CHAPTER 41

MAINTAINABILITY DEMONSTRATION

CONTENTS

1 INTRODUCTION

1.1 At the end of the design and development stage phase of a project, the maintainability of the final design should be verified as to whether it conforms to the specified requirements. If analytical studies or design reviews will not provide sufficient evidence that the minimum acceptable maintainability requirements will be satisfied, then maintainability demonstrations will be required.

1.2 Maintainability demonstration is only one of many maintainability verification methods. However, it is often the only method that is used in a contract as a basis for maintainability verification, before the acceptance of the system.

1.3 This Chapter describes:

a) The purposes of maintainability demonstration.

b) The principles.

c) The requirements for demonstration.

d) The planning and implementation.

PtDCh6 describes the mathematical basis for maintainability demonstration plans.

2 PURPOSE OF MAINTAINABILITY DEMONSTRATION

2.1 The purpose of a formal maintainability demonstration is to show whether an equipment, or part of an equipment, has achieved a specified level of maintainability with a certain level of confidence. Other demonstrations, such as Ease of Maintenance Assessments are not normally contractually binding and provide qualitative maintainability assurance.

2.2 A demonstration test can be any form of test which is agreed between a Contracting Authority and a Contractor to give the necessary assurance that a particular requirement has been met. It need not necessarily be a statistical test although this is often preferred, as it provides defined pass/fail criteria. However, it is essential that the demonstration requirements are unambiguous and agreed before the demonstration.

2.3 As well as verifying whether maintainability requirements have been satisfied, the demonstration can identify deficiencies in the following:

a) The design of the system.

b) Maintenance instructions.

c) Maintenance personnel training.

d) Spares, tools, test equipment and facilities.

3 PRINCIPLES OF DEMONSTRATION

3.1 General

3.1.1 Maintainability requirements can be either quantitative or qualitative. A quantitative requirement normally defines a mean, median or maximum active maintenance time*, where the maximum value has an associated percentile (a typical value is 95). BS 6548: Part 1: 1984[1] presents the following table, giving examples of subjects for which qualitative requirements may be specified.

1.	Maintenance skill level requirements.
2.	Need for special tools or test equipment.
3.	Need for adjustments.
4.	Parts standardisation.
5.	Clear subsystem function identification.
6.	Visual inspection access.
7.	Built-in test facilities.
8.	Properly marked test points.
9.	Colour coding and labels as appropriate.
10.	Use of plug-in units.
11.	Use of captive fasteners.
12.	Use of handles on replaceable units.
13.	Scope and range of technical manuals.
14.	Human factor limitations in the design of the item.

Table 1: Examples of Qualitative Subjects for Which Requirements may be Specified

3.1.2 The basic principle of a demonstration is that a sample of equipment are tested under conditions which are representative of their actual maintenance environment use. Based on the results of the test, a decision is taken to accept or reject the population of equipment which the sample represents (this may be future production equipment). Maintainability

* The maintainability requirement may be for Corrective Maintenance, Preventive Maintenance or both.

demonstrations may also be carried out early in the design process to provide verification of any maintainability prediction.

3.1.3 With any sampling test, there are risks to the customer and the producer that a wrong decision will be made. As the sample size of the maintenance tasks to be demonstrated will affect the degree of risk, it is essential that the test plan should be agreed by both parties.

3.1.4 To be a valid demonstration it must:

a) Use an equipment which is accepted by both parties to be representative of the production equipment.

b) Use agreed environmental, usage and support conditions.

c) Contain a sufficient number of tasks to produce statistically significant results.

d) Use appropriately trained maintenance personnel.

3.1.5 The most realistic demonstration test would be to allow failures to occur in their normal operating environment and record and analyse the corrective maintenance times. However, as maintainability demonstrations are often contractual, they need to be completed in a short period of time and insufficient faults may occur to give a representative sample. The alternative is induce or simulate faults based on their predicted frequency of occurrence.

3.1.6 The maintainability demonstration is typically carried out for a particular level of maintenance. For example, the user/operator may be required to be able to replace the electronic boxes within a system, whereas 2nd Line maintenance may be required to replace components within the electronic boxes. The qualitative and quantitative maintainability requirements for each level of maintenance will be different, and hence the demonstration should reflect the appropriate level.

3.2 Types of Demonstration

3.2.1 Maintainability demonstrations can take many forms; some are more appropriate to some types of equipment than others. The type of demonstration or combination of demonstrations chosen should based on the merits of each. DEF-STAN 00-43 Part 2[2] describes four forms of demonstration and the aspects which should be considered. There are three aspect of maintenance which can be demonstrated:

a) “Replenishment Tasks”. These are typically the replacement of fuels, lubricants and consumables used during operations.

b) “Scheduled Maintenance” (Preventive Maintenance). This can include the demonstration of daily checks to major platform overhauls.

c) “Unscheduled Maintenance” (Corrective Maintenance). These are remedial tasks resulting from faults or damage.

3.2.2 There are four forms of a demonstration:

a) **Bench demonstration (factory intrinsic).** This form of demonstration takes place at the factory, normally at equipment level before installation on the platform. The demonstration could take place at any stage during development to provide an early indication that the requirements will be satisfied. The last test will be on the equipment build standard for incorporation into the production units. These demonstrations are not contractually binding or monitored by the customer.

b) **Platform installed demonstration (platform intrinsic).** This demonstration takes place with the equipment installed on the platform. It is likely that it will be a contractually binding statistical demonstration with a defined accept/reject criteria. The advantage of the this form of demonstration over the factory based demonstration is that the environment will be more representative of operational conditions.

c) **Simulated demonstration (platform intrinsic (modified)).** This is essentially the same as b. above, except that the demonstration is carried out on some other agreed facility. This may be necessary if the platform is not in a suitable state to accommodate the demonstration

d) **Complete platform demonstration.** This a demonstration of the maintainability of the complete platform, and could either be a quantitative or qualitative demonstration. This is normally carried out as an in-service demonstration.

3.3 Statistical Demonstration

3.3.1 A statistical demonstration is used to make a accept/reject decision on a limited test sample in order to assess the maintainability of the total population. The maintainability is typically defined as follows:

a) Active maintenance time.

b) Active repair time.

c) Active preventive maintenance time.

The requirement is then specified by a mean, median or maximum active maintenance time (or a combination thereof), where the maximum value has an associated percentile (a typical value is 95%). The active task time includes diagnostic time, technical delay, restoration time and final check time.

3.3.2 Times to carry out predetermined maintenance tasks are recorded, and these are compared with the test plan criteria to reach a decision whether to accept or reject. No absolute maintainability figure is determined, only that the achieved maintainability is better than the specified requirement with a stated level of confidence. Many test methods can be used for a statistical demonstration; the actual one selected will depend on the maintainability requirements.

3.3.3 Two reference documents are available which detail statistical test methods, MIL-HDBK-470-A[3] and BS 6548: Part 6[4]. The test methods form the basis of a contractual agreement between the contractor and the Contracting Authority and both parties should be aware of the risks involved. These risks are discussed in PtDCh6. Each method can be used for demonstrating maintainability, but each method makes different assumptions regarding the maintenance time distribution and a plan on how the sample of tasks should be determined.

3.3.4 The method of task sampling involves determining the relative frequency of each possible maintenance task. The spread on tasks is determined, based on the likelihood of each task occurring, giving consideration to the number of each item in the system.

3.4 Ease of Maintenance Studies

3.4.1 An ease of maintenance study is carried out by the contractor at an appropriate stage during system development to provide an indication of the achieved maintainability. The contractor may target those areas of the system which are expected to suffer from low reliability, with a view to making recommendations for redesigns to improve maintainability. Alternately, the contractor may strip the system down to various levels appropriate to each level of maintenance, e.g. user/operator, 1st line maintenance etc.; in order to determine the time to carry out each maintenance task, and to confirm the tools and test equipment, and spares required. The study may also consider the skills required by maintenance personnel to carry out the tasks and hence their training needs. This information may then be used by the contractor to populate the LSAR and develop technical publications for the system.

3.4.2 The Contracting Authority may also carry out an ease of maintenance study, either to assess whether the system satisfies the qualitative requirements in the specification before acceptance, or during a competitive tender assessment of COTS systems. An assessment against the specification will take the form of a design review of the system build against specific maintainability requirements, using a maintainability design checklist. The output is typically recommended design, operating or procedural changes which are categorised in terms of desirability. The competitive assessment will be carried out in a similar manner, but the output being a weighted score for the maintainability of each system under consideration.

3.5 In-Service Demonstration

3.5.1 An in-service maintainability demonstration can either be a qualitative or quantitative assessment. A qualitative maintainability assessment is achieved by monitoring system behaviour during operation. With a suitable recording and feedback system, various maintainability features can be monitored. This can include the suitability of maintenance instructions, tools and test equipment, and the adequacy of the defined support concept and training, as well as the feasibility of the maintenance tasks.

3.5.2 The purpose of an in-service quantitative maintainability assessment is to show statistically with a level of confidence that the achieved mean active maintenance time or other appropriate parameter, is less than the specified requirement. An operational evaluation also provides the opportunity to demonstrate characteristics such as:

a) Maintenance cost per operating hour.

b) Number of hours of labour per operating hour.

c) Number of personnel per maintenance action.

d) Maintenance cost for life cycle.

An in-service demonstration provides the best opportunity to quantify the achieved maintainability and can provide a good source of information for future projects. However, due to operational pressures, the data recording can be poor, preventing a firm conclusion being drawn.

3.6 Testability Verification

3.6.1 Testability may be demonstrated as part of the maintainability demonstration for a system, or separately as a series of individual demonstrations, or as part of a platform demonstration. DEF-STAN 00-13[5] and MIL-HDBK-2165[6] describe a method of assessing testability using a design review checklist. However, MIL-HDBK-2165 describes how the

various aspects of testability can be demonstrated through either maintainability or reliability demonstration tests. Typical testability characteristics which can be verified by an in-service reliability or maintainability demonstration include:

a) Proportion of failures detected by BITE.

b) Proportion of 'false alarms' generated.

c) Proportion of 'no faults found'.

4 REQUIREMENTS OF MAINTAINABILITY DEMONSTRATION

4.1 Requirements for maintainability demonstration must be established by the precurement authority's Project Manager during the early stages of a project and must be included in the contract. When deciding whether a maintainability demonstration is worthwhile, or whether the demonstration should be quantitative or qualitative, pre-production or in-service, the Project Manager should consider cost-effectiveness. Consideration should be given to the following:

a) The overall consequences of not achieving the specified maintainability requirement (e.g. increased manpower resources).

b) The availability of hardware, test facilities and resources for an effective demonstration.

c) The ability to describe and quantify the maintainability requirements in a contract.

d) The consequences of a reject decision (e.g. redesigns, delays in the programme plan, contract penalties).

e) The total cost of implementing the maintainability demonstration

4.2 When the decision has been made to demonstrate maintainability, the contract must include:

a) The project milestone by which demonstration is to be completed.

b) The build standard to be demonstrated.

c) The specified value for maintainability which the system is required to achieve and any associated statistical confidence parameters, and/or well defined qualitative requirements.

d) The demonstration test characteristics (e.g. decision criteria, consumer's and producer's risk).

e) The consequences of failing to meet the decision criteria.

f) The consequences of meeting the decision criteria.

4.3 The requirements for maintainability demonstration and the detailed means by which the requirements are to be met must be stated in the R&M Plan[†] (see PtCCh48). Typical factors to be considered in the planning and implementation of demonstrations are described in Section 5 below.

[†] Sub-divisions of the time under demonstration which might otherwise be forgotten, such as software restoration times, should be listed.

5 PLANNING AND IMPLEMENTING DEMONSTRATION

5.1 The demonstration must be planned, at least in outline, during the Project Definition stage, along with other maintainability verification aspects of the R&M plan, so that progressive evidence can be obtained to provide the maintainability assurance necessary.

5.2 A maintainability demonstration plan should include the following:

a) A list of the demonstration tasks should be selected according to the following criteria:

i) Preventive maintenance - representative tasks from those planned for the system.

ii) Corrective maintenance - tasks to be selected to cover a representative sample of possible tasks.

Task selection methods are discussed in PtDCh6.

b) The composition of the test team and the responsibilities of each member. The defined responsibilities of the team members should include:

i) Team organisation, including points of contact.

ii) Specific responsibilities.

iii) Training - the training and experience of the maintainers, both and specific and general used in the demonstration should be representative of a typical maintainer in-service.

c) A list of the support material, facilities and documentation including:

i) Number of systems required and their build standard.

ii) Tools and test equipment.

iii) Maintenance manuals and fault diagnosis charts.

iv) Safety equipment and procedures.

v) Calibration equipment.

vi) Special maintenance facilities.

d) Demonstration procedure and statistical test methods (see Pt D Ch 6), including how the demonstration data is to recorded, and the format of the demonstration report.

e) Ground rules including:

i) Fault insertion - either so that the maintainer is aware (if diagnosis is automatic) or unaware (to demonstrate fault diagnosis) of the fault inserted.

ii) Rules regarding retest following a demonstration failure.

iii) Funding of any design changes.

iv) Exclusions from the demonstration, such as the maintenance on the test equipment used, secondary failures resulting from failure simulation, or repair due to accidental damage.

f) The quantitative and qualitative parameters to be demonstrated.

g) The timing of the demonstration should ensure that the system concerned is representative of the approved production build standard and allows sufficient time for the purchaser to review the plan, and have any comments incorporated.

h) Describe the location, i.e. either in-service, supplier's factory, or a special facility and, if appropriate, the environmental conditions.

i) Define the levels of maintenance for which the demonstration applies.

5.3 More detailed guidance can be found in NES 1017[7]

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2 DEF STAN 00-43 (Part 2)/Issue 1. 28 July 1995. *Reliability and Maintainability Assurance Activity Part 1: Maintainability Demonstration.*

3 MIL-HDBK-470A. Volume 1. 04 August 1997. *Designing and Developing Maintainability Products and Systems.* US Department of Defense.

4 BS 6548: Part 6: 1995. *Maintainability of Equipment Part 6. Guide to Statistical Methods in Maintainability Evaluation.*

5 DEF STAN 00-13. Issue 3. 14 June 1994. *Guide to the Achievement of Testability in Electronic and Allied Equipment.*

6 MIL-HDBK-2165. 31 July 1995. *Testability Handbook for Systems and Equipment.* US Department of Defense.

7 NES 1017 Issue 3. January 1993. *Requirements for Maintainability Demonstrations of Naval Systems.*

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2. DEF STAN 00-40 (Part 2)/Issue 1 (R&MP-2). 14 December 1994. *Reliability and Maintainability Part 2: General Application Guidance on the Use of Part 1 (R&MP-1).*

3. DEF STAN 00-40 (Part 6)/Issue 1 (R&MP-6). 09 December 1988. *Reliability and Maintainability Part 6: In-Service R&M.*

4. DEF STAN 00-41 Issue 3. 25 June 1993. *Reliability and Maintainability MOD Guide to Practices and Procedures.*

5. DEF STAN 00-60 (Part 1)/Issue 1. *Integrated Logistic Support Part 1: Logistic Support Analysis (LSA) and Logistic Support Analysis Record (LSAR).*

6. SSP No. 41. Issue 3. June 1996. *Project Availability, Reliability and Maintainability (R&M) Handbook. Part 10: The Maintainability Demonstration (MDEM) Model Guide to PC Operations.*

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