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Full document details: 21/30436071 DC

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.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
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.	



56/1918A/CD

COMMITTEE DRAFT (CD)

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56/1884/CD, 56/1892A/CC

IEC TC 56 : DEPENDABILITY	
SECRETARIAT: United Kingdom	SECRETARY: Mr Amit Patel
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

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TITLE:

Dependability management - Part 3-10: Application guide - Maintainability and maintenance

NOTE FROM TC/SC OFFICERS:

Secretary's note: 56/1918A/CD replaces 56/1918/CD which was issued with an incorrect draft.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DEPENDABILITY MANAGEMENT –

**Part 3-10: Application guide –
Maintainability and maintenance**

FOREWORD

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International Standard IEC 60300-3-10 has been prepared by IEC technical committee 56:Dependability.

This second edition cancels and replaces the first edition published in 2001 This edition constitutes a technical revision.

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

a) This section shall be completed for CDV when the agreed changes are known.

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

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

181

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

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

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

- 188 – reconfirmed,
- 189 – withdrawn,
- 190 – replaced by a revised edition, or
- 191 – amended.

192

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

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

197

198

INTRODUCTION

199 This document provides guidance for identifying and applying appropriate analysis and
200 assurance techniques for the dependability attribute of maintainability, including best practice,
201 the measures appropriate for requirements and how to evaluate them, and the relationship with
202 other dependability attributes.

203 Maintainability is the ability of an item to be retained in, or restored to a state to perform as
204 required. Maintainability is concerned with the relative ease and economy of time and resources
205 to undertake maintenance actions in a defined context.

206 For software, maintainability is the ease with which the software can be modified without major
207 reverse engineering or redesign to address faults and changing needs. The purpose of software
208 maintenance is to retain the value of software over time.

209 Maintenance actions are those necessary to retain inherent levels of safety and reliability and
210 to restore those levels when degradation occurs. The relative ease and economy of
211 maintenance actions relates to the total economic impact resulting from the actions' frequency,
212 timing and duration. Such maintenance and associated maintainability characteristics are an
213 inherent feature of the item design to achieve the desired timeliness, cost and quality of support
214 for required operational and maintenance action.

215 This standard provides managers and technical professionals involved in specification, design,
216 development, manufacture, acceptance and use of products and services with guidance on how
217 to achieve, analyse and assure maintainability and maintenance.

218 Guidance in this standard can be used at any time during the life cycle of an item or project to
219 guide the planning and implementation of a maintainability or maintenance program with a
220 balance of cost, risk and performance, and their associated levels of assurance. These
221 outcomes can be explicit in contractual agreements and statutory obligations or implicit in
222 commitments to all stakeholders.

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

226 The maintainability and maintenance programme content described in this document can be
227 tailored to suit the needs of the application.

228 This document is one of the six 'top level' interrelated dependability standards that provides
229 managers and technical personnel with guidance on how to effectively plan and implement
230 dependability activities. As such, this standard should be used in conjunction with:

- 231 – IEC 60300-1 which provides guidance for recognizing the importance of dependability, how
232 to integrate dependability activities into existing management systems and life cycle
233 processes, and the management activities to achieve and improve dependability outcomes;
- 234 – IEC 60300-3-4 which provides guidance for writing dependability requirements in
235 specifications together with a means of assuring the achievement of those objectives;
- 236 – IEC 60300-3-1, IEC 60300-3-14 and IEC 60300-3-17 which provide guidance for identifying
237 and applying appropriate analysis and assurance techniques for reliability, supportability
238 (and support) and availability.

DEPENDABILITY MANAGEMENT –

Part 3-10: Application guide – Maintainability and maintenance

Scope

This part of IEC 60300 gives guidance to technical or financial personnel on the basic principles of maintainability and maintenance activities that are applicable to any business model.

This document describes:

- the value and nature of maintainability and maintenance characteristics;
- the interfaces and potential trade-offs with related dependability attributes of reliability and supportability that can be made during the life cycle of an item;
- the elements of maintainability and maintenance programmes;
- the application of maintainability and maintenance programmes through the life cycle;
- assurance of achieving maintainability and maintenance requirements;
- maintainability and maintenance data and information management.

This document is applicable to equipment, software, services, plant or structures, and gives guidance on matters of common interest to any business supplying, purchasing or sustaining products, services, plant or structures.

Normative references

There are no normative references for this document.

Terms, definitions and abbreviations

For the purposes of this document, the terms and definitions given in IEC 60050-192 and the following apply.

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

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

3.1 Terms and definitions

3.1.1

item

subject being considered

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

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

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

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

3.1.2

maintenance plan

structured and documented set of tasks that include the activities, procedures, resources and the time scale required to carry out maintenance

Note 1 to entry: See also ISO/TR 12489:2013, 3.4.6.

[SOURCE: EN 13306:2010, 2.5, modified – Note 1 to entry has been added.]

3.1.3**Off-the-shelf**

OTS

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

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

3.1.4**Hard time maintenance task**

item repair or replacement activity at regular intervals

Note 1 to entry: Sometimes referred to Fixed Age Maintenance Task.

3.1.5**Indenture level**

level of sub-division within a system hierarchy

EXAMPLE System, subsystem, assembly and component.

Note 1 to entry: From the maintenance perspective, the indenture level depends upon various factors, including the complexity of the item's construction, the accessibility of sub items, skill level of maintenance personnel, test equipment facilities, and safety considerations.

[SOURCE: IEC 60050-192:2014, 192-01-05]

3.1.6**Maintenance echelon**

a position in an organization where specified levels of maintenance are to be carried out on an item

Note 1 to entry: Examples of maintenance echelons are in situ, repair shop, depot.

Note 2 to entry: Maintenance echelon is characterized by the skill of the personnel, the facilities available and the location

3.1.7**maintenance concept**

definition of the 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 60050-192:2014, 192-06-02]

3.1.8**maintenance policy**

intentions and direction of an organization as formally expressed by its top management

[SOURCE: ISO 55000:2014, 3.1.19]

3.2 Abbreviations

ATE	automatic test equipment
BIT	built-in test ^[1] _{SEP}
BITE	built-in test equipment ^[1] _{SEP}
OTS	off-the-shelf
FMEA	failure modes and effects analysis ^[1] _{SEP}
FMECA	failure modes, effects and criticality analysis
ILS	integrated logistic support
ILSA	integrated logistic support analysis
ILSP	integrated logistic support plan ^[1] _{SEP}
LCC	life cycle cost ^[1] _{SEP}

330	LORA	level of repair analysis
331	LRU	line replaceable unit ^[1] _{SEP}
332	MLDT	mean logistic delay time
333	MTTM	mean time to maintain (preventive tasks)
334	MTTR	mean time to restoration (or repair or recovery)
335	MaxTTR	maximum time to repair
336	OEM	original equipment manufacturer
337	RCM	reliability centred maintenance
338	TA	task analysis

339 Maintainability and maintenance overview

340 4.1 Description of maintainability

341 Maintainability is a measure of the ease and speed with which an item can be restored to or
342 retained in an operational status, having reached a defined failed state. It is a characteristic of
343 the item design, construction, installation and commissioning. That maintainability
344 characteristic is influenced by the delivery of the actual operating and maintenance support
345 applied to undertake the restoration or preventive maintenance activity.

346 Software differs from hardware in that it does not wear out and faults originate in the
347 specification, design logic or coding process and they can lie hidden until specific input
348 conditions occur. For software, maintainability relates to the ease and speed with which
349 software can be modified to change or add capabilities to correct faults or defects, improve
350 performance or other attributes, or to adapt it to a different environment.

351 Maintainability can be measured as the probability that a given maintenance action, performed
352 under stated conditions, using specified procedures and with defined support, can be completed
353 within a specific time period. This defined support may include personnel with defined
354 competencies, spares, tools, information, facilities, and logistics applied within a defined
355 organizational context.

356 How maintainability is addressed is dependent on the context. Item designers and
357 manufacturers are generally responsible for the maintainability characteristics however the item
358 might be OTS, where the manufacturer has no knowledge of the final application and interfaces,
359 it might be a bespoke design for a known application allowing for specific design characteristics
360 to support the user, or it might be a combination, using OTS items with inherent maintainability
361 characteristics in a design for a known application. Maintainability programmes can be tailored
362 for the various contexts.

363 Maintainability considerations when utilizing subcontractors or supplier products are described
364 in Clause 5.12.

365 4.2 Description of maintenance

366 Maintenance is described as the combination of all technical and administrative actions,
367 including supervisory actions, intended to retain an item in, or restore it to, a state in which it
368 can perform as required when required.

369 The use and maintenance (utilization) stage is by far the most enduring and can be considered
370 as the centrepiece of the item life cycle. It begins as soon as the item is accepted and enters
371 into service and ends with the decision to dispose of that item. During the utilization stage,
372 effort is focussed on the continued availability of the item to provide a defined service and also
373 on the maintenance and support of those systems to assure a continuing service capability.

374 The types of maintenance tasks necessary to achieve the required availability of a system or
375 item need to be identified before a maintainability programme can be fully defined and
376 implemented. Not all items are maintainable and are run to failure. Many items are
377 unmaintainable after failure by design intent and others because possible maintenance action
378 is not cost effective versus an alternative.

Comparatively, maintenance is the sum of actions undertaken to return the items to a serviceable condition whereas maintainability is a measure of the ease of completion of those actions and their effectiveness. Support is the external resources required to complete the maintenance actions and supportability is a measure of the ease of the provision of those external resources and their effectiveness.

4.3 Principles

Evaluation and control of maintainability and maintenance is founded on a set of principles. These principles should directly influence the intent of, design for, and delivery of an organization's maintenance activity.

These principles are as follows.

1) Maintenance exists to provide value.

Maintenance tasks, and the associated maintainability characteristics of an item, exist to provide value to stakeholders. Value is what is important to the business, reflected in organizational objectives. Value can be tangible, such as increased volume of product, or intangible, such as improved consumer confidence. It can be financial, such as reduced cost to repair an item, or non-financial, such as improved safety.

This principle requires, when designing maintainability characteristics of an item or a maintenance program, that:

- a) the organizational objectives are known and understood;
- b) the item's context of use is known. This requires:
 - i) the item function and definition of function loss to be clearly defined,
 - ii) item configuration, operating characteristics and operating environment should be defined sufficiently for the specified purpose.
- c) maintenance tasks are determined using a defensible process. This assures alignment between the objectives and resultant maintenance tasks and requires:
 - i) processes to be data-driven, with all required financial and technical data to be obtained or derived with justified confidence to achieve the requirements;
 - ii) risks from item failure to be determined and maintenance tasks developed to treat those risks;
 - iii) human capability, such a physical and mental limitations, and physical capabilities, such as sparing, tools and access, to be considered when tasks are developed.

2) Maintainability and maintenance tasks are inherent to a design solution.

Maintainability is an inherent characteristic of a design solution. This means that it is a permanent attribute of that design which cannot be improved without a design change. Maintainability and maintenance tasks are inextricably linked such that maintenance tasks become a consequence of the design solution.

This principle requires that maintainability and maintenance activities are:

- a) commenced during the development phase;
- b) consistent with functional requirements;
- c) conducted concurrently and are iterative in nature;
- d) influence the design solution.

3) Maintainability can be balanced against other dependability attributes and stakeholder requirements to achieve organizational objectives.

Maintainability, reliability and supportability can be balanced and traded-off to achieve availability, a measure commonly aligned with business success. Dependability attributes can also be balanced and traded-off with other organizational considerations such as cost and assurance level required. A number of combinations of attributes and other requirements can result in organizational objectives being achieved. Maintainability and maintenance tasks' contribution to organizational objectives is to be considered in each activity.

- 429 a) organizational objectives are known and understood;
- 430 b) there is an understanding of the contribution and balance of dependability attributes
- 431 which can support achievement of organizational objectives;
- 432 c) analyses and studies are conducted to determine and measure dependability attributes
- 433 considering the item's context of use.
- 434 4) Maintainability and maintenance activities continue during use to assure that the item
- 435 continues to meet stakeholder requirements.
- 436 During the use of an item, the environment, stakeholder requirements and other factors can
- 437 change and, thus, continued achievement of maintainability will need to be re-evaluated.
- 438 This principle requires:
- 439 a) dependability data and information is collected, analysed and evaluated to determine
- 440 the realized maintainability measures;
- 441 b) realized maintainability measures are compared with other realized measures to
- 442 determine contribution to, and achievement of, organizational objectives;
- 443 c) necessary changes to maintainability and maintenance requirements are considered in
- 444 conjunction with other dependability attributes as organizational objectives evolve; and
- 445 d) new iterations of maintainability and maintenance activities are conducted as the
- 446 requirements and context evolves.
- 447 When applying these principles to develop a maintainability or maintenance programme
- 448 activities should be tailored taking into account market conditions, item complexity and
- 449 stakeholder requirements together with the size and experience of the organization.

4.4 Benefits

451 Benefits of controlling maintainability and maintenance include:

- 452 – supporting the achievement of organizational objectives;
- 453 – providing justified confidence that the maintainability of items will be as required, when
- 454 required;
- 455 – managing the risks of failure or degraded performance in an effective way to achieve a
- 456 balance of cost, risk and performance;
- 457 – enabling design weaknesses to be identified and improved with consideration for
- 458 performance, risk and through-life cost;
- 459 – providing information and data that support the continual improvement of maintainability
- 460 performance;
- 461 – establishing an appropriate and cost effective maintenance programme;
- 462 – reduced item down time resulting in improved availability;
- 463 – reduced maintenance effort;
- 464 – improved security of software;
- 465 – improved timeliness of maintenance delivery;
- 466 – improved quality of maintenance resulting in higher realized levels of reliability;
- 467 – improved safety of maintenance personnel;
- 468 – improved sustainability by increased life and possibility of re-used.

4.5 Interfaces

4.5.1 Description of dependability

471 Dependability is the ability to perform as and when required. A dependable item is one where

472 there is justified confidence (developed through testing, analytical and risk based approaches)

473 that an item will operate as desired and satisfy agreed stakeholder expectations. Dependability

474 has many attributes but is usually characterized in terms of reliability, maintainability,

475 supportability (including maintenance, operations and support to both).

Reliability, maintainability and supportability each have influencing interfaces that are interlinked and together define availability. The two interfaces that relate to maintainability and maintenance are reliability and supportability. The way that maintenance and support are carried out will also influence the reliability and availability that are achieved in practice. The maintainability of an item is determined by the design but with trade-offs between maintainability and both reliability and supportability that could impact not only the resultant availability but also other factors such as performance, risk and cost. For example, improving the maintainability of an item could result in higher reliability but with the consequence of the need for increased maintenance that requires more supportability and support and could result in decreased availability. Trade-offs between maintainability and other requirements can be required for software design as well. For example, designing flexibility in software can make it more difficult to maintain, and safety requirements can increase the time required for maintenance due to process complexity.

4.5.2 Effect of maintainability on reliability

Maintainability and reliability are both determined by the design. For some items, due to the expected life or use of that item, there is no need to incorporate maintainability. For other items with a longer expected life, maintainability is important so that the maintenance can be applied to achieve required reliability by preventing failures.

For hardware, maintenance is intended to manage the consequences of item failures. Maintenance cannot change the inherent reliability or maintainability characteristics of the item but can influence the operational outcomes.

Inherent reliability assumes the product receives perfect maintenance and represents “a measure of reliability that includes only the effects of an item design and its application, and does not account for effects of the operational and support environment”. This is sometimes referred to as “intrinsic” reliability.

Partial repair or imperfect maintenance can result in elements of the item having a lower realized reliability. Conversely, the conduct of additional maintenance actions, while not cost effective, may achieve a target level of operational reliability that is increased from the level in the optimal balance intended from the original design.

Repairs to items that have a random failure pattern will not influence the operational performance of the item unless they introduce additional degradation or defects which decreases the failure rate.

Any maintenance intervention brings the likelihood of improvement or reduction in reliability and performance. Maintainers can determine improvements in the maintenance process and can provide feedback to the developers about the product itself to improve reliability. There is also potential for errors in maintenance which can lead to reduced reliability. Such impacts can affect both preventive maintenance and corrective maintenance outcomes.

Such effects may be quantified by values such as task effectiveness, resulting from human performance. In these cases, task effectiveness can relate to the either the likely success in identifying a degraded condition or the effectiveness of a repair task in returning the item to its intrinsic reliability.

For software, maintenance includes the evolution of the software program and, therefore, maintenance can result in the improvement or degradation of both the item's inherent reliability and maintainability. This can affect the ongoing maintenance needs. If the item is highly maintainable, the probability of inducing faults through the software evolution is minimised, resulting in software which meets the reliability requirements with a reduced ongoing need for further evolution.

4.5.3 Effect of maintainability on supportability

Maintainability provides the ability to perform maintenance with the subsequent need for support. The degree and type of maintainability that is designed into the item will influence the supportability of the item.

Support is the integrated set of resources, such as personnel, spares, information, training, tools, facilities, communication systems, and transport logistics that are necessary to deliver desired organizational objectives. Supportability is the ease of the provision of those external resources and their effectiveness.

Improved maintainability can:

- reduce the number of personnel and associated competencies required to maintain the item due to decreased complexity of preventive actions, fault finding and repair processes;
- enhance supportability through the use of common skill levels to perform the maintenance;
- minimize the sparing, transport logistics, supply management and information requirements by assuring commonality in components and tooling where appropriate;
- control the required facilities, their locations and associated supporting elements by simplifying the maintenance requirements. For example, designing modular systems can allow items to be easily and effectively replaced on site, with failed modules transported to a central facility for repair.

These elements can affect the quality, timeliness and cost of maintenance support.

Quality of delivery refers to the conduct of the task in accordance with authorised descriptive media which can be words, video or some other equivalent information source. The potential for either human error or human violation to vary the authorised task content should be known so as to assess that quality. Quality relates not only to compliance with the task content but the use of all integrated support defined for that task including spares, tools, facilities and logistics such as warehousing, transport, packaging and handling.

Timeliness of delivery refers to the time delay between the identified failure event and the completion of all preparatory activity necessary to the actual conduct of the maintenance task. For unplanned repair tasks this period would include:

- notification of task;
- permit to work;
- assembly of material, spares, tools and task information;
- travel to site;
- unloading and transport to work position of any required support equipment such as tools and plant.

Cost of delivery refers to the affordability of all actions defined for the maintenance task. Imbalance between purchase price and ongoing cost of ownership can result in future costs of maintenance being unaffordable and hence threaten achievement of inherent characteristics of reliability and supportability through lack of proper funding.

Manager responsibility

Managers representing owners, users, operators, manufacturers, suppliers or customers are responsible for assuring desired outcomes from controlling maintainability and maintenance.

There are six basic responsibilities for managers when implementing maintainability and maintenance programmes over the life cycle:

- assigning responsibility for maintainability and/or maintenance to a competent person(s);
- providing adequate resources, including analysis tools, to undertake the programme;
- maintaining sound communication with internal and external stakeholders;
- integrating the programmes into overall product development, utilisation or improvement;
- establishing controls for suppliers to the programme;
- supporting continuous improvement.

It is the responsibility of managers to assure that system maintainability and maintenance characteristics are balanced with other measures of system effectiveness and constraints such

as cost and risk. Managers should consider the following trade-offs and constraints at all stages of the life cycle when determining and implement maintainability and maintenance measures:

- trading product availability against possible LCC impacts;
- trading maintenance and support requirements against possible LCC impacts;
- eliminating safety hazards in accord with statutory direction.

Managers are responsible for ensuring that maintenance plans and related support are provided as a component of an overall dependability plan to meet the economic operating conditions and achieve organizational intent. This includes:

- establish a maintenance policy;
- planning for required operations and maintenance and its support during the design and development stage;
- making decisions on possible trade-offs between functional capability, and reliability, maintainability and supportability using tools such as life cycle costing;
- providing and improving all resource requirements during the operation and maintenance stage.

For some items, this responsibility begins and remains with the original designer or manufacturer generally titled as “designated design authority”. For others, the designer or manufacturer has initial responsibility for identifying likely maintenance support needs but the end user or operator takes final responsibility for completing the planning process and implementing the results.

Maintainability programme

6.1 Overview

A maintainability programme is a series of activities which prescribes, develops and assures the maintainability characteristics of an item. The purpose of a maintainability programme is to support the delivery of the desired balance between performance, cost and risk as defined by stakeholder objectives.

The key benefits of a maintainability programme are to:

- improve availability of items through reduced downtime and improved preservation of inherent reliability levels;
- reduce life cycle cost through reduced maintenance effort and related support resources;
- reduce the probability of human induced errors;
- provide information necessary to ongoing maintenance management and continuous improvement.

An effective maintainability programme should be planned, integrated, and developed together with other design, development and production functions to assure delivery of organizational objectives. The programme content and structure should be selected to match the constraints of the application and the expected potential importance of maintenance in the item life cycle.

Only those tasks which are expected to provide a positive return on investment should be included in the programme. Such structuring should be consistent with the criticality of the output, the complexity of the design, the level of technical innovation and the production techniques to be applied.

NOTE 1 The full programme described in this document would only be applied to a major complex product with the potential for long-term usage. For less complex maintainable products, a simpler programme should be adopted by tailoring the programme to suit the degree of complexity and the requirements of the customer

NOTE 2 Related IEC standards and guides, notably IEC 60706-5, can be used as reference documents or tools to provide more detail as to how a particular maintainability programme task should be undertaken

The programme should be integrated with related development tasks such as maintenance requirements determination and support analysis to assure best use of resources. Typical project resources would include:

- 623 – required managerial and technical capabilities to do defined tasks;
- 624 – plans that define those tasks, their durations and associated milestones to give clear
- 625 direction;
- 626 – processes necessary to guide the conduct of defined tasks;
- 627 – programme governance to assure programme delivery.

628 NOTE 3 Support analysis and maintenance requirements determination both require effort to identify maintenance
629 tasks and resource applications necessary to a maintainability programme. Care should be taken that such
630 information is efficiently shared and not recreated unnecessarily.

631 A maintainability programme should at least have the following elements:

- 632 – management and organizational activities to assure effective and efficient implementation
- 633 of the programme;
- 634 – a set of maintainability analysis tasks to be performed;
- 635 – specialist support activities to provide the necessary information for the programme;
- 636 – transitioning arrangements that allow application of continuous improvement actions during
- 637 item use.

6.2 Key elements of a maintainability programme

639 Typical elements of a maintainability programme are:

- 640 – plan the maintainability programme;
- 641 – determine the maintainability activities and associated resources;
- 642 – perform the maintainability activities;
- 643 – finalize the maintainability activities.

644 The techniques used within each of these activities and rigour applied is determined by the
645 complexity of the item, the stage of the life cycle and the relationship with the user.

6.3 Plan the maintainability programme

6.3.1 Establishing the context

648 All maintainability programmes must be tailored to their context which includes internal and
649 external factors. This contextual tailoring can require the following factors to be taken into
650 account during the maintainability programme development.

- 651 a) Control of the programme. The control arrangements of the programme and system can
652 determine what activities are available for inclusion in the programme. For example,
653 systems being designed internally can undertake system modelling, maintainability
654 allocation or qualitative design requirements, systems being designed externally to the
655 product owner but are bound by contractual arrangements can be subject to quantitative
656 requirements, design reviews, and testing and verification processes.
- 657 a) Complexity. The complexity of an item will determine the complexity of the maintainability
658 programme. For example, the degree of testability will depend on the level of diagnostic
659 capability required.
- 660 b) Maturity. Mature items such as OTS will have well-established maintenance procedures,
661 but for less mature products account has to be taken of the extent of unproven technology
662 and the need to develop and assess procedures appropriate to the design.
- 663 c) Technical constraints. When the design is constrained by technical or physical parameters
664 beyond the control of the designer, more complex maintenance action can be required.
- 665 d) Programme constraints. Tight schedules or funding limitations can restrict freedom of
666 design or analysis techniques when seeking balanced outcomes.
- 667 e) Maintenance support conditions. The maintenance plan, location of facilities and support
668 resources, level of outsourcing and personnel skill levels of staff available to the operator
669 can influence task effectiveness and hence MTTR and MaxTTR. This information is
670 generally included in the Maintenance Policy (see Clause 7.4.1).
- 671 f) Operational conditions. Environmental severity, time in use and operating cycles can govern
672 the frequency of maintenance action and hence the maintainability solution.

- g) Customer related factors. The customer's maintenance experience and the extent to which the customer's staff will carry out maintenance action and the importance of the product to the customer.
- h) Supplier related factors. The supplier's maintenance experience, and the degree to which the supplier will provide maintenance support will govern the location of maintenance action and the level of maintenance, which can be undertaken.
- i) Life cycle stage. If the product does not require a full development programme, the relevant life cycle stages need to be considered, with the degree of maintainability analysis needed to meet the requirement.
- j) Safety requirements. Items with high safety requirements, such as nuclear power plants, drive the maintenance and, therefore, maintainability requirements.
- k) Compliance requirements. Statutory and regulatory requirements can determine maintenance and maintainability characteristics.
- Organizational design effects the ability of an organization to provide timely, quality and cost effective delivery of the support determined as necessary to achieve inherent maintainability characteristics. Provision of the defined support necessary to deliver inherent reliability and maintainability performance also requires effective leadership and culture in the delivering organization.

6.3.2 Define the objectives and scope

The desired objectives of a maintainability programme will be influenced by the contextual factors and can include:

- identification and prioritisation of maintainability deficiencies;
- evaluation of maintainability performance;
- maintainability improvement;
- determination of the relationship between maintainability performance and cost;
- achievement of desired balance between maintainability performance and cost;
- achievement of a specific level of maintainability performance;
- development of information required as inputs to supportability and support analyses (IEC 60300-3-14).

Only activities which achieve the desired objectives should be undertaken. For example, if the objective is to improve maintainability, it might not be financially effective to quantitatively evaluate the maintainability of the entire system, including both hardware and software. Maintainability can be sufficiently improved by identifying and rectifying a small proportion of key deficiencies.

The scope of the maintainability programme is influenced by the boundary of the system of interest, the life cycle phases the programme spans and interfaces with other organizational programmes.

6.4 Determine maintainability activities and associated resources

6.4.1 Overview

Planning the maintainability activities for effective maintainability programme during any of the product life cycle stages requires knowledge of maintainability principles, methods and techniques. It also requires an understanding of the product itself and its technology, its intended use, its various related cost factors, its design and customer expectations.

The maintainability activities described in the following clauses represent the totality of those which can be undertaken where the complete life cycle of an item can be influenced by the organisation undertaking the activities. Activities should not be undertaken if the user of the results does not have the ability or authority to implement those results.

Activities can be limited by the following elements:

- need for absolute or comparative analysis;

- 723 – level of accuracy or sensitivity required;
- 724 – available data;
- 725 – available resources.

726 There can be a number of alternative activities which achieve similar programme outcomes and
727 so a comparison of alternative combinations of activities should be undertaken with evaluation
728 criteria including cost, time, required and available skills, outcome confidence and any future
729 benefits or benefits to external programmes.

730 Maintainability activities can be undertaken consecutively, concurrently or can be iterative. To
731 assure that the overall organizational and dependability programme objectives are met, the
732 conduct of maintainability activities should be sequenced and aligned with the dependent and
733 interrelated activities of other external programmes.

734 When determining the maintainability activities which will be undertaken as part of the
735 maintainability programme, the resources and skilled required to execute those activities should
736 be estimated, as well as the schedule and organization requirements. (see 7.4). Any exit criteria
737 which will halt selected activities should be documented. Programme alternatives for in the case
738 that any exit criteria are reached can also be determined and documented.

739 **6.4.2 Characteristics of maintainable items**

740 Maintainability characteristics are an inherent characteristic of design. The maximum
741 opportunity to influence maintainability is where decision-making and modifications only affect
742 a 'theoretical' item and no materials have been committed. There will therefore offer the ability
743 to identify and analyse trade-off opportunities with the other dependability attributes and
744 stakeholder goals.

745 The objectives of maintainability are to meet the availability requirements of operating items to
746 assure value is achieved. Failure to achieve maintainability performance can result in expensive
747 modifications after the item has been built and fielded, resulting in much higher future expense
748 to rectify.

749 Maintenance is most cost effectively achieved by limiting its adverse effects on service or
750 product delivery. This is achieved by:

- 751 – design such that maintenance does not need to interrupt operation (hardware);
- 752 – providing redundancy to allow for a known period of reduced redundancy when maintenance
753 can be conducted with the item shut down (hardware);
- 754 – defining shutdown arrangements that allow for efficient packaging of required maintenance
755 tasks for delivery in a defined period at a suitable time (hardware);
- 756 – standardized components, restoration and repair processes, and special tools and
757 equipment which support streamlined maintenance conduct (hardware);
- 758 – modularisation of discrete components such that they can be changed with minimal effect
759 on other components (hardware and software);
- 760 – increased accessibility to reduce time to conduct the maintenance, as well as minimise the
761 probability of inadvertent impact on surrounding items (hardware and software);
- 762 – maximising modifiability where items can be efficiently and effectively modified without
763 introducing defects (software);
- 764 – increasing the degree to which test criteria can be determined and the fault criteria can be
765 tested for to indicate the underlying failure mechanism (hardware and software).

766 While maintainability characteristics are generally determined during design, characteristics
767 such as accessibility can be influenced by the installation or configuration as determined by the
768 user.

769 Ensuring that a product is testable requires adherence to some basic testability design
770 principles. A brief description of the most common testability design principles are below.

- 771 a) Physical and functional partitioning. The ease or difficulty of fault isolation depends to a
772 large extent upon the size and complexity of the units that are replaceable. Partitioning the
773 design such that components are grouped by function (i.e., each function is implemented