the item is designed for a defined operational life.

The inclusion, or not, of redundant elements is another factor that affects the choice of the reliability measure. The specification should state whether reliability refers to loss of individual redundant elements or loss of the function which they together provide.

For every item, it is necessary to select and define each reliability characteristic that is required and to specify a quantitative requirement for each characteristic. When specifying quantitative requirements for an item, it is important to state the following:

- the application and / or use profile of the item;
- the failure criteria or the definition of a failure, i.e. what constitutes a failure in the particular item in the intended application;

NOTE A failure may be defined in various ways according to the consequences, for example, the loss of a service, the need for repair (see also 5.4).

- the duration during which the requirements must be fulfilled;
- the operating conditions;
- the environmental conditions;
- the methods intended to be applied for the evidence of compliance with and assurance of the requirements.

Without such statements, the specification of a reliability performance measure such as  $R(t)$ ,  $F(t)$ , MTTF, MTBF, numbers of failures in a time interval, Weibull or Power Law parameters would be meaningless.

In order to select a realistic and meaningful value of the reliability performance measure to be specified, the following factors should be taken into account:

- the limits imposed by the technological state of the art and the nature and complexity of the item;
- the experience of the purchaser in operating and maintaining the particular type of item;
- the feasibility of verifying the specified requirement;
- the reliability level of units, components, etc., from which the item can be manufactured;
- the cost of design, production and verification and validation of the item with a specified level of reliability.

If, during the development of a project, it becomes evident that the underlying assumptions are not valid, the reliability performance requirements should be reconsidered and changed where necessary. If the specification is to be changed, this should only be done with the agreement of all the parties concerned.

If the reliability performance measure is known to, or is likely to, vary with time, the dependability should be specified by, for example, Weibull parameters for unrepairable items (see IEC 61649) or Power Law parameters for repairable items (IEC 61164 and IEC 61710). Alternatively the mean failure intensity over a stated time period can be specified.

### 5.3.2 Application of mean failure rate measure

The mean failure rate measure, specified for a given time period, can be an appropriate reliability performance measure in cases where it is expected that the failure rate shows a clear non-constant (typically increasing) variation over time, and it can be argued that the maximum failure rate is limited. In this case, specifying the maximum failure rate as the measure may be overly stringent; in particular, if there are several repairable components of a given type and these are replaced independently (which results in a kind of mixture of failure rates over time).

EXAMPLE bearings in a safety context where the failure rate is essentially a hazard rate.

### 5.3.3 Application of mean time to failure measure

The mean time to failure measure is typically used for non-repairable items. This measure can be useful if the specific variation of the failure rate is not so relevant, but rather the number of failures during a given time period. This, for instance, determines the average number of times a maintenance crew is demanded, or the number of times a process in an industrial plant is interrupted (which may every time cause long startup times with significant production losses).

EXAMPLE pumps in an industrial plant.

### 5.3.4 Application of mean failure intensity measure

The mean failure intensity is similar to the reciprocal of the mean time to failure measure (section 5.3.3) but is applied to repairable items. Other than this difference, the reasons for specifying the mean failure intensity as a reliability performance measure are the same as those given in section 5.3.3.

### 5.3.5 Application of mean time between failures measure

The mean time between failure measure is similar to the mean time to failure measure from Section 5.3.3, but is used for repairable items. However, the reasons for specifying the mean time between failure as a reliability performance measure is the same.

### 5.3.6 Application of useful life measure

The (remaining) useful life can be a suitable reliability performance measure (sometimes in combination with other measures), if analyses or requirements are based on assumptions that are valid only during the useful life. In this case, the items need to be replaced once the useful life is reached.

EXAMPLE a minimum useful life may be specified for automation devices in an industrial plant because safety arguments are based on assumed failure rates during the useful life, and the devices need to be replaced afterwards.

### 5.3.7 Application of reliability measure

The reliability measure is typically an appropriate reliability performance measure for one-shot systems where uninterrupted operation during a specified mission time is essential, and repair / replacement is unfeasible.

EXAMPLE subsea installations, or systems operation in space such as satellites.

### 5.3.8 Assurance by testing

The quantitative requirements should be clearly specified in a form against which it will be possible to compare test or in-service performance results subsequently obtained.

Where evidence of conformity to the quantitative requirements is to be provided through testing, the confidence level required should be specified, or the actual test plan to be used should be specified. If a test plan is specified, the specification should include the test duration and the acceptance / rejection criteria.

A number of different types of reliability demonstration test exist and, generally, sequential test plans (see IEC 61123 and IEC 61124) should be used in preference to test plans terminated at a fixed time or a fixed number of failures, as the former are more efficient. See IEC 60300-3-5 for information on statistical distributions.