

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Dependability management –
Part 3-14: Application guide – Supportability and support**

**Gestion de la sûreté de fonctionnement –
Partie 3-14: Guide d'application – Supportabilité et soutien**



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**Gestion de la sûreté de fonctionnement –
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DEPENDABILITY MANAGEMENT –**Part 3-14: Application guide – Supportability and support**

FOREWORD

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IEC 60300-3-14 has been prepared by IEC technical committee 56: Dependability. It is an International Standard.

This second edition cancels and replaces the first edition published in 2004. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) consistency with the other core dependability standards prepared by IEC TC 56;
- b) expansion of supportability and support principles and activities in dependability.

The text of this International Standard is based on the following documents:

Draft	Report on voting
56/2050/FDIS	56/2055/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2 and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 60300 series, published under the general title *Dependability management*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

This document provides guidance on how to identify and apply appropriate analysis and assurance techniques for supportability and support on an item. This document includes good practice, the measures appropriate for requirements and how to evaluate them. This document also includes the relationship with other dependability attributes together with the elements of an effective supportability and support programme. Support, in the context of this document, is the provision of quality resources to enable an item to perform as required. Supportability focuses on:

- identifying and quantifying:
 - support for a defined item in a given context of use;
 - time to provide that support;
 - resourcing, cost and quality of the support activity;
 - quality of the delivered support;
- influencing the design of an item and support arrangements to achieve value over the item's life.

A primary objective of "designing for item supportability" is to influence the support activity during operations and maintenance. However, supportability is not just an attribute of the design as it is also dependent on the conditions of use and the organization providing the support arrangements. Achieving the desired capabilities inherent in an item design implies that the necessary support capability is also designed, implemented and continuously evolved to align with changes to the item's configuration and its conditions of use including the capability of the managing organization and its suppliers. Supportability of an item ensures that:

- support requirements to achieve a desired item capability are balanced and known;
- financial capability to deliver that support is known for the short and long term;
- there is a desired balance between item design, the design of the support and the design of the organization delivering that support in order to achieve technical and financial requirements.

Support is a major contributor to the overall costs for an item to operate smoothly throughout its life for a given life profile. The current trend is to extend the life of an item by ensuring spares and other support resources are readily available over a longer period of time (particularly for items which will have problems such as obsolescence). The current trend also aims to ensure that parts are retired and recycled in a sustainable manner. Supportability will benefit from innovative solutions if it is to meet these future sustainability and circularity demands.

An item which is easily supported is better able to withstand adversity and recover from it. Such an item is more resilient and less reliant on the people and systems that can be affected by serious adverse events and situations.

An effective supportability and support programme ensures that the customer will have increased confidence in the support organization, with lower life cycle costs, improved availability and fewer modifications due to supportability deficiencies. In turn, this will result in improved customer confidence in the item leading to improved sales as well as improved sales for future items from the same company.

This document is one of the "top-level" interrelated 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 the means of assuring the achievement of those requirements;
- IEC 60300-3-10 which provides guidance on how to identify and apply appropriate analysis and assurance techniques for maintainability (and maintenance);
- guidance documents to cover reliability and availability which are under development.

DEPENDABILITY MANAGEMENT –

Part 3-14: Application guide – Supportability and support

1 Scope

This part of IEC 60300 introduces the dependability attribute of supportability (and support) and the relationship with related dependability attributes of reliability, maintainability and availability.

This document can be used at any time during an item's life to guide the planning and implementing of supportability and support activities focused on achieving an intended balance of performance, cost and risk. All activities can be tailored to the nature of the item and its conditions of use.

Guidance is offered on how supportability and support activities can be applied at any life cycle stage for newly designed items, existing items available for commercial procurement, or for items during their operational life.

This document considers the life cycle implications by formally managing risks associated with the management and delivery of activities to create, operate, maintain and refurbish an item to achieve its stated purpose.

This document describes the:

- nature of supportability and support;
- role of supportability and support in achieving item value over its life;
- trade-offs associated with supportability and support to achieve desired balance of cost, performance and risk during the life of an item;
- importance of aligning the structure of an organization with its objectives, with the ultimate aim of improving efficiency and effectiveness in order to deliver the required supportability and support.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

availability

ability to be in a state to perform as required under given conditions

Note 1 to entry: Availability depends upon the combined attributes of the reliability (IEV 192-01-24), maintainability (IEV 192-01-27), supportability (IEV 192-01-31) and the maintenance and support provided.

Note 2 to entry: Given conditions include aspects that affect availability, such as: mode of operation, stress levels, environmental conditions and maintenance, as well as conditions defined in the life profile.

Note 3 to entry: Availability can be quantified using measures defined in IEC 60050-192, Section 192-08, Availability related measures.

[SOURCE: IEC 60050-192:2015, 192-01-23, modified – The definition is no longer specific, "under given conditions" has been added and the existing Notes to entry have been replaced with new Notes to entry.]

3.2

built-in test

BIT

integrated capability of a test item enabling automatic fault recognition and fault localization

[SOURCE: IEC 60706-5:2007, 3.1.1]

3.3

built-in test equipment

BITE

hardware and firmware built into an item exclusively for the purpose of carrying out built-in test

3.4

corrective maintenance

maintenance carried out after fault detection to effect restoration

Note 1 to entry: Corrective maintenance of software invariably involves some modification.

[SOURCE: IEC 60050-192:2015, 192-06-06]

3.5

dependability

ability to perform as and when required

Note 1 to entry: A dependable item or service is one where there is justified confidence that it operates as desired and satisfies agreed stakeholder expectations.

Note 2 to entry: In most cases, the term "dependability" is used as an umbrella term to express its core attributes of reliability, maintainability and supportability and the resulting availability. In some cases, attributes such as resilience, recoverability, durability, integrity, safety, security, and trustworthiness are included in or overlap with dependability.

Note 3 to entry: In order to express the ability to perform, requirements are specified in terms of functions to be performed, when the performance is to be achieved, and the life profile conditions.

Note 4 to entry: The attributes of dependability can be expressed qualitatively or quantitatively.

Note 5 to entry: It is also a common practice to use the term "dependability" in the context of a subject of study or discipline.

[SOURCE: IEC 60050-192:2015, 192-01-22, modified – The definition is no longer specific, existing Notes to entry have been replaced with new Notes to entry.]

3.6

item

subject being considered

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

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. See sub item (IEV 192-01-02) and indenture level (IEV 192-01-05).

[SOURCE: IEC 60050-192:2015, 192-01-01, modified – In Note 1 to entry, "material, product, service or process" has been added and the Notes referring to IEC 60050-191 have been deleted.]

3.7

life cycle

series of identifiable stages through which an item goes, from its conception to disposal

EXAMPLE A typical system life cycle consists of: concept and definition; design and development; construction, installation and commissioning; operation and maintenance; mid-life upgrading, or life extension; and decommissioning and disposal.

Note 1 to entry: The stages identified will vary with the application.

[SOURCE: IEC 60050-192:2015, 192-01-09]

3.8

life profile

stresses on an item, their levels, content, duration and sequence encountered during the life cycle

Note 1 to entry: Stresses can be internal (such as operating cycles) or external (such as environmental stress, input power level and rate of service requests over the network).

Note 2 to entry: Life profile can be actual, expected or predicted.

3.9

maintainability

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

Note 1 to entry: Given conditions include location for maintenance, accessibility, maintenance procedures and maintenance resources as well as conditions defined in the life profile.

Note 2 to entry: Maintainability can be quantified using appropriate measures. See IEC 60050-192:2015, Section 192-07, Maintainability and maintenance support: measures.

[SOURCE: IEC 60050-192:2015, 192-01-27, modified – The definition has been generalized and reworded, "of use and maintenance" has been deleted and the existing Notes to entry have been replaced with new Notes to entry.]

3.10

maintenance concept

maintenance objectives, line of maintenance, indenture levels, maintenance levels, maintenance support and their interrelationships

Note 1 to entry: The maintenance concept provides the basis for maintenance planning, determining supportability requirements and developing logistic support.

[SOURCE: IEC 60050-192:2015, 192-06-02, modified – The first preferred term "maintenance policy" has been deleted and in the Note, "policy" has been replaced with "concept".]

3.11 **mean waiting time** **MWT**

average time for a spare part to be made available to repair an item

Note 1 to entry: If a spare part is available as a stock item, then the waiting time is zero. The worst waiting time is the repair turnaround time.

3.12 **off-the-shelf** **OTS**

non-developmental item of supply that is both commercial and sold in substantial quantities in the commercial marketplace

Note 1 to entry: Sometimes referred to as COTS (commercial off-the-shelf) or MOTS (modified off-the-shelf).

[SOURCE: IEC 62741:2015, 3.1.3]

3.13 **preventive maintenance**

maintenance carried out to mitigate degradation and reduce the probability of failure

Note 1 to entry: See also condition-based maintenance (IEV 192-06-07) and scheduled maintenance (IEV 192-06-12).

[SOURCE: IEC 60050-192:2015, 192-06-05, modified – The second preferred term "preventative maintenance" has been deleted.]

3.14 **repair turnaround time** **RTRT**

time taken for a failed part to be repaired and returned to store (including transportation)

3.15 **replacement rate**

rate at which an item is replaced to meet specified operational requirements over a period of time

Note 1 to entry: The likelihood of failures detected when no fault is found shall be included in the calculation of the replacement rate. Some failures (secondary failures) are induced by external events, such as inappropriate repair, failure of other items. For these reasons the replacement rate, and not the failure rate, shall be applied in spare parts quantification. The replacement rate includes all factors which are influencing the number of replacements of an item.

3.16 **special type equipment** **STE**

equipment which is required for performing a specific task for a specific item

EXAMPLE Tools, jigs and test equipment.

3.17 **support**

<in dependability> provision of resources to enable an item to continue to function as required

Note 1 to entry: Examples of resources are human effort, training, tools, jigs, test equipment, lifting equipment, materials, spare parts, facilities, documentation, information and information systems.

Note 2 to entry: Support provides a quality resource to the correct location at the best time for the optimum cost, taking into account environmental, social and economic impacts.

3.18

supportability

ability of an item to be supported to perform as required with a defined life profile and given resources

[SOURCE: IEC 60050-192:2015, 192-01-31, modified – The definition has been generalized and extended and the Note to entry has been deleted.]

3.19

system

<in dependability> combination of interacting parts that achieve one or more purposes

Note 1 to entry: A system is sometimes considered as a product or as the service it provides.

Note 2 to entry: Parts can include the associated equipment, facilities, material, computer programs, firmware, technical documentation, other systems, services and personnel required.

[SOURCE: IEC 60050-192:2015, 192-01-03, modified – The definition has been reworded to be specific and the existing Notes to entry have been replaced with new Notes to entry.]

3.20

useful life

interval, from the defined first use until a defined end state is reached, due to performance, obsolescence or economic factors

Note 1 to entry: The first use has to be defined. In this context, "first use" excludes testing activities prior to hand-over of the item to the end-user. The "first use" can commence after an initial period of early mortality.

Note 2 to entry: The end state has to be defined and can include safety margins that prevent the onset of failure or percentages of accumulated failures.

Note 3 to entry: The applicable interval 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 4 to entry: In some cases, the useful life of an item is more than that required by an organization in which case it will have residual value and can be repurposed.

Note 5 to entry: For items where the useful life ends when the item fails, the life of the item can be specified as the time when a stated percentage of the items have failed. This is often stated as a L_{10} or B_{10} value for 10 % accumulated failures.

Note 6 to entry: For consumer products and other products produced in large volumes, where only a small percentage of the products fail, the L_{10} or B_{10} value can be used as an approximation.

[SOURCE: IEC 60050-192:2015, 192-02-27, modified – The definition is no longer specific, has been reworded and the existing Note to entry has been replaced with new Notes to entry.]

4 Overview of supportability and support

4.1 Description of supportability and support

Supportability is involved 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 quality of the delivered support. Specifically, supportability addresses "what is required" for an item to continue to function as well as "how to implement" this requirement. The "what is required" element is inherent within the item design, but the way in which it is implemented is determined by the organization undertaking the support. Hence the organizational aspects can heavily influence supportability and therefore supportability should be an integral part of the design and development of an item. Supportability can change during the life of an item: for example, if the number of items requiring support changes.

Support is the provision of resources to enable an item to continue to function as required throughout its life for a given life profile. Examples of resources are personnel, training, tools, jigs, test equipment, lifting equipment, materials, spare parts, facilities, documentation, information and information systems including the maintenance and calibration of these resources. In essence, support provides a quality resource (including quantity) to the correct location at the best time for the optimum cost, taking into account environmental, social and economic impacts.

In order to clarify the difference between supportability and support: supportability management establishes the required support and manages changes (improvements) within the area of support which can involve changes to the item design as well as changes in the organizational structure; support addresses the day to day management and operation for the provision of the specified support resources in order to ensure that the quality of these resources and their timeliness of delivery is always maintained.

There are two types of supportability and support that can be considered: operational and maintenance. Operational support examples can be providing accommodation and sustenance for an aircrew that has landed in a foreign country or providing a helpdesk service. However, the boundaries of support have to be clearly understood. The above examples are support, but will not necessarily be within a support organization. For example, they can form part of the duties conducted by customer services which the company has classified as a separate cost centre involving support and non-support activities and therefore excluded from support accountability. Measurement of specific support activities for quality, timeliness and cost-effectiveness cannot be easily obtained from the data if the organization has other non-support duties and the effectiveness and efficiency of the organization is measured collectively. As mentioned in 5.4, measures for cost centres and profit centres are outside the scope of this document.

Interface boundaries are also an important consideration. For example, the maintenance support organization is responsible for ordering spare parts, but the purchasing of these spare parts can be conducted by a procurement department. Procurement can be responsible for determining the financial viability of a company and also conducting competitive bidding. These would be outside the responsibilities of support, but the support organization has to clearly understand this interface if any undue delay is to be pre-empted for the timely delivery of the spare part.

4.2 Principles

Supportability and support are founded on a set of principles. Applying these principles will ensure that the support organization is economically viable and that the reliability, maintainability and availability measures established during design and development are achieved

Supportability principles are:

- simplifying, minimizing and eliminating aspects of support particularly with regard to the inherent design;
- collectively analysing supportability, reliability, maintainability and availability to provide a balanced solution at an optimum overall cost;
- establishing an organizational structure that is efficient and effective and is constantly striving to improve its effectiveness and efficiency whilst taking into account changes in environmental, social, and economic requirements;
- structuring the organization to incorporate the different support approaches depending on the different types of support (such as addressing different types of restoration and maintenance);
- providing resources as required, ensuring that these resources have been defined, including the quality of these resources;

- delivering resources to known locations as well as providing flexibility in delivery where these locations can change;
- providing support with minimal delay time;
- ensuring support is cost-effective.

4.3 Benefits

Supportability and support activities facilitate the assurance that integrated technical, financial and organizational decisions associated with sustained operation and maintenance of an item or group of items, can be achieved in a balanced manner. The benefits from controlling supportability and support activities include:

- providing justified confidence that spare parts will provide value by performing as and when required;
- enabling supportability design weaknesses to be identified and improved with consideration for performance, risk, other dependability characteristics and costs during the whole life;
- providing information and data that enable continual improvement;
- providing justification for the cost of supportability activities and demonstrating affordable levels of supportability and support performance;
- reducing item down time resulting in improved availability;
- optimizing supportability and support effort;
- assisting in achieving defined, technical and financial outputs for the organization;
- improving resilience to disruptive events.

From these benefits, the stakeholder will have increased confidence in the support organization, with lower life cycle costs, improved availability and fewer modifications due to supportability deficiencies. In turn, this can result in improved stakeholder confidence in the item leading to improved sales as well as improved sales for future items from the same company.

4.4 Interfaces

4.4.1 General

Supportability is an attribute of dependability (see IEC 60300-1). The other main dependability attributes are reliability, maintainability and availability. Support, as an outcome of supportability, provides the quality and timeliness of delivery for the resources that are required and can therefore influence these attributes. The interfaces between these are explained in more detail in 4.4.2 to 4.4.5.

Supportability and support are influenced during the design stage by the intended types of restoration (7.2.2) and the intended types of maintenance (Annex A) and the potential loss in revenue due to delays. During use of the item, supportability and support are influenced by the variations in the use of the items in relation to the life profile and variations in the quantity of items that will be supported.

Conversely, all design activities (including modifications) require supportability and support to be considered so that any design decisions address the impact upon support to ensure an optimized solution is achieved. Hence, the primary interfaces are systems design and manufacture, dependability requirements (IEC 60300-3-4), reliability, maintainability and maintenance (IEC 60300-3-10) including testability and diagnostics (IEC 60706-5), availability and also life cycle costing (IEC 60300-3-3).

Additional interfaces include project management, risk management, safety and hazard analysis, human factors analysis (IEC 62508), trials and acceptance, quality, environmental, social issues, design reviews, including dependability reviews (IEC 62960), sustainability, resilience and organizational aspects.

4.4.2 Effect of supportability and support on reliability

Supportability and support activities undertaken can adversely impact reliability. Hence these activities should ensure that:

- any consumables or restored parts delivered are of the quality required (including packaging, handling, storage and transportation aspects);
- restored parts are correctly calibrated (if they require to be calibrated) and the calibration period is of sufficient duration at the point of installation;
- any associated resources such as jigs, tools, test equipment and facilities are in correct order to enable the work to be undertaken. This can involve calibration checks, environmental checks as well as the availability and ease of access for these resources;
- the staff members conducting the work have been trained and are sufficiently competent;
- the system is tested to a sufficient degree to give confidence that the work has been satisfactorily accomplished and the system will function as required;
- incorrect configuration or counterfeit spares and materials are prevented as these can also have a significant adverse impact on the reliability.

It is possible that the system reliability has degraded gradually and that it can take time to identify the true cause of the degradation. Hence during the development stage the risks associated with support activities, particularly areas that can impact upon safety, should be carefully assessed and suitable remedial action taken.

4.4.3 Effect of supportability and support on maintainability

Any of the activities mentioned in 4.4.2 above can also impact upon maintainability. If any of the above support activities are unsatisfactory, then the maintenance time will increase. However, the cause of the increase in maintenance time is likely to be more readily identified and prompt action will be taken to remedy the problem.

4.4.4 Effect of supportability and support on availability

Supportability optimizes support delay times and in some cases (such as mean waiting time), it is possible it will not be cost-effective to completely eliminate these delays. Any delay will impact upon availability and the consequences should be considered to establish the best solution. The significance of these possible delays should be assessed during the development stage (such as the types of maintenance – see Annex A).

4.4.5 Effect of supportability and support on life cycle cost

Supportability activities are ongoing and they can influence the support costs throughout the life of the item. Introducing supportability early in the development process can provide major savings during the life of the item. Further information on the effect of supportability and support on life cycle costs are provided in Annex B and Annex C.

5 Specifying for supportability and support

5.1 General

The supportability and support programme should specify the support boundaries (see 4.1) and they should be clearly understood. Changes in the design, reliability, maintainability, availability, manufacture, operation, transportation, storage and potential revenue gains and losses, are all factors that can influence support so it is important that trade-offs are addressed throughout the item's life. Other factors such as environmental, social, economic, security should also be considered.

It is usually recommended that supportability and support programmes are a continuation of a programme that has been established for previous products by the same company. Reuse of existing resources will provide cost saving benefits. Established facilities for maintenance are preferred, taking into account the capacity of the facility and the estimated quantity of new items likely to undergo maintenance. Where items are to be distributed globally, then facilities will also be required to be globally distributed to minimize transportation issues from an environmental and cost viewpoint.

An effective supportability and support programme should be planned, integrated and developed together with other programmes intent on achieving value through balancing reliability, maintainability, performance, cost and risk outcomes. Such programmes should be established at the concept stage of the life cycle and performed through development, realization, utilization and retirement and reuse stages.

A support data repository can be used to identify the operating and maintenance support activities so that the areas of concern can be cross-related (see 7.2.4), but the number of activities undertaken will depend upon the agreed funding.

5.2 Defining requirements

The specification process for supportability and support should follow the general guidelines outlined in IEC 60300-3-4. This provides guidance for writing dependability requirements in specifications, together with a means of assuring the achievement of those requirements. The measures listed in 5.4 can be used to guide the development of required outputs.

The requirements can be classified as six elements:

- information resources (see Clause 9);
- human resources (see 10.2);
- training (see 10.3);
- support equipment (see 10.4);
- support facilities (see 10.5);
- spare parts and consumables (see 10.6).

Where there is a gradual increase in the number of items being utilized, as mentioned in 5.1, using a continuation of existing resources provides benefit in that real time data can be used to modify any predicted data.

5.3 Attributes of supportable items

During the early stages in the development of an item, there can be more than one engineering facility and manufacturing facility used during the concept, development and realization stages and each of these facilities will have their own associated support activities. This associated support (such as providing support to an engineering facility) is external to the support related to the item, but the data output related to the item itself (such as technical documentation) is important. This data should be consistent, transferable and sufficiently comprehensive for supportability analyses to take place. Once the item enters the utilization stage, aspects such as manufacture (for repair), engineering (for possible changes) and information handling become the responsibility of the supportability and support organization.

Attributes of supportable items are associated with the operating support and maintenance support elements. Hence supportable items have the following attributes:

- cost-effective maintenance;
- compatibility of parts;
- testability;
- ease of installation;
- usability;
- fully documented configuration of the item and support equipment;
- identification and implementation of calibration requirements;
- event reporting;
- personnel suitably trained to ensure level of competence;
- obsolescence considerations – see IEC 62402;
- access to appropriate technical support when required;
- security and integrity – to resist unauthorized changes;
- robustness, resilience, recoverability and upgrades to software and hardware.

NOTE Usability relates to how easily a person can interface with an item and the ability to prevent errors during repairs. Where usability relates to a user operating a system then this would be a design attribute.

Quantitative attributes include:

- effective repair turn-round time;
- optimized risk of shortage (see 5.4);
- optimized waiting time;
- cost of ownership.

Where the facility caters for multi-items, consideration is given to:

- areas of commonality. Items such as nuts, bolts, screws, washers, oils, greases, fuels, jigs, tools, lifting equipment and test equipment applicable to the system and to the facility where the work is undertaken;
- using commonly available support equipment as opposed to special type equipment (equipment designed and produced specifically for the item requiring support – see 10.4.2). Where this is not possible, consideration should be given to using built-in test equipment (BITE) as an alternative – see 10.4.8.

5.4 Measures of supportability

Supportability is usually measured as a time interval. If the resource required is not available then a delay is incurred and it is this delay which is measured. The delay time (sometimes referred to as logistic delay time) can be aggregated over time to establish a mean delay time. Each of the resources for a particular operation can cause a delay such as human resource not available to commence work, spare part not available, special type equipment in wrong location, maintenance procedures being unavailable and environmental conditions unsuitable. In these cases, the overall support delay time is assigned to the delay for a particular activity. Adding individual times for a particular delay would not be appropriate as these individual times can overlap. See also Annex D. The overall support delay times for all activities are then used to establish the mean delay time. The overall time taken for each resource is important and these are usually measured to ensure they are within the acceptable margins of variation. This can be an important feature where maintenance is centralized for several different systems and delays to one system is caused by work being undertaken on other systems, thus reducing the resource availability.

The risk of shortage (the probability that a spare item will not be immediately available upon demand) for the procurement of spare parts can also be specified. Alternatively, the mean waiting time is defined which is determined from the spare replacement rate and the spare shortage probability. Further details are available in IEC 62550.

A mean administrative delay time can also be specified, but this is not usually support related. It relates to the time taken between when a support operation is required and when support have been notified. This delay can be significant and the current trend is to introduce automated systems wherever possible to minimize this administrative delay.

An example of the support delay times and other associated times is given in Annex D.

Cost is another measure that supportability should consider. Usually the cost is not a specific measure during design unless prior knowledge is available, such as support activity costs for similar products. Instead it is an assessment of the support activities with the aim of reducing the cost, such as adjusting the activity so that it can be undertaken by an unskilled person resulting in a less expensive activity, as well as reducing the risk on the unavailability of qualified persons to undertake the activity.

Both cost and delay time measures should be monitored to ensure that any issues are addressed and resolved. Simplification of the support activities and the removal of any issues will improve the resilience of the item. Unexpected delays can also affect stakeholder confidence in the product. In addition to the quantitative measures mentioned above, there are qualitative measures that can be specified such as the preparation and documentation of training programmes and the method of data gathering and analysis during the utilization stage.

Other measures related to organizational cost centres and profit centres are also important factors, but not within the scope of this document.

6 Supportability and support programme

6.1 General

The programme should ensure that all supportability and support aspects are considered at the early concept stage and all subsequent life cycle stages including effective retirement. It should also ensure a flexible approach is adopted so that improvements in support can be made to an item throughout its life, such as modifications required to deal with obsolescence.

The programme will be dependent upon the aims of the supplier (designer and manufacturer) accepting that these have been established based upon the dependability requirements. There are a wide range of possible scenarios and the following three cases provide examples where these scenarios will influence the programme:

- Case 1 – the total cost of a support activity is required to be optimized. The item is sufficiently competitive in the market place and the servicing and repair costs are required to make a profit.
- Case 2 – the operating costs are required to be optimized. This involves balancing reliability, maintainability and supportability. Warranty clauses will require the repairs to be minimal and at low cost. However, this does not necessarily include servicing costs.
- Case 3 – the total system costs (operating costs and revenue) during the utilization (and retirement) are required to be optimized. Items where the loss in revenue is of major importance, particularly where penalty clauses are included within the contract, require careful consideration. For example, a railway system where failure to comply with the declared timetable will incur penalties.

The programme will also be determined by the type of support that is intended to be undertaken. The following four examples should be considered:

- The user undertakes all support activities (including maintenance).
- The user subcontracts the support as and when required (including maintenance). Any replacement parts can be provided by the original manufacturer or by a third party.
- The user subcontracts support as a long term contract (including maintenance). Any replacement parts can be provided by the original manufacturer or by a third party.
- The supplier provides the item as a service and undertakes all support. This usually applies to software and some service based contracts.

The supportability and support programme specified in 6.2 and 6.3 covers all possible situations, but would have to be tailored to meet a specific scenario.

Overall, the outcome of such a programme should be a balance between the effectiveness of the system and the whole life cost with respect to the following goals:

- achieving the desired balance of item availability or reliability and whole life cost by conducting trade-offs between reliability, maintainability and supportability;
- achieving resilience to disruptive events;
- resolving ongoing risks such as supply chain risks and resource risks;
- delivering agreed assurance levels for support timeliness, quality and cost outcomes in accordance with supportability specifications.

6.2 Project management

In order to achieve acceptable supportability in a planned and systematic manner, a supportability and support programme, in conjunction with reliability, maintainability and maintenance programmes, should be integrated with the overall project design, transition and operating process. There are six basic responsibilities in such a programme as with any project including:

- assigning responsibility for supportability to a suitably qualified and experienced person;
- providing adequate resources, including analysis tools, to enable a set of supportability tasks to be performed;
- maintaining sound communication with internal and external stakeholders;
- integrating the programme into overall item development or improvement;
- establishing controls over suppliers to the programme;
- supporting continuous improvement.

Such a supportability programme should at least have the following elements:

- management, organizational and review activities to ensure effective and efficient implementation of the programme;
- a set of supportability tasks to be performed;
- transitioning and operating arrangements that allow application of continuous improvement actions during item use.

6.3 Planning and constraints

The supportability programme should be tailored for a specific item or project and its expected context of use, giving appropriate consideration to the relevant conditions, requirements and complexity. The full supportability programme described in this Subclause 6.3 would only be applied to a large and complex item being developed from the concept stage to production. For less complex items, or the application of existing designs, a simpler programme can be achieved by selecting applicable parts of the full programme.

Planning an effective supportability programme during any of the item life cycle stages requires knowledge of supportability principles, methods and techniques. Planning also requires an understanding of the organization's structure. Planning should take into account:

- intended use, life profile and useful life;
- various related cost factors;
- aligning the structure of an organization to accommodate supportability and support efficiently and effectively;
- stakeholder expectations.

In order to obtain effective results, supportability activities are best integrated with the other design and development activities rather than managed separately.

Supportability considerations depend on requirements such as item life, reliability, safety and availability and on the financial considerations related to different market situations. For example, flight systems and nuclear power plants require a high degree of safety and reliability, which drive maintenance, operating and support requirements. With other items, the cost of support resources related to the operating cost can be the driving factor, which can determine the degree of supportability required.

Examples of the supportability and support planning activities are listed below:

- determine supportability boundaries, responsibilities and interfaces with stakeholders where necessary;
- identify activities that require support;
- for each activity identify the required support resources;
- incorporate packaging, handling, storage and transportation costs and timescales with consideration of any requirements and constraints;
- establish a review process to reduce cost, delay times and potential risks or errors;
- provide inputs to trade-off studies involving reliability, maintainability, maintenance, availability and life cycle costs (these inputs should address sustainability and resilience aspects);
- accumulate all resources, taking into account the total number of items planned to be utilized;
- establish commonality of resources for an item and thence for all items;
- establish commonality of resources within the proposed facilities.

As the item is utilized, the following tasks should be included within the supportability and support activities:

- Identify external problems that can impact upon the support activities and implement improvements within the support organization (such as the actual number of items utilized is greater or less than the predicted number).
- Identify potential internal problems and resolve (such as an alternative supplier is required as the current supplier is no longer viable).
- Identify areas for improvement that can reduce costs and delays (such as technological advancements so that several items of test equipment can be combined into one).

All supportability programmes should be tailored to their context. This contextual tailoring can require the following factors to be considered during the maintainability and supportability programme development:

- Supportability requirements: the required level of supportability for operations and maintenance to provide a specified availability performance.
- Complexity: the complexity of an item determines the complexity of the support facilities. For example, if an item at a difficult-to-access site provides a high level of diagnostic capability, sophisticated accessibility to built-in test equipment (BITE) and availability of highly skilled operators are required.
- Maturity: mature items such as widely used OTS often have well-established support arrangements of known attributes, which can reduce support analysis effort, but for less mature items account should be taken of the extent of unproven technology and the development of procedures appropriate to the design.
- Criticality: support criticality should be derived from associated operations and maintenance task criticality. For example, maintenance is designated as critical where safety is a primary concern and nuclear plants and aircraft are obvious examples of safety critical items. Operational and economic issues can also be critical, such as the breakdown of a processing or manufacturing plant and essential services such as water supply and sewage and gas and electrical power supply.
- Technical constraints: higher supportability is called for when the maintenance support requirements involve more complex access requirements or related support resources such as information systems, purpose built facilities and plant and higher skill levels of personnel.
- Programme constraints: tight schedules or funding limitations can restrict freedom in the item design and the structure of the organization necessary to achieve desired levels of dependability. Additional support resources or improved organizational culture and leadership can be necessary to meet the dependability requirements.
- Operating conditions: operating conditions of items often drive the decisions in establishing the support. For example, the siting of support capability becomes critical when items are widespread and unmanned (e.g. consider a 500 km dual track rail line in an unoccupied desert where staff cannot stay out overnight).
- Storage and transportation: constraints caused by the type of support required and the special needs of any specific storage, handling and transport actions can adversely impact support delay time.
- Customer related factors: the customer's ability to support the required operations and maintenance through local carriage of spares and maintenance plan can influence the timeliness and costs associated with delivering support.
- Supplier related factors: the supplier's operations and maintenance experience and the degree to which the supplier provides access to spares or specialist staff often governs the location of maintenance actions and hence ease of support.
- Use of authorized and known sources of spares and required competence of staff can adversely affect support timing and cost.
- Environmental emissions: support necessary to the operations and maintenance of items should ensure that the emission limits set by the stakeholder or external regulation continue to be met when delays to the conduct of maintenance or the failure to deliver the necessary quality of support occur.
- Life cycle stage: the quality of support knowledge often vary as the item design and the supporting organization mature. Proactive programmes should be in place to identify early the actual support required along with the effectiveness of the supplying organization.

7 Managing supportability and support over the life cycle

7.1 General

IEC 60300-1 explains the life cycle process of an item from concept to retirement. The life cycle cost is strongly influenced by the support requirements necessary to achieve a desired operational and maintenance solution. The balancing of this ongoing support cost with operational capabilities and related risk exposure should be considered at each agreed stage of the life cycle. Such considerations are necessary to achieve the required supportability and support targets and their associated whole life costs.

Stakeholders should be confirmed at each life cycle stage as it is possible they will not be consistent for all life cycle stages. The role of supportability and related support outcomes in each potential life cycle stage is discussed in 7.2 to 7.6.

7.2 Concept stage

7.2.1 Initial considerations

Supportability and support should be considered at the earliest stage of the life cycle. Decisions made at this point will enhance or limit the effectiveness of support in later life cycle stages. Consideration should be given to the following:

- proposed useful life of the item and the intended quantity to be utilized;
- locations where support activities are to be undertaken and whether existing facilities or new facilities are intended to be established;
- locations where the item(s) are to be utilized;
- environmental conditions that can impact upon the support activities.

7.2.2 Restoration options

7.2.2.1 General

A system can be considered as being comprised of a series of indenture levels such as subsystem, unit, module and component. Progressing down through the indenture levels, three restoration options are usually considered:

- repair in situ;
- replace and repair externally (the removed part);
- replace and dispose of (the removed part).

The costs for each option should be compared together with any potential revenue loss to establish the preferred option. The option selected will be affected by the types of support required and will also take into account the quantity of systems requiring support and the time period that the system will be supported and to what extent this time period is covered by a warranty. Reliability, maintainability and maintenance are usually considered in conjunction with support to derive a balanced solution.

During the design and development stage these restoration options are extended further to establish the location of the maintenance activity (sometimes referred to as maintenance echelon or line of maintenance). These positions in an organization where specified levels of maintenance are to be carried out (such as field, repair store and manufacturer's facility) is dependent upon the skill and training of the personnel involved.

The above restoration options can be applied to operational support. As mentioned previously, an aircrew requiring a period of respite will be replaced with another aircrew if it is considered that the loss in revenue (due to the plane being idle) is greater than the cost of employing a replacement aircrew over a defined period.

7.2.2.2 Option 1 – Repair in situ

This option considers the repairable part being removed and having the necessary equipment to test the part, to identify the exact location of the fault and to carry out the repair in situ. The costs can include additional test equipment and tools as well as a repair facility area (such as a clean room) in addition to lower level parts or components available in store to achieve a repair. There is a possible waiting time delay for any failed parts to be provided from the store (see option 2 below) as well as the maintenance time (see IEC 60300-3-10).

Software can be considered as a repairable item, but the software activity is usually contained within maintenance and outside the boundary of support. However, the resources and the maintenance of those resources to enable software repairs are usually part of support. Examples of these resources are: computers, routers, servers, data repositories and their inter-connections, software operating platform with built-in security controls, configuration management processes (including checking in and checking out of software), associated facilities, the databanks, servers, software and facilities for remote back-ups as well as the resources to upload the item's software.

7.2.2.3 Option 2 – Replace and repair externally

These costs include the costs to replace the repairable part as well as the cost to repair externally. Usually the replacement part is presumed to be fully functional with final testing being undertaken on the assembled system. There is a delay in waiting for the part to be repaired before it becomes available for reuse, but spare parts held in stock can reduce this delay time. In order to effect a repair, transportation, handling and packaging costs for the part to be sent away for repair, as well as the costs to repair the part together with any testing to certify the suitability of the part, require consideration.

7.2.2.4 Option 3 – Replace and retire

One assumes that the repair of a failed part is less costly than the purchase of a new part, but support costs such as storage and transportation can outweigh the benefits. Usually there is a minimum cost ceiling where a cheaper part, below the cost ceiling, is retired. An extreme example is where the system is completely retired (such as an electronic watch). In this case, the cost of purchase is likely to include the cost of anticipated replacements and transportation during the warranty period, but it does avoid the costs for maintenance, maintenance facilities, testing and the storage of replacement parts.

There is sometimes a limit on the number of times a particular part can be repaired, in which case a new replacement part is provided.

Retirement of the unrepairable part should consider environmental, security, industrial proprietary rights as well as the recovery of any useful materials.

7.2.3 Types of support

Support can be provided by the supplier of the item, by the user, stakeholder, by a third party or by any combination thereof. If the part requiring restoration is an OTS part, then the OTS vendor is involved in determining the preferred option (repair, replace or retire). Similarly the design of a system can contain items being designed by other different organizations so that repair, replace or retire options depend upon the subcontractors, particularly if proprietary rights are applicable. When using a third party, suitable training is required to ensure the quality of service provided.

In certain cases, it is the final user and operator that is responsible for planning and developing support activities and these take place during the initial stages of operation and maintenance. This often occurs when OTS items are selected and installed into a larger system such as a manufacturing facility or petrochemical plant. The manufacturer(s) of the OTS items normally specifies recommended support activities and resources, but the user should consider the intended life profile of the system in relation to the specified life profile for the individual OTS items.

7.2.4 Establish a support data repository

During the concept stage, it is recommended that a data repository is established to detail all necessary support information.

The support information is usually linked to a part or sub-assembly of the system and changes in design are reflected in this data repository in conjunction with the configuration management data repository (which manages the design structure and all changes to the design). The amount of detail within the support data repository depends upon the complexity of the system, knowledge of the items involved (a new item can require more information than an established OTS item) and where there are differing facilities with differing support content.

The purpose of the support data repository is twofold:

- to establish sufficient information to enable supportability improvements to be initiated;
- to provide all technical information that will be eventually published, such as within an illustrated parts catalogue, operator manual, maintenance manual, training manual as well as any associated items' manuals (such as a special type equipment, jigs, tooling and test equipment).

Further details on support data repositories can be found within IEC 60300-3-12 and IEC 62550.

7.2.5 Supportability analysis

During the concept stage, estimations are made of the reliability and maintainability measures to provide an approximation of the support required to identify areas where the support costs are considered to be high and where alternative approaches can be adopted to reduce overall costs. This can result in changing the balance with reliability and the maintainability in order to reduce the loss in revenue as well as reducing the support costs. There are many factors that should be considered when undertaking supportability analysis and some examples are provided within Annex B.

7.3 Development stage

During the development stage, the supportability and support activities are modified, developed and refined in conjunction with the development of the overall system. Techniques such as reliability block diagrams, maintainability block diagrams, fault tree analysis, failure modes effects and criticality analysis, reliability centred maintenance and level of repair analysis are used to continue the supportability analysis commenced during the concept stage.

Trade-offs can be made and supportability can be adjusted to optimize performance, reliability, maintainability, testability, safety, life cycle cost and revenue. It can be desirable to eliminate the necessity for maintenance if it is technically possible or economically feasible. There is a close relationship between maintenance and the ensuing maintenance support. Further details on the types of maintenance and their impact upon support is given in Annex A.

During this stage, the operation and maintenance activities become finalized to enable the following associated support decisions to be made:

- whether maintenance personnel are provided by the organization or whether they are obtained from external sources;
- identification of the operator support activities and any associated support resources;
- who provides the spare parts, materials and consumables for operator and maintenance activities, e.g. inventory, local sourcing or external supply;
- where special tools, transportation, packaging, lifting, testing and common tools are sourced;
- condition monitoring equipment and support software to be obtained;
- facilities for maintenance, administration, technical and associated information systems that are provided to implement maintenance and operator support;
- maintenance of the support equipment (as opposed to maintenance of the item) to keep it in a serviceable state to carry out its function including any documentation;
- training documentation, aids and equipment should be identified and provided at the time that training is performed prior to operation and maintenance. This training continues as necessary during the utilization stage and into the realization stage;
- preparation of any required documentation to enable operator and maintenance support such as the illustrated parts catalogue, operator manuals, maintenance manuals and handbooks.

During development, risks to the support that is required during operation and maintenance should be identified and understood. Examples include risks to the supply chain, risks affecting personnel or other resources. Risks associated with obsolescence should also be considered (see IEC 62402). Plans should be put in place to reduce any risks which are considered to be unacceptable or to mitigate any consequences that can occur.

Stakeholders should be consulted to ensure their support needs are understood and documented. The development of systems increasingly apply OTS items rather than bespoke designs. This approach increases dependence upon suppliers or other support organizations to provide the maintenance and support related information or services required during the life of the item. This scenario of OTS item integration requires an integrated support approach as described in IEC 60300-3-12. The original supplier provides basic support planning, but the design and construction organization should consider the consequences of the use of the OTS items and their integration in the final system design.

7.4 Realization stage

The supportability and support analysis undertaken (see Annex B) provides the estimations for support. During this stage, final estimates are verified, in particular the number of items to be produced and their rate of delivery. If the user or purchaser intends to provide the support, or plans to subcontract it as opposed to relying upon support from the supplier, then the user or purchaser should verify that appropriate contracts are in place and all necessary information (such as the illustrated parts catalogue) has been successfully transferred.

During the manufacture, installation and commissioning of the system, all the resources required by support should be initiated so that at the commencement of the utilization stage all required resources are readily available. This should take into account any additional time for the commissioning of required facilities, any complex support equipment and any special warehousing requirements. For the manufacture of many systems which are planned to be delivered in batches, then any increases in the required support resources should be delivered, ideally, in advance of the subsequent system deliveries.

Personnel involved in the manufacture, assembly and installation processes should record any problems encountered so that support personnel can establish if these problems can have an impact upon the support activity. Examples are more failures than expected during inspection and ambiguity in the assembly instructions. Awareness of counterfeit and obsolescent items are also important considerations when dealing with large quantities being delivered over a long timescale.

If the system undergoes a prolonged installation and commissioning stage, then support activities can be required and this should be taken as an opportunity to verify these support activities to provide confidence in the supportability analysis process.

7.5 Utilization stage

During this stage, customer satisfaction is key. Resolving any support issues identified by the user or purchaser will provide trust in the item and can result in more items being procured as well as confidence in future products that will be produced by the supplier.

Supportability analysis continues during this stage to gather data, to identify areas of weakness, areas for improvement and to monitor results where changes have been introduced. During operation and maintenance, the required support resources will change for a number of reasons:

- it is possible that the manufacturer will have agreed to provide support only for a fixed period;
- it is possible that the original life profile or customer needs, or both, will have changed and this can impact upon the amount of required resources;
- the support organization wishes to introduce change because of quality or cost;
- advances in tools and condition monitoring can result in improved quality and cost;
- the introduction of improvements or modifications can impact on the support resources;
- changes in the quantity of systems in use such as customers procuring more technically advanced systems, i.e. the system itself is becoming obsolete;
- changes in the risks increasing or decreasing, such as supply chain risks;
- enhancements to the item that can impact the support activities.

7.6 Retirement or reuse

Throughout the utilization stage, support can be involved with the retirement of spare parts and items that can no longer be reused. Hence support should have already established processes for the retirement of various items within the system in the most sustainable manner.

The decision to replace and retire a complete system requires consideration of at least the following criteria:

- ability to perform its intended function, under stated conditions, for a specified period of time (reliability);
- ease by which it can be maintained (maintainability);
- availability and capability of maintenance support activities, including an appropriately skilled workforce and spares obsolescence (maintenance support);
- economic cost, where system replacement can be more cost-effective than ongoing repair (economic cost);
- technological advancements have resulted in the system becoming obsolete.

8 Assurance

8.1 Assurance objectives

Supportability and support assurance is intended to provide assurance to all relevant stakeholders that agreed qualitative and quantitative requirements for supportability are met and will continue to be met in the future. Assurance objectives can be general, across the totality of the supportability and support programmes, or it can be targeted towards specific requirements, bounded by a life cycle stage or physical boundary.

8.2 Methods of assurance

8.2.1 Verification

The formal system engineering process requires verification of achievement of specification and validation of the end item against user requirements and needs in the actual environment. Supportability verification is a continuous process of generating, collecting, analysing and evaluating support related data as they become available in the course of project development and comparing results with specified supportability requirements.

Methods of supportability verification differ according to the programme stage. In the majority of cases, estimations are gathered regarding the repair turnaround time and replacement rate, but other factors are usually predictions such as number of items in operation, number of support personnel required and support equipment availability. These factors usually have risk margins included and the capability of the support organizations is usually predicted based upon past experience. Actual measurements can only occur after entering the utilization stage.

Much of the verification is based upon the collection of data to show that all factors have been considered. For example:

- Based upon the number of items that are in operation at any given time, it is possible to estimate the number of support personnel that require to be trained and the rate at which this training should take place. A risk margin is usually incorporated from which it is possible to estimate the facilities and equipment required, the staff necessary to conduct the training and the costs required to accomplish this activity. Previous experience is required to determine the timescale to initiate this activity and knowledge of recruitment for specific skills are required if the training involves additional staff. If the equipment involves the system or a simulation of a system then the timescales and costs involved should be incorporated.
- The storage of spare parts depends upon the number of spares that are estimated to be required, based upon the repair turnaround time, the replacement rate and the risk of shortage applied to all possible items within the system as well as the proposed number of systems planned to be in operation. The volume of storage (the sum of all the volumes of spares to be stored) should be estimated as well as any variations in the conditions of storage. From this, the required storage facilities, the personnel to maintain the store as well as the costs involved can be estimated. It can be necessary to have some flexibility in the storage facility in case the number of systems in operation increases.
- Risks associated with the non-functional attributes should also be considered and evidence gathered to demonstrate how they have been addressed, for example security risks (impacting the item itself as well as impacting its data), risk of obsolescence, possible supply chain risks.

Any item failures identified during manufacture are used to verify and validate the replacement processes within the illustrated parts catalogue. In addition, there are other practices that can also provide assurance, such as:

- quality processes within a quality management organization that provides assurance to stakeholders that outcomes have been achieved through defensible techniques and are repeatable;
- the monitoring of personnel skills and ensuring that they are periodically reviewed so that they are maintained and appropriate for the task being undertaken;
- management of any third parties involved. The boundaries of the third party responsibilities should be clear, with interfaces, exchange of data and method of reporting fully documented (see also IEC 60300-3-16).

8.2.2 Dependability case

The dependability case (see IEC 62741) provides an expanding body of evidence which aims to progressively decrease the uncertainty around the achievement of dependability requirements.

The results from any of the supportability and support activities, as well as additional evidence, such as user feedback, can be collected into an evidence framework to provide the argument.

As the context or supportability and support requirements change during the lifecycle, the dependability case requires review to determine how that affects the existing evidence and what additional evidence is required to be collected to maintain the claim.

9 Supportability and support information

9.1 Data collection

Data is best collected at source in its original support analysis format (e.g. using drop down menus or dialog boxes in associated information systems such as works orders, defect management, failure reporting and corrective action systems). Such menu driven data collection:

- limits choices to predetermined likely options (this can be disadvantageous when unanticipated support events occur);
- ensures consistency of response;
- speeds the data collection process;
- eliminates errors caused by typing or spelling.

The amount of information involved with supportability and support require the data to be stored in a computerized information system which is capable of cross-communicating with other computerized data systems (see IEC 60300-3-12: Integrated logistic support).

When retiring an item, the lifetime of data can be collated and analysed to inform the supportability and support performance during the life cycle. This information can be used for the improvement in the development, realization and utilization of future items.

Information developed from supportability studies during design falls into one of three categories:

- functional configuration that defines the functional capability of an item as represented by artefacts or information items such as specifications;
- physical configuration that describes the design solution as represented by artefacts such as plans and drawings;
- derived information that represents the support necessary to ensure that a physical configuration can achieve its functional requirements in a sustained manner.

9.2 Configuration management

During the concept and design stages, the structure of the drawings are configured to establish a master record index (technical file). Each indexed item contains a complete list of all the drawings and associated instructions required to build the specific item. Changes to the design are directly related to a specific indexed item. These indexed items become the intended replaceable items once the design is completed. If a change crosses the boundary of two indexed items, then usually two changes are required together with a change identified at a higher indexed item if these changes impact one another. In this way any specific build related to a master record index, precisely defines the issue status of all drawings and associated instructions. Supportability and maintainability are involved in defining the ideal replaceable parts and as such, can greatly influence the structure of the master record index in order to meet the dependability requirements.

Configuration is a precise engineering description of the functional and physical attributes of an item as described within the design documents. Also included is operational or "derived" information necessary to the ongoing support of the item. The approved configuration of an item represents the approved baselines plus all the approved changes to those baselines.

Configuration baseline documentation also includes the cross mapping of configuration documents to provide connectivity between functional, physical and operational information. An example is an allocated baseline that maps functional requirements to physical configuration items.

The current configuration of any item is the actual functional, allocated and physical baseline status of that item at that time. The configuration of new items is established by the "as-built" record produced at the completion of acquisition projects and is verified by a physical and functional configuration audit. The configuration of existing items can be established by physical audits as necessary and by a review of engineering plans and records. Maintenance often introduces components and modules with a new serial number. Therefore, the configuration lists will be updated.

Configuration management is an essential element of dependability. It is important for several reasons, including the following:

- accurate knowledge of the approved configuration is necessary to establish and to maintain engineering control over the integrity and suitability of the item for its intended purpose;
- approved configuration provides the basis for determining maintenance and support requirements for the item;
- management of changes, which ensures that the current configuration remains in line with the approved design, provides the means of assuring that the item is capable of performing the required functions, safely and reliably.

Management of item configuration after delivery is a continuing process, involving the progressive identification, tracking and approval of engineering changes during the life of the item. This includes review and updating of support provisions for the item, to ensure that they remain in line with the functional requirements, physical construction and condition of the item.

Changes to an item's configuration (functional and physical) are managed via a formal change control process involving integration of engineering or design authority for technical aspects and a configuration control board for business aspects.

9.3 Document management

The data held within the support data repository is progressively updated as the design progresses from concept to modifications during utilization. An adequate change control mechanism is required to control the updating and entry of new data. When a design is updated, all the associated data is not updated simultaneously and it is important to recognize where updates have occurred and where they are still to be updated or where the update is not necessary. For example, the design update can occur in the configuration management data repository, but it can be some time before the failure rate is updated and, in some cases, it is possible that the failure rate will not change.

It is necessary to decide how documentations will be supplied with an item. Solutions range from hardcopy, through downloadable portable document format (PDF) to fully interactive technical publications.

It is also important that support data repositories holding different data, but assimilated in differing formats, are designed with unique identifiers for each data element so that interfacing across data repositories can occur. This ensures that data is not repeated resulting in data errors.

9.4 Technical manuals

9.4.1 General

Technical manuals and technical documentation for hardware as well as software and services should contain information and procedures so that operators and maintainers perform their job correctly, safely, efficiently and cost-effectively. They should also be used as training aids so that the training is based on the same documentation as that available in use. They should be designed to suit the needs of the user and organized for easy access and reference.

Suppliers should ideally provide documentation written in a language specified by the customer and understandable to the user. Where this is not possible, critical and safety instructions should be provided in the local language. The cost-effectiveness of translating other documentation should be examined. Concepts such as the Aerospace, Security and Defence Industries Association of Europe simplified technical English specification (ASD-STE100) helps to ensure clarity of information.

In the majority of cases the technical manual usually includes an illustrated parts catalogue and provides the link between the physical location of an item within the system and the unique identification applied for supportability. A general approach to compiling data presents an engineering breakdown in disassembly sequence, identifying all assemblies and their individual components together with other detail parts, which cannot be assigned to assemblies, in accordance with their engineering drawings and build of materials. Sequencing of these items is by using unique identification and it is this practice which enables production of the illustrated parts catalogue from the same data. The engineering breakdown is to the level which matches the customer's maintenance plans. In addition to the engineering breakdown, the following can also be listed:

- raw materials;
- consumables;
- repair kits;
- shipment and storage of parts.

Particular items are required to be listed at the end of a figure such as:

- storage and shipping parts;
- un-programmed devices and data carriers;
- markings (placards, decals, etc.);
- storage and shipping containers;
- repair kits;
- parts kits.

Specific items require to be contained in separate figures. Types of items may include:

- raw material;
- consumables such as screws and gaskets;
- general tolerance figures;
- test equipment and tools;
- repair kit breakdown.

Technical manuals for complex systems can also contain a general description, applicable theory and procedures that cover items such as:

- operation;
- fault diagnosis;
- repair;
- preventive maintenance;
- service;
- test;
- schematics or wiring diagrams;
- tools and special support equipment;
- facilities information (e.g. voltage required);
- description of applicable software programs.

The level of detail within maintenance documentation should be tailored to the scope of maintenance activities allowable to the user. Too much detail is confusing and can lead to inappropriate attempts to undertake maintenance beyond the capability of maintenance staff and support equipment.

The person responsible for documentation should be user-oriented and familiar with personnel considerations. The following factors should be considered:

- user attributes, requirements and formats;
- item attributes;
- environmental conditions;
- job design;
- training design;
- level of maintenance and operator support.

The documentation will be provided by using physical means, such as paper manuals, audio, video, or electronically on computer media or the internet, as is appropriate for users.

9.4.2 Development of a technical manual

Emphasis on the development of a technical manual should be given to those tasks which:

- are difficult to perform;
- occur frequently;
- influence item capability, availability and reliability;
- have safety implications.

The best technical manual layout is that which is most obvious to the user although it varies from one case to another. In practice, an effective technical manual will be organized in the following way:

- natural order (performance or occurrence);
- most critical to least critical;
- most frequent to least frequent;
- location, distance, or availability;
- required to maintain capability;
- clear distinction between notice (something that makes the task easier), caution (something that can damage equipment) and warning (something that has safety implications).

Maximum use should be made of existing technical information. This is achieved in the following ways:

- evaluating existing technical information for adequacy in meeting specification requirements;
- determining the most cost-effective approach, such as:
 - use of existing information;
 - upgrading of existing information;
 - preparation of new information.

All requirements for technical information should be included in the item contract. They can include the following:

- source data;
- proprietary data;
- reproduction rights;
- changes, modifications or alterations.

Where existing documentation is used that applies to a range of applications (e.g. commercially available manuals for common items), guidance should be included relating to the applicability of the manual to the specific application, item configuration and environment being maintained.

Technical manuals should be prepared in formats that make them easy to read and understand. The following principles should be followed:

- use of simple, familiar words;
- text and illustrations integrated;
- good style and language;
- technical information matched to the medium.

9.4.3 Evaluation

The effectiveness of a technical manual can be best evaluated during actual use, to see if the user can do the job efficiently. The general criteria are as follows:

- Can the representative users do the job to the required standard?
- Can the overall system performance be improved (assumption: improving maintenance performance improves system performance)?

In addition, implementation of suggested improvements from users are essential for an effective technical manual.

9.4.4 Amendment of documentation

Procedures should be developed and implemented to enable changes to item information, maintenance tasks, procedures, spare parts and other information contained in the maintenance information system and associated maintenance documentation in order to keep them up-to-date.

9.4.5 Event reporting

Usually the event reporting procedure is a support activity and plays an important role in the monitoring of detrimental events and the control of modifications to overcome them. Serious faults or defects that have an impact on safety and availability (incidents) should be closely monitored. For example, failures can be due to the quality of the replacement part (perhaps containing counterfeit parts) or ambiguity in the assembly instructions. A procedure should be adopted that identifies such errors or faults and initiates investigative actions to identify the cause and any subsequent action that can be required to rectify the problem. In some cases, the discovery of a serious failure requires urgent action to ensure that safety issues are addressed and all other users of the equipment are aware of the problem.

9.4.6 Communication

Many organizations produce service bulletins that advise all users about the possibility of serious failure and of the checks to be made to ensure that an item is in a safe condition and retains its required level of functionality. This can include extra planned maintenance checks or inspections to be undertaken until design action can be taken to correct the defect. To this end, further maintenance actions and modification instructions can be issued to correct the defect and return the item to full functionality. Examples of such bulletins can be seen in the recall of vehicles to have important safety modifications incorporated, or the grounding of aircraft after an accident or incident pending an inspection.

A means of communicating information to users and maintainers should be considered, if it does not already exist and the following list is a guide to the type of information it can include:

- defects discovered by users or maintainers which would be pertinent to users;
- modifications introduced and their applicability;
- changes to spare parts lists to introduce modified items;
- changes in maintenance procedures that have been introduced;
- changes in operating procedures to improve safety or prevent damage;
- customer satisfaction reports.

10 Resource management

10.1 Provision of resources

The primary resources applicable to support are as follows:

- human resources, including both internal and external personnel, used to carry out support activities;
- training;
- spare parts and consumables used to repair or service items;
- support facilities used to conduct work on the item (such as servicing and repair), accommodation to house any computerized support information systems;
- support equipment;
- information resources required to manage and execute all support activities. These are a follow-on from the supportability and support information mentioned in Clause 9;
- financial resources to fund support.

Resources for support are initially identified during support planning in the design and development stage. As conditions change in the development stage, the type and amount of these resources should be reviewed and updated on a regular basis. Many factors influence support resources such as the following:

- location of facilities and items to be maintained;
- location of support resources;
- level of dependability required;
- type of item being supported;
- importance of item functionality;
- economic factors;
- corporate objectives.

10.2 Human resources

To achieve operational objectives at the lowest overall life cycle cost, it is required that qualified and trained personnel be available. For the majority of systems, the most expensive element of operational and maintenance support are the personnel. Careful selection of personnel and their effective training and supervision can minimize this cost or increase the benefit of support.

For complex systems that employ advanced state-of-the-art designs, the number of personnel, their skill levels and their training should be derived from an analysis of maintenance needs. Personnel specialties, skill levels (i.e. basic, intermediate and high) and numbers required can be identified by evaluating the complexity and frequency of tasks as part of the maintenance support analysis. Specialties and skill levels should be established for each location where an item is operated and where maintenance is performed.

The qualifications of personnel assigned to perform maintenance and maintenance support should be kept up-to-date. Special certification can be required for some tasks.

10.3 Training

Training should be developed so that it is consistent with the system design, operator or maintenance concept, support equipment, procedures and the available skill levels of all personnel involved. It will be necessary for training aids and documentation to be developed and provided, which are specific to the context in which they are used.

Training, data and the technical manual are interdependent. It is necessary to establish training requirements based on available skills, job requirements and the technical manual. Trade-offs among technical manual, training and training materials, equipment and aids should be made on the basis of overall programme cost-effectiveness.

Personnel should be selected and trained to become knowledgeable and capable technicians on site when the delivered item becomes operational. Personnel training should include both initial and continued training to cover attrition, skills decrement, replacement of personnel and the impact of item changes or modifications.

A personnel training plan should cover the following:

- operator training, including type of training, basic entry requirements and a brief course outline;
- maintenance training at all applicable lines of maintenance, including type of training, basic entry requirements and a brief course outline;
- training equipment, devices, aids and data required to support operator and maintainer training activity;
- proposed schedule for initial operator and maintainer training;
- proposed approach for further training throughout the system life cycle.

A training programme should consist of the following major components:

- a training needs analysis (TNA), which includes specific training objectives;
- implementation of the training, which includes methods for delivery of instruction, method for assessing trainees, and criteria for evaluating the effectiveness of the training programme.

Where elements of maintenance have been delegated to other support organizations, the training plan should be tailored to address just those elements under the responsibility of the maintenance organization and any interfaces required with other organizations.

10.4 Support equipment

10.4.1 General

All equipment required for maintenance, servicing and inspection of an item, but not essential for its operation, is called support equipment. The types and quantities depend on the type of support work required.

Support equipment includes the tools required to undertake the maintenance tasks, stands and fixtures to enable work to be carried out safely and measuring equipment to test mechanical, electric and electronic operating parameters. It can also include interface jigs and equipment to allow an item to be tested separately from the equipment or assembly it belongs to.

10.4.2 Types of support equipment

Support equipment is classified by use, availability and source into two principal categories of common or general-purpose support equipment and special type equipment (STE):

- common support equipment includes any equipment that is of general supply, such as tools, jacks and general-purpose meters, which can be bought off-the-shelf or is generally available and applied to the support of the product;
- STE is that equipment, which is required for performing a specific task for a specific item, such as special fixtures to allow measurement of mechanical parameters, or a special electronic analyser or tester that is manufactured or adapted for the support of the item.