CHAPTER 39

AVAILABILITY DEMONSTRATION

CONTENTS

1 INTRODUCTION

1.1 Dependability requirements can be expressed in terms of either Reliability, Maintainability or Availability performance. The validation of a specified Availability requirement is often done by means of compliance testing under simulated or field conditions. An Availability Demonstration, although not performed as frequently as a Reliability or Maintainability Demonstration, can also provide assurance that the final design exceeds the minimum required for entry into service. An Availability Demonstration is often called an Availability, Reliability, and Maintainability (R&M) Trial, as it is the collection of R and M data that allows the demonstration of Availability.

1.2 Availability Demonstration is concerned with measuring whether or not a specific, contractually binding requirement has been met. The test can highlight design inadequacies, poor maintenance procedures and training, and insufficient spares.

1.3 This Chapter describes:

a) The purposes of an Availability Demonstration;

b) The principles involved;

c) The requirements for demonstration;

d) The factors to be considered during planning and implementation of a demonstration.

1.4 PtDCh9 describes the mathematical basis for availability demonstration plans. It describes the criteria for selecting and implementing test plans. More detailed information regarding Availability Demonstrations is given in BS5760: Section 10.3[1].

2 PURPOSE OF AVAILABILITY DEMONSTRATION

2.1 The purpose of an Availability Demonstration is to show whether an equipment or platform (including hardware and software) has achieved a specified level of Availability. This involves the collection of sufficient Reliability and Maintainability data to provide a statistical assessment of equipment Availability. A demonstration is normally contractually binding and often has associated contract incentives and penalties. A demonstration can provide evidence of the following:

a) The equipment complies with the Availability requirements;

b) The equipment meets in-service acceptance requirements;

c) Deficiencies in the equipment design and maintenance support.

3 PRINCIPLES OF DEMONSTRATION

3.1 General

3.1.1 The principles of an Availability Demonstration are the same as those for a Reliability Demonstration. It is the demonstration of a sample of items under test conditions which are as representative to operational conditions as possible. Based on the results of the test, a decision is taken to accept or reject the population of equipment that the sample represents.

3.1.2 For a demonstration to be worthwhile, and warrant the costs involved, it must:

a) Provide sufficient test observations to produce results which are statistically significant or can be assessed in a qualitative manner;

b) Use items which are accepted to representative of production items;

c) Represent typical operational use of the equipment as closely as practicable.

3.1.3 As with any sampling test there are risks to the consumer and the producer that a wrong decision will be made. The sample size and test duration will determine the degree of risk, and therefore these factors must be agreed by both parties before testing.

3.2 Definitions of Availability

3.2.1 There are three commonly used definitions of Availability:

a) Operational Availability;

b) Intrinsic Availability; and

c) Effective Availability.

3.2.2 The definitions of these terms are important aspects when contracting for Availability and defining Availability Demonstration requirements.

3.2.3 Def-Stan 00-49[2] defines Operational Availability as:

> "The proportion of the defined operational period during which the equipment is available for use without any performance limitations",

i.e.

$$A_o = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}}$$

measured over an operational period.

3.2.4 Operational Availability may also be expressed by the formula (from Def-Stan 00-49[2])

$$A_O = \frac{OT + ST}{OT + ST + TPM + TCM + ALDT} \tag{1}$$

Where: OT = Operating Time

ST = Standby Time

TPM = Total Preventive Maintenance Time

TCM = Total Corrective Maintenance Time

ALDT = Administration and logistics delay time spent waiting for parts, maintenance personnel or transportation.

3.2.5 Def-Stan 00-49 refers to R&MP-7[3] for the definition of Intrinsic Availability. R&MP-7 defines Intrinsic Availability as:

> "The probability that an system/equipment is operating satisfactorily at any period in time when used under stated conditions, where the times considered are **operating time** and **repair time** (active). Thus intrinsic availability excludes from consideration all free time, storage time, administration delay time and logistic delay".

The standard describes 'Operating Time' as:

> "The time during which the system or equipment is turned on and actively performing at least one of its functions".

In other words, Intrinsic Availability as defined by R&MP-7, is as per equation 1, less the standby time, the administration and logistic delay time and total preventive maintenance time terms.

3.2.6 The definition for Intrinsic Availability, given in NES 1016[4] states:

> "The probability that an item, when used under specific conditions, without consideration for any scheduled (preventive) maintenance action, in an ideal support environment (i.e. available tools, spares, manpower, downtime, etc.) is available at any instant of time".

This definition differs from that given in R&MP-7, in that standby time is included.

3.2.7 The demonstration of Intrinsic Availability is often required in a contract, as it does not consider administration and logistic delay times. As these times are completely under the control of the Contracting Authority and can not be influenced by the contractor through design. Definitions of availability can vary, in terms of what is included and what is excluded. It is essential that the contract is unambiguous regarding the definitions to be used.

3.2.8 Effective Availability addresses the contributions to unavailability due to preventive maintenance and failure of items which are not immediately repairable (e.g. while a ship is at Sea).

3.3 States and Time Classification

3.3.1 Statistical test methods used to demonstrate Availability can only treat equipment with two states, i.e. up-state and down-state. Therefore, it is essential to have definitions of what constitutes the equipment being in the up-state and the down-state, and which incidents constitute a failure of the equipment.

3.3.2 Uptime is generally defined as that time when the equipment is powered up and performing at least one on its functions to an acceptable level. The Availability measure defined in the requirements, i.e. Operational, Intrinsic or Effective, will influence the classification of down times as either relevant or non-relevant. Before the test begins, the test plan must define the classification of non-relevant down times in detail. Relevant down time, is time that will contribute to equipment unavailability, whereas non-relevant time will not.

3.3.3 Preventive maintenance is often classified as non-relevant if the requirement is defined in terms of Intrinsic Availability, and may be also when Operational Availability is specified. Down time for corrective maintenance is always classified as relevant down time, except for non-relevant failures (see Section 3.5). This down time includes fault diagnosis, isolation, fault repair and testing time. Logistic delay, such as the time for spares and manpower to reach the equipment, and administration delays, such as fault reporting, are not included in the corrective maintenance down time and are classified as non-relevant for Intrinsic Availability. When considering Operational Availability, logistic and administration delays are considered relevant, but the classification of these delays should clearly defined in the test plan.

3.3.4 The test plans presented in BS 5760 are intended for equipment which is in continuous use. Availability is determined from the downtime in the relation to the total time of the test. If these test plans are to be used on equipment which is being used intermittently, consideration should be given to corrective maintenance which is undertaken during periods when the equipment is not required. These aspects of the demonstration should be described fully in the test plan.

3.3.5 The classification of equipment states is a key area when analysing test data. NES 1016[4] presents the following states for an R&M trial:

a) Hardware Failure
b) Corrective Maintenance
c) Awaiting Material Support
d) Degraded
e) Preventive Maintenance
f) On: Fully Powered
g) Off
h) Awaiting Maintainer
i) Software Failure
j) Software Incident
k) No Fault Found

Additional states are added to this set, depending on the equipment and the requirement specification. An extended set, now known as incident sentencing codes, is given in Def-Stan 00-40, part 3[5] Table A.

3.3.6 In order to determine the required R&M measures, the states listed above are then grouped under event headings:

a) Systems Available : Off, On: Fully Powered, Degraded, Preventive Maintenance, Software Incident, No Fault Found
b) System Not Available : Hardware Failure, Corrective Maintenance, Awaiting Material Support, Awaiting Maintainer, Software Failure

c) System Running Time: On: Fully Powered, Degraded, Preventive Maintenance, Software Incident, No Fault Found

d) ystem Not-Running Time: Off, Hardware Failure, Awaiting Material Support, Corrective Maintenance, Awaiting Maintainer, Software Failure

e) System Failure: Hardware Failure, Software Failure

f) System Active Repair Time : Corrective Maintenance

3.4 Failure Definitions

3.4.1 The measure of Availability performance is based on the definition of up and down times. Therefore, it is essential to classify equipment states as either up or down, and whether some failures are deemed non-relevant. These definitions must be agreed by the consumer and producer before the test begins.

3.4.2 An equipment failure is normally defined as the termination of its ability to perform a particular function. However, mechanical equipment often exhibits an element degradation before complete failure, which raises the question of how much degradation in performance can be tolerated before the equipment has failed. For example, when does a coolant leak from a flange become a failure. The unacceptable level of degradation is best defined using a function and a performance parameter, such as coolant flow within the system below 6 litres per minute, or at least 3 out of 12 channels failed.

3.4.3 Depending on the requirement specification, failure definitions may concentrate on the function of the equipment, without consideration to the actual hardware or software. For example, a communication link may be regarded as functional as long as communication is possible. However, the failure classification may be undertaken at a greater depth, by classifying states at the top-level and continuing down to the definition of states for hardware and software failures.

3.5 Statistical Demonstration

3.5.1 A statistical demonstration is used to make an accept/reject decision on a test sample in order to assess the Availability of the total population. There are three types of statistical test available:

a) Fixed time test plans, where testing continues until a pre-determined test time.

b) Fixed number of failures test plan, where testing continues until a pre-determined number of failures have occurred.

c) Sequential test plan, in which both the test time and failures are compared with an established criteria, to decide to reject, accept, or continue testing.

3.5.2 Each type of test has advantages and disadvantages, and these are discussed in PtCCh40. The mathematical basis of the test plans is discussed in PtDCh9.

3.5.3 The test methods illustrated in BS 5760[1] and in PtDCh9 can be used to demonstrate statistically the Availability of items that only have two states, up-state and down-state. The test methods are only applicable under the following conditions:

a) One single repair item.

b) All up times have the same negative exponential distribution. This implies that testing should only start when the equipment exhibits a constant hazard rate, i.e. following any period of early life failures.

c) Downtimes have the same gamma distribution. The gamma distribution being an approximation to the lognormal distribution usually associated with corrective maintenance times. Methods for verifying distributions are presented in PtDCh7.

d) Preventive maintenance is not included in the downtime

e) The test methods use unavailability as the measure of performance.

3.5.4 In the case of high reliability equipment which has a high level of redundancy it may be difficult to develop a test plan which will prove statistically that the equipment has satisfied the Availability requirement within a sensible time frame. This can be overcome by allocating the overall Availability requirement to the equipment at a lower level, and undertaking a separate test at this lower level. If this option is implemented, care should be taken, as there will be a greater probability of failing of one of the tests[*]. An example of this principle can be found in PtCCh40.

3.6 Test Conditions

3.6.1 In order to achieve a good correlation between the demonstration test and in-service, test conditions should be as representative as possible of those experienced in-service. This may be difficult, other than actually undertaking an in-service demonstration. Nevertheless, consideration should be given to all the aspects that affect reliability, maintainability and maintenance support performance.

3.6.2 The choice between factory or in-service testing is normally decided by the type of equipment to be tested. Typically, small and moderately sized equipment with large numbers produced, could be tested in the factory, whereas large equipment with small numbers produced, are more likely to be tested in-service.

3.6.3 The important factor of a factory test, is that the conditions should be as realistic to in-service as possible. For in-service, the important factors are the quality of the data reporting and the correctness of the incidents sentencing, as to whether they are relevant or non-relevant.

3.6.4 The conditions which need to considered are

a) Operating conditions – usage conditions which affect the reliability.

b) Environmental conditions – environmental conditions which will affect reliability.

c) Maintenance conditions – the preventive maintenance schedule, instructions, tools, training, spares should be as in actual use.

3.7 In-Service Demonstration

[*] If there are 10 sub-tests each with a Producer's Risk of 10% then there is a high probability of failing at least one of them, even if all the lower level true Availabilities are acceptable. The probability is approximately 0.65 ($1-0.9^{10}$).

3.7.1 For an in-service demonstration, effort should be made to ensure that the data being recorded is correct. Up and down times must be classified correctly and agreed as relevant or non-relevant by the customer and purchaser. It is important that the data reporting system concentrates on the information required to demonstrate Availability, as requesting too much information can have a detrimental effect on the quality of the data. A trial data collection period or ‘shakedown period’ is recommended to test and improve the data collection procedures.

3.7.2 A successful in-service demonstration depends on the co-operation of users and maintainers to provide timely and high-quality incident data. Test instructions and briefings are a useful way of informing the personnel involved of the purpose and conduct of the trial. The feedback of result information from the analyst to the people collecting the data is very important in gaining their co-operation.

3.7.3 It is recommended that data should be collected by the continuous monitoring of the up and down times of the equipment. Data can be collected in a semi-automatic manner by utilising the equipment Built-In-Test-Equipment (BITE), which has the advantage of continuous surveillance and constant monitoring of equipment state. However, where BITE does not exist or is limited in its application, a log book or a computer database which records events in chronological order is often the best approach.

3.7.4 It should be noted that the use of BITE for automatic data collection does not satisfy the need to record the reasons for incidents. This must still be recorded in support of data sentencing.

3.7.5 A copy of typical log sheet extracted from NES 1016 is shown in Figure 1. The calendar time of all the transitions of equipment states and the maintenance action and their reason must be recorded.

a. SHIP NONSUCH SYSTEM SEACEPTOR MONTH JAN YEAR 1999 PAGE NO 1

b.	c.	d.	e. UNIT STATE										f. COMMENTS
EVENT DATE	EVENT TIME	EVENT DATE	SEARCH RADAR	CONTROL CONSOLE	DISPLAY 1	DISPLAY 2	DISPLAY 3	COMPUTER	GUIDANCE SYSTEM	HANDLING SYSTEM	LAUNCHER 1	LAUNCHER 2	Brief record of any work done with references to defective item NSN, Location Code and S2022s number.
			1	2	3	4	5	6	7	8	9	10	
21	0830	F	F	F	F	F	F	F	F	F	F	F	SYSTEM CHECKS
21	0900	F	F	F	F	F	F	F	F	F	F	X	LAUNCHER 2 NOT REQUIRED
21	1120	Q	F	F	F	F	F	Q	F	F	F	X	PROGRAM WILL NOT RUN
21	1123	Q	F	F	F	F	F	Q	F	F	F	X	REBOOT
21	1130	F	F	F	F	F	F	F	F	F	F	F	SUCCESSFUL RUN
21	1309	D	F	F	F	F	H	F	F	F	F	F	CRT FAULT CONTR SW TO DISP 2
21	1312	D	F	F	F	F	C	F	F	F	F	F	CHANGING CRT (1234-99-560-7890)
21	2100	F	F	F	F	F	F	F	F	F	F	F	DEFECT CLEARED S2022 A16923
22	0900	F	F	F	F	F	F	F	F	F	X	X	SYSTEM CHECKS
22	1100	P	P	P	P	F	F	F	F	F	X	X	MAINT OPS 6,7 & 9
22	1800	X	X	X	X	X	X	X	X	X	X	X	OFF, NOT REQ'D
22	2030	F	F	F	F	F	F	F	F	F	F	F	TRACKING EXERCISE

SYSTEM/UNIT STATES:

X - Off
F - ON:Fully Powered
Z - No Fault Found

H - Hardware Failure
D - Degraded
P - Preventative Maintenance
C - Corrective Maintenance

M - Awaiting Support
W - Awaiting Maintainer
Q - Software Failure
Y - Software Incident

Figure 1: Typical Completed Record Log

4 REQUIREMENTS OF AVAILABILITY DEMONSTRATION

4.1 Requirements for Availability Demonstration must be established by the MoD (PE) Project Manager during the early stages of a project and must be included in the contract. When deciding whether an Availability Demonstration is worthwhile, the Project Manager should consider cost-effectiveness. Consideration should be given to the following:

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

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

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

d) The total cost of implementing the Availability Demonstration

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

a) The Availability definition or performance measure to be used. See Section 3.2 above

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

c) The build standard to be demonstrated.

d) The specified value for Availability that the equipment is required to achieve and any associated statistical confidence parameters, and/or well defined qualitative requirements.

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

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

g) The consequences of meeting the decision criteria.

4.3 The requirements for Availability 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 demonstration are described in Section 5 below.

5 PLANNING AND IMPLEMENTING DEMONSTRATION

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

5.2 An Availability Demonstration plan should include the following:

a) The requirements and their understanding, in particular the definition of Availability and which incidents contribute to up-time and down-time.

b) Definitions of failure.

c) The means by which states and times will be classified.

d) Test conditions.

e) The type of test to be undertaken, e.g. fixed number of failures, fixed time test or sequential test.

f) Consequences of rejection, e.g. penalties, incentives, conditions for payment for any re-designs.

g) An extremely long test time may be required to reach a decision for very reliable equipment. In this situation there may be few or no downtimes to determine the Availability performance and therefore make an statistically based accept/reject decision. The demonstration plan should include a way forward which is agreeable to the both Contracting Authority and the contractor for this eventually.

h) For complex equipment with many prime functions, requirements may be defined for each function separately. If this is the case, test plans can still be applied, but for one function at a time. The plan will need to reflect this situation, in terms of the contractual outcome of a reject decision on some functions and an accept decision on others.

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REFERENCES

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3 R&MP-7. Edition 1. March 1996. *NATO R&M Terminology Applicable to R&MPs.*

4 NES 1016. Issue 2. February 1993. Requirements for the In-Service Collection and Analysis of R&M Data for Naval Systems.

5 DEF STAN 00-44 (Part 3). Issue 1. 29 August 1997. *Reliability and Maintainability Data Collection and Classification, Part 3: Incident Sentencing - Sea*.

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