NATO STANDARD

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ENVIRONMENTAL GUIDELINES FOR DEFENCE MATERIEL

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NORTH ATLANTIC TREATY ORGANIZATION
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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

8 December 2016

1. The enclosed Allied Environmental Conditions and Test Publication AECTP-100, Edition E, Version 1 ENVIRONMENTAL GUIDELINES FOR DEFENCE MATERIEL, which has been approved by the nations in the Life Cycle Management Group (AC/327), is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4370.

2. AECTP-100, Edition E, Version 1 is effective upon receipt and supersedes AECTP-100, Edition 4 which shall be destroyed in accordance with the local procedure for the destruction of documents.

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4. This publication shall be handled in accordance with C-M(2002)60.

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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RECORD OF SPECIFIC RESERVATIONS

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ENVIRONMENTAL GUIDELINES FOR DEFENCE MATERIEL

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ENVIRONMENTAL GUIDELINES FOR DEFENCE MATERIEL

1. SCOPE

1.1 Purpose

1.1.1 The purpose of this ‘Allied Environmental Conditions and Test Publication’ is to guide project managers, programme engineers, and environmental engineering specialists in the planning and implementation of environmental tasks. An important function of AECTP-100 is to provide guidance to project managers on the application of AECTP-200 to 250 ‘Environmental Conditions’, AECTP-300 ‘Climatic Environmental Tests’, AECTP-400 ‘Mechanical Environmental Tests’ and AECTP-500 ‘Electrical / Electromagnetic Environmental Tests.’

1.2 Application

1.2.1 The guidance provided in AECTP-100 is applicable to joint NATO defence materiel projects. It may also be applied to defence materiel (multi-) national projects and is compatible with NATO publication AAP-20, ‘NATO Programme Management Framework (NATO Life Cycle Model).’ AECTP-100 should be useful to environmental engineering specialists during the procurement cycle.

1.3 Limitations

1.3.1 There are two ways of subjecting an item to environmental conditions. These are laboratory testing and field exposure. This document discusses laboratory testing and is not intended to address field exposure. For details on field exposure refer to the appropriate national documentation. The following section discusses the relative merits and issues associated with each approach.

1.3.2 Laboratory testing (e.g. climatic chambers or electrical shakers) should be fully and creatively exploited, to determine if any basic problems exist, before testing is conducted in field environments, unless such testing is impractical. Testing in a controlled environment such as a laboratory is economical, reduces test times and serves as a screening procedure to identify design defects early in the acquisition process. Laboratory testing will:

a. Be used to determine if a system satisfies the performance requirements as stated in the requirements documents or system specifications.
b. Provide data for assessing the risk associated with not conducting testing in the natural environment.
c. Limit the need to expose personnel to hazardous materiel prior to qualification.

Systems that fail simulated environmental testing should not be subjected to field exposure until causes for the failure(s) are resolved and corrections have been applied. Laboratory testing has the advantage that it allows the simulation to be undertaken in defined and controlled conditions. It is also useful for gathering data on the difference made by mitigation factors, but cannot wholly simulate real conditions.

Laboratory equipment like climatic chambers and shakers do not properly simulate the actual field environment because they cannot concurrently reproduce all of the synergistic effects associated with that natural environment. However it is possible to test with combined environments to more closely replicate the naturally occurring environment.

1.3.3 Field exposure should not commence on an item until the risks from the materiel have been fully identified, corrected and verified through the use of laboratory testing, on either the item or its sub-components. Field exposure may be more convenient for large and awkward objects, and may be essential where the object interacts significantly with the (combined) conditions of the environment. Field exposure reflects real situations but can only be 'snapshots' of the final environment. Seasonality and the limited duration of exposure must be considered when determining the total affect on materiel. Field exposure trials should be conducted when the environment is expected to be at its most extreme. Caution is advised in the interpretation of data obtained during natural environment testing as there is no way to ensure that the test item encounters events such as storms, local differences or climatic extremes. Field exposure trials will:

a. Allow the item to be incorporated into its full system for testing.
b. Ensure that all personnel and the item are in their correct relative positions; consequently, field trials can be expected to expose materiel to relevant failure mechanisms.
c. Allow for measurement of the environment to validate and/or update appropriate laboratory test severities.

1.3.4 AECTP-100 through 600 were not developed specifically to cover the following applications, but in some cases they may be applied:

- Weapon effects other than electromagnetic pulse (EMP);
- Munitions safety tests;
- Suitability of clothing or fabric items intended for military use;
- Environmental stress screening (ESS) methods and procedures.

1.3.5 The test methods as mentioned in AECTP 300, 400 and 500 are also applicable to materiel in its packaged condition or to assess the durability of the packaging itself. These tests however do not assess the way the packaging protects the materiel. Refer to Stanag 4340 [ref. 1] for assessing compliance of the packaging against NATO standard requirements. Refer to Stanag 4434 [ref. 2] for packaged materiel that can be susceptible to electro static discharge.

1.4 Test Instrumentation

1.4.1 Ensure the sensors, instrumentation used for measuring environmental conditions and recording responses of test items are suitable for the intended circumstances. The various test conditions may unintentionally affect the accuracy or reliability of the test. For example;

a. Accelerometers used in a combined high temperature/vibration test could give erroneous readings if not designed for high temperature use;
b. A large specimen in/on a relative small test apparatus will affect the accuracy of the controlled parameters within the required tolerances;
c. Direct radiant heat or excessive airflow can give an unrealistic response of a test item during a climatic test.

1.4.2 The ability of test facilities to simulate environmental conditions within the specified tolerances and the accuracy of the instrumentation shall be verified to the satisfaction of the procuring activity. All instruments and test equipment used in conducting the tests must:

a. be calibrated to laboratory standards, traceable to the National Standards via primary standards;

b. meet the calibration interval guidelines of ANSI/NCSL Z540 [ref. 3], ISO 10012 [ref. 4] or equivalent National Standards;

c. have an accuracy at least equal to 1/3 the tolerance of the variable to be measured. In the event of conflict between this accuracy and guidelines for accuracy in any one of the test methods of this standard, the latter governs.

For critical tests, it is recommended to verify the accuracy of instruments and test equipment prior to and following the test.

1.5 Test interruption

1.5.1 Test interruptions can result from multiple situations. The following items are possible causes for test interruptions. More specifics and recommended paths forward can be found in each of the test methods as presented in AECTP 300 and 400.

a. Interruption due to laboratory equipment malfunction.
b. Interruption due to test item operation failure.
c. Interruption due to a scheduled event.
d. Interruption due to exceeding test tolerances.

2. DOCUMENTS

2.1 Related Documents

-	NATO AAP-20	NATO Programme Management Framework (NATO Life Cycle Model)
-	MIL-STD-810	Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
-	Defence Standard 00-35	Environmental Handbook for Defence Materiel
-	CIN-EG01	Guide pour la prise en compte de l'Environnement dans un Programme d'Armement
-	AOP-15	Guidance on the Assessment of the Safety and Suitability for Service of non-nuclear Munitions for NATO Armed Forces

2.2 Referenced Documents

[1]	STANAG 4340	NATO Standard Packaging Test Procedures (AEPP-3)
[2]	STANAG 4434	NATO Standard Packaging for Materiel Susceptible to Damage by Electrostatic Discharge (AEPP-2)
[3]	ANSI/NCSL Z540	General Requirements - Calibration Laboratories and Measuring and Test Equipment
[4]	ISO 10012	Requirements for Measurement Processes and Measuring Equipment

[5] IEC 60068 Environmental Testing

3. CONTENT OF AECTP-100 THROUGH 600

The content of the series of nine AECTP under covering STANAG 4370 is summarised below. The use of these documents is addressed in chapter 8.

3.1 AECTP-100 - Environmental Guidelines for Defence Materiel

3.1.1 AECTP-100 contains the general introduction for the use of the complete series of AECTP-100 through 600. AECTP-100 also provides guidance on the management of the total environmental engineering task for materiel development projects. The focus of this guidance is the environmental project tailoring process which can accommodate different methods of procurement and a range of test types including safety and reliability testing. The documentation that supports the management guidelines is also described.

3.2 AECTP-200 - Environmental Conditions

3.2.1 AECTP-200 provides information and guidance on climatic, mechanical and electrical environments that materiel are exposed to during its life cycle. It describes conditions and data that have been compiled from established sources within NATO countries. Advice is given on the selection of suitable test methods. Test procedures for the environments defined in AECTP-200 are presented in AECTP-300 through 500. Note that the environmental descriptions in these documents are only examples and should not be used to derive test severities.

3.3 AECTP-230 - Climatic Conditions

3.3.1 AECTP-230 series of leaflets describe characteristics and data samples of natural and induced climatic environments. Examples include those that occur as a result of a materiel being enclosed or covered during transportation, storage, transit, deployment and use.

3.4 AECTP-240 - Mechanical Conditions

3.4.1 AECTP-240 series of leaflets describe the mechanical conditions, particularly vibration and shock that can occur. Examples include those that occur as a result of the proximity of materiel to excitations arising from its configuration, mode of transportation, storage, host platform and use.

3.5 AECTP-250 – Electrical and Electromagnetic Environmental Conditions

3.5.1 AECTP-250 describes the electrical environments. Examples include radiated, conducted, magnetic and electrostatic conditions that occur during materiel transportation, storage, deployment and use.

3.6 AECTP-300 - Climatic Environmental Tests

3.6.1 AECTP-300 provides a series of climatic test methods for use during the design, development and qualification of materiel. The test methods are presented in a prescriptive style so that they can be readily invoked by the user. As far as has been possible the test methods included are those internationally agreed and published.

3.7 AECTP-400 - Mechanical Environmental Tests

3.7.1 AECTP-400 provides a series of mechanical test methods for use during the design, development and qualification of materiel. The test methods are presented in a prescriptive style so that they can be readily invoked by the user. As far as has been possible the test methods included are those internationally agreed and published.

3.8 AECTP-500 - Electrical/Electromagnetic Environmental Tests

3.8.1 AECTP-500 provides a series of electrical test methods for use during the design, development and qualification of materiel. The test methods are presented in a prescriptive style so that they can be readily invoked by the user. As far as has been possible the test methods included are those internationally agreed and published.

3.9 AECTP-600 – The Ten Step Method for Evaluating the Ability of Materiel to Meet Extended Life Requirements and Role and Deployment Changes

3.9.1 AECTP-600 describes the process known as the Ten Step Method that has been developed to determine the ability of materiel to meet extended life requirements or changes in deployment. It gives engineering principles to consider during the evaluation in a life extension programme.

4. THE ENVIRONMENTAL PROJECT TAILORING PROCESS

4.1 Environmental Project Tailoring

4.1.1 Environmental Project Tailoring (EPT) is the process of assuring that materiel is designed, developed and tested to requirements which are directly derived from the anticipated service use conditions.

4.1.2 A test programme should normally reflect environmental stresses anticipated throughout the materiel's life cycle, and tests should be based on the anticipated environmental scenarios. The specified tests and their severities should be derived from the most realistic environments, either single or in combination. In particular, data obtained from real-world platforms as influenced by natural environmental conditions should be used to determine test criteria.

4.1.3 Specific test procedures and severities are necessary to provide adequate confidence in the performance, reliability and safety of the materiel. Test severity levels are often more severe for tests conducted for materiel safety, because these severities need to reflect the maximum levels to be expected in service.

4.2 Responsibilities of Project Managers and Environmental Engineering Specialists

4.2.1 It is the responsibility of each Project Manager to provide assurance that materiel will perform satisfactorily while exposed to and following environmental stresses which are likely to be encountered in service as defined in materiel specifications. The Project Manager determines the particular strategy for the project. This strategy is to be defined in the Project Manager's General Environmental Management Plan (GEMP). To ensure the process is conducted effectively and economically, Project Managers should:

a. Involve environmental engineering specialists in relevant tasks associated with the materiel specification, definition and performance validation (see paragraph 4.2.3);

b. Ensure the appropriate resources are allocated in order that all these tasks can be properly accomplished;

c. Ensure the life cycle environments anticipated for the materiel in service are adequately specified in the 'Requirements' documents. In order to enable specialists to conduct valid studies, 'Requirements' documents should state the real deployment scenarios which the materiel is expected to encounter;

d. Task environmental engineering specialists to develop environment-related management documents, environmental test programme documents and environmental planning documents. These documents (which are addressed in paragraphs 5.1 to 5.5) should be available as early as possible in the project for approval by the Project Manager;

e. Ensure materiel provided for environmental testing is representative of that which is intended for service;

f. Approve any changes to the agreed environmental plans;

g. Ensure the performance of materiel is validated against the life cycle environmental profile.

4.2.2 Environmental Engineering Specialists are responsible for the application, as appropriate, of Environmental Project Tailoring to test programmes. Tailoring tasks, which cannot be implemented during the tailoring process, should be reported to the Project manager as early as possible.

4.2.3 Environmental Engineering Specialists develop documents that govern and record the application of environmental tasks in accordance with the General Environmental Management Plan. These documents are described in paragraphs 5.2 to 5.5. Where appropriate, arrangements should be made to ensure that modifications to the design that have been made during the course of the project are verified by further testing. The specialists should advise and assist in resolving potential conflicts between the performance requirements and the ability to resist effects of the environments. They should participate actively during project development to harmonise the decisions made concerning the actual environments to which materiel will be subjected. The maximum advantage is achieved when environmental issues are addressed during the first conceptual studies.

5. DOCUMENTATION

5.1 General

5.1.1 The following documents are required to support the planning and implementation of environmental engineering tasks.

5.2 General Environmental Management Plan

5.2.1 The purpose of the General Environmental Management Plan (GEMP) is to define, as early as possible in the project, the major requirements and plans involving environmental engineering tasks and testing. This plan may be used to provide cost estimates for the required resources.

5.2.2 The GEMP is one of the first tasks to be completed during the procurement of defence materiel, and defines the plans for accomplishing the other environmental tasks throughout the remainder of the project. The plan should reflect the type of procurement, for example, as a development project or as an off-the-shelf purchase. It will include a list of the documents (see paragraphs 5.3 to 5.7) to be prepared and will provide a schedule showing required completion dates.

5.2.3 During preparation of the GEMP, guidance should be obtained from Environmental Engineering Specialists.

5.3 Life Cycle Environmental Profile

5.3.1 The purpose of the Life Cycle Environmental Profile (LCEP) document, sometimes known as the Environmental Requirement, is to define the events which could influence the materiel function and which are expected to occur during the life of the materiel, thus enabling logical decisions to be made regarding design and test requirements. Sufficient information is required to define all of the expected (natural and induced) climatic, mechanical and electrical environments, along with expected duration and probability of exposure. Information contained in the LCEP will subsequently be used to prepare the Environmental Design Criteria and the Environmental Test Specification.

5.3.2 The LCEP defines all of the events (conditions) to which the materiel will be subjected from the time it leaves the factory until it is removed from service. The LCEP includes transport, handling, storage, operational use, and maintenance operations, with the respective frequencies of occurrence.

The LCEP should contain as appropriate:

a. A Service use profile describing each of the specific events that can occur during the life of the materiel. These specific events should include, for example, transportation methods, geographical locations and types of storage enclosures and approximate duration of each event;

b. The configuration of the materiel as it could modify the effects of the environments to which the materiel is exposed;

c. All relevant types of platforms (e.g., man, aircraft, ground vehicles, ships);

d. The geographical locations (e.g., deployment) where the materiel will be stored and operated during its lifetime;

e. A summary of environments (and combinations thereof), which lists the expected environments to which the materiel could be exposed during its service life. Extensive guidance on the identification of environments is provided in AECTP-200.

f. Identification of the operational (e.g., operating, stand-by, testing, non-operating) state associated with each phase of the life cycle including expected function and associated performance. The LCEP is intended to define all possible realistic environmental conditions to which materiel will be exposed during its life. Guidance is given in AECTP-200.

Some examples of typical natural and induced environments are listed in Annex A. The list is not intended to be comprehensive.

Guidance on which situations or conditions may be applicable for the LCEP can be found in the questionnaire in Annex B.

5.3.3 The LCEP must be completed in time to serve as a prime input to the preparation of the Environmental Design Criteria and the Environmental Test Specification.

5.4 Environmental Design Criteria

5.4.1 The purpose of the Environmental Design Criteria (EDC) is to identify probable environments or combinations of environments that could impact safety, availability, reliability, maintainability or operational capability of the materiel. Compliance with the EDC is generally verified by tests in conjunction with an assessment, but in some cases may also be verified by studies, computer models, etc.

5.4.2 The EDC document defines specific environments (see AECTP-200, 'Environmental Conditions') which have been selected as design requirements, and gives rationale for their selection. The rationale for the selection of a specific design requirement should clearly state whether the decision is based on an extreme value or otherwise, and specify the duration of exposure. Additionally, the rationale should include:

a. probability of occurrence of a particular environment or a combination of environments;

b. expected effects and failure modes;

c. effect of possible failure on mission success.

5.4.3 The EDC document forms the basis for the Environmental Test Specification.

5.5 <u>Environmental Test Specification</u>

5.5.1 The purpose of the Environmental Test Specification (ETS) is to contain a definition of all the proposed environmental tests, together with rationale for each test, in such a manner that all personnel and organisations involved in the development of the materiel understand how the EDC will be verified.

5.5.2 The Environmental Test Specification defines all of the equipment, organisational responsibilities, test conditions and methods necessary to conduct the tests. This specification also includes the configuration, quantity of test items, test sequence and inspection of the test item before, during and after testing. Where possible, test methods should be selected from AECTP-300 'Climatic Environmental Tests', AECTP-400 'Mechanical Environmental Tests' and AECTP-500 'Electrical/Electromagnetic Environmental Tests'.

5.5.3 The Environmental Test Specification includes, where relevant, quantification of the performance parameters that characterises each service function and associated technical functions including the limits of acceptability. The specification links them with the life cycle profile situations by specifying the corresponding normal, limited and extreme environmental domains which are defined as follows:

a. Normal Environmental Domain: The range of environments (characteristics and levels) within which the materiel is expected too fully satisfy all performance specifications. Within this range, product reliability can also be assessed;

b. Limited Environmental Domain: The range of environments (characteristics and levels) within which the materiel is expected to satisfy reduced performance specifications and will comply with all safety requirements. The materiel will satisfy full performance levels when returned to the normal environmental domain. Reliability cannot be properly assessed;

c. Extreme Environmental Domain: The range of environments (characteristics and level) within which the materiel fails to satisfy its performance requirements but meets its safety requirements. The failure to perform satisfactorily may be irreversible.

5.6 <u>Environmental Test Instruction</u>

5.6.1 The purpose of an Environmental Test Instruction document is to set out the precise and detailed instructions necessary for laboratory staff to conduct a particular environmental test.

5.6.2 The content of an Environmental Test Instruction is based on the summary definition for a particular test contained in the Environmental Test Specification.

5.6.3 Guidance on the details to be specified in an Environmental Test Instruction, relating to the manner in which the test is to be conducted, is given in the relevant test method included in AECTP-300, 400 or 500.

5.7 Environmental Test Report

5.7.1 The purpose of the Environmental Test Report (ETR) is to record in a totally objective manner, the results of all environmental testing which might have a bearing on the quality, reliability and safety of the materiel.

5.7.2 The Environmental Test Report records the results of all environmental testing, including whether or not the materiel met specified performance requirements. Included in the Environmental Test Report is a detailed record of each test with appropriate data and test records, a list of the test equipment used, a description of the test facility, a description of the instrumentation system, and the test procedure used to perform the test. Anomalies that occur and deviations from the test plan are to be included.

5.7.3 The Environmental Test Report is prepared when all testing has been completed. It shall be reviewed for technical accuracy, but care should be taken to retain the objectivity of the report. Attention must be given to the fact that the results in the Test Report cover all the major requirements and plans for environmental tasks and testing as defined in the GEMP.

The Environmental Test Report is to be prepared in time to serve as guidance in making the decision to begin production and to introduce the materiel into service. Note that the ETR (or parts of it) are often drafted during the test programme since the test programme can take years to complete. It is finalised when the test programme is complete. Otherwise details of tests could be lost as people leave the test facility or memory fades.

6. GENERIC USAGE PROFILES

6.1 <u>General</u>

6.1.1 Annex C presents a series of generic usage profiles covering the storage, transportation and deployment of materiel. These profiles can be used to derive project specific environmental requirements and to aid the specification of test severities and durations.

6.1.2 Usage profiles and environmental requirements for a specific project should be based on the information provided in the requirements documents and the user must verify that the profiles assumed are applicable to the item under consideration. The generic usage profiles within this section can be used to support production of and aid the validation of the requirements documents to ensure gaps are not present. They also provide added detail to supplement the information in these documents.

7. SEQUENTIAL TEST PROGRAMME

7.1 <u>General</u>

7.1.1 Annex D describes a ten step process for developing a sequential test programme. The process presented in this chapter is essentially a framework document supported by example. The purpose of this framework document is to demonstrate the engineering principles involved when evaluating the environmental, design, programme and laboratory inputs necessary to develop a sequential test programme. The process is comprehensive and systematically addresses the issues to be resolved.

7.1.2 The process is applicable to all materiel projects. It is especially applicable to munitions of advanced design, such as air carried guided weapons.

8. THE USE OF AECTP-100 THROUGH 600

8.1 <u>General</u>

8.1.1 The strategy embodied in AECTP-100 through 600 centres on a ‘flow down’ process to select the most effective test methods, severity’s and programme schedule for materiel to meet in-Service conditions.

8.1.2 The ‘flow down’ process systematically demonstrates materiel compliance with the environmental descriptions that have been derived directly from the Life Cycle, also known as the Manufacture to Target or Disposal Sequence (MTDS). Consequently, the documentation supporting the flow down process, as described in Chapter 5, should be used as a management tool for ensuring that materiel is fit for service use.

8.1.3 Although this AECTP favours the flow down process, it also accommodates ‘minimum integrity’ testing strategies. It also acknowledges the ‘hardening’ testing strategies that predominate in commercial standards such as IEC 60068 [ref. 5].

8.1.4 A consequence of the development of progressive editions of AECTP-100 through 600 is the increasing harmonisation of its content with that of commercial test methods, where such standards exist and where they are appropriate for the testing of defence materiel.

8.1.5 The following paragraphs show how the content of the AECTP should be utilised to derive environmental descriptions and environmental design criteria; also to select test methods for materiel qualification to be included in the Environmental Test Specification.

8.2 Environment Descriptions and Environmental Design Criteria

8.2.1 An essential precursor to deriving environmental descriptions for the Life Cycle Environmental Profile (LCEP) is access to the definitive (i.e. fully agreed) Life Cycle or MTDS.

8.2.2 The steps to be undertaken to derive environmental descriptions include:

a. Breakdown the Life Cycle into elements where the materiel ‘state’ is identical, for example: packaged state, arming state, etc.

b. Use AECTP-200 to identify the transportation, storage, deployment and use environments applicable to each state, ignoring only the trivial environments.

c. Use AECTP-200 to compile the generic environmental description and characteristics for each environment. AECTP-230, Leaflet 2311 should be used for the natural climatic environments.

d. Finalise environmental descriptions for each condition using statistical approaches where relevant to derive amplitudes, especially for power spectral density and/or shock spectra formats. Also finalise evaluations of the number of occurrences and their duration where relevant. Guidance is given in AECTP-200 on many of these aspects.

8.2.3 In AECTP-200 the description of the environmental characteristics is supported by examples. For specific materiel, amplitudes and duration of environments must be confirmed by measured data or precedent.

8.2.4 Completion of the above steps enables the LCEP document to be finalised. This completion, in turn, allows the Environmental Design Criteria (EDC) document to be compiled.

8.2.5 The steps to be undertaken to determine environmental design criteria include:

a. Identify the critical environmental conditions from the LCEP document (derived using AECTP-200) that are likely to influence the design of the materiel.

b. Use AECTP-200 through 500 to assist the derivation of design levels. Also use these AECTP to support the design activity by selecting the test methods that are the most likely to reveal realistic design weaknesses. The selected test methods are most likely to be minimum integrity test methods for this application.

8.2.6 Completion of these steps enables the EDC document to be finalised, the content of which allows detail design tasks to proceed.

8.3 Test Methods for Materiel Qualification

8.3.1 It is strongly recommended that the test methods for materiel qualification are compatible with the environmental project tailoring (EPT) process described in Chapter 4 of this AECTP. In particular, tailored test methods and severities are preferred to minimum integrity test methods and severities. Test methods and severities based on ‘hardening’ concepts, i.e.: those methods and severities that cannot be directly related to the LCEP for the materiel, should be avoided.

8.3.2 The inputs needed to select test methods for materiel qualification include the LCEP document, materiel design features and knowledge of the materiel's potential failure modes.

8.3.3 The steps to be undertaken to select test methods and associated severities include:

a. Identify the primary potential failure modes including any vulnerability to fretting and/or sine tones.

b. Review the LCEP and EDC documents for environmental descriptions to which compliance of the materiel is to be demonstrated.

c. Consider the type of test methods most likely to induce realistic failure modes.

d. Re-examine potential failure modes regarding the extent to which combined mechanical/climatic tests, such as vibration/temperature or vibration/ (temperature/humidity/altitude), are necessary.

e. Use AECTP-200 through 500 and available specific tailored test data to select the most relevant test methods and associated test severities.

8.3.4 Completion of these steps then enables the test methods and severities, also the test programme schedule, to be optimised to obtain the most cost-effective solution. The optimisation activities should proceed as follows:

a. Eliminate non-restraining environmental conditions and their associated tests, ensuring that potential failure modes are stressed elsewhere. Guidance is given in AECTP-240 Leaflet 2410.

b. Add in to the remaining tests, where applicable, additional conditions to compensate for the effects of the eliminated tests.

c. Introduce 'composite' tests where relevant and where possible to cover, for example, several modes of transportation or deployment platforms.

d. Finalise test severities and duration's including any requirements for stepped levels to cover the range of potential failure mechanisms. Guidance is given in AECTP-240 Leaflet 2410.

e. Check the compatibility of the selected test methods in terms of any conflicts that could arise from mixing 'minimum integrity' tests, or 'hardening' tests, with 'tailored' tests in a test sequence.

f. Check that the order of the test programme reflects the actual sequence of environmental conditions as defined in the Life Cycle, and where necessary amend the test programme to suit.

8.3.5 Completion of these optimisation steps enables the Environmental Test Specification (ETS) document to be finalised. When the content of this document is available, design evaluation and development activity can be undertaken with confidence, followed by the formal materiel qualification task to demonstrate compliance with the environmental descriptions as specified in the LCEP and EDC documents.

8.4 <u>Life extension</u>

8.4.1 The purpose of AECTP 600 is to describe the process that has been developed to determine the ability of materiel to meet extended life requirements and role and deployment changes. The purpose of the document is to acquaint project (programme) managers with the engineering principles involved when evaluating the implications of extended life requirements, and with the outline of a management tool that systematically addresses the issues to be resolved.

9. DEFINITIONS

9.1 General

9.1.1 Annex E presents a glossary of terms which can aid the understanding of the AECTP-200 through 600. This list gives definitions for some of the terminology used in climatic and mechanical testing.

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ANNEX A - TYPICAL ENVIRONMENTAL FACTORS IN A GENERALISED LIFE CYCLE ENVIRONMENT

The situations and environments are not intended to be comprehensive but to serve as a guide only.

SITUATIONS	NATURAL	INDUCED
1. STORAGE PHASE		
a. Depot	Controlled or known temperature and humidity testing.	Shock due to handling. Vibration due to handling. Conducted EM interference due to Nuclear effects.
b. Sheltered	High temperature (Dry/Humid). Low temperature/ freezing. Salt Mist. Chemical attack. Mould growth. Diurnal (cycling Temp)	Shock due to handling. Vibration due to handling. Conducted EM interference due to handling. Susceptibility to EM radiation. Nuclear effects.
c. Open	High temperature (Dry/Humid). Low temperature/ freezing. Sand and dust. Salt mist. Solar radiation. Mould growth. Chemical attack. Rain, hail, snow, ice. Diurnal (cycling Temp)	Shock due to handling. Vibration due to handling. Conducted EM interference due to testing. Susceptibility to EM Radiation. Electrostatic discharge (Handling). Lightning. Nuclear effects.
2. TRANSPORTATION PHASE		
a. Road	High temperature (Dry/Humid). Low temperature. Rain, hail, snow, ice. Sand and dust. Solar radiation. Immersion. handling.	Shock due to road surface and handling. Vibration due to road surface and engine. Susceptibility to EM radiation. Lightning. Electrostatic discharge when

TYPICAL ENVIRONMENTAL FACTORS IN A GENERALISED LIFE CYCLE ENVIRONMENT

SITUATIONS	NATURAL	INDUCED
b. Rail	High temperature. Low temperature. Rain, hail, snow, ice. Sand and dust. Solar radiation.	Shock due to rail transport and handling. Vibration due to rails.
c. Air	Low temperature. Reduced pressure. Sand and dust. Rapid Pressure Change.	Shock due to landing and handling Vibration due to engines and airflow.
d. Sea	High temperature-humid. Low temperature. Rain, hail, snow, ice. Salt mist. Temporary immersion. Mould growth. Sand and dust.	Shock due to wave motion, underwater weapon detonation and handling. Vibration due to wave motion and engine.
3. DEPLOYMENT PHASE		
a. Man Carried	High temperature. (Dry/Humid). Low temperature/ freezing. Rain, hail, snow, ice. Sand, dust and mud. Salt Mist. Solar radiation. Mould growth. Chemical attack.	Shock due to weapon firing and handling. Acoustic noise. Nuclear effects. EM Interference. Chemical and biological attack. Corrosive atmosphere Free-fall. Electrostatic discharge.
b. Tracked & Wheeled Vehicles	High temperature (Dry/humid). Low temperature/freezing Rain, hail, snow, ice. engines.	Shock due to road surface, Weapon firing, detonation and handling. High temp. in glassed enclosure. Vibration due to road surface and

TYPICAL ENVIRONMENTAL FACTORS IN A GENERALISED LIFE CYCLE ENVIRONMENT

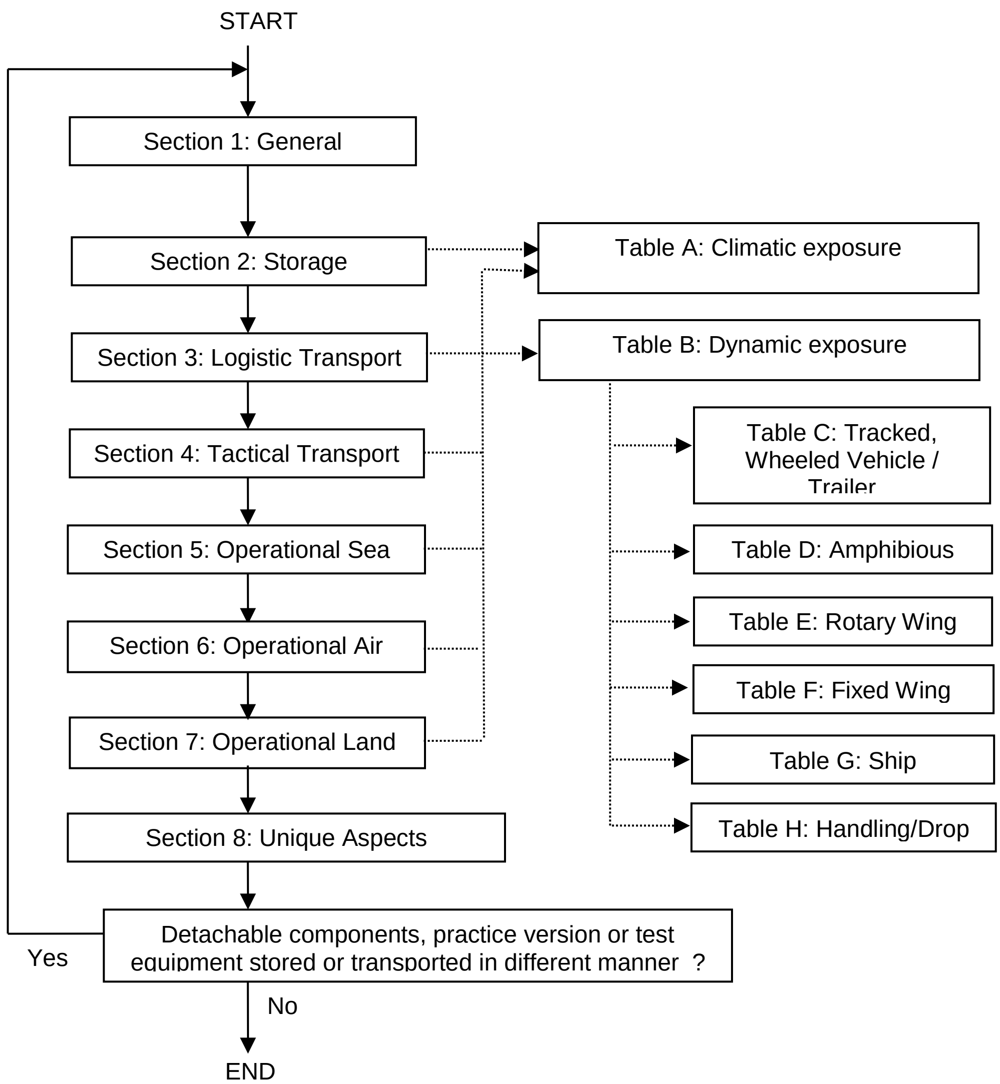
SITUATIONS	NATURAL	INDUCED
	Sand, dust and mud. Salt mist. Solar radiation. Mould growth. Chemical attack. Temperature shock. Immersion.	Acoustic noise. Nuclear effects. EM interference. Electrostatic, Lightning. Chemical and biological attack. Corrosive atmosphere.
c. Fixed Wing & Rotary Aircraft	High temperature Dry/Humid). Low temperature/freezing. Rain. Sand and dust. Salt mist. Solar radiation. Rain and dust erosion. Mould growth. Chemical attack. Bird strike. Low pressure. Hail. Rapid temp/humidity change.	Shock due to assisted take-off, landing and weapon blast. Vibration due to runway surface. Manoeuvre, gunfire, aerodynamics blade tones/engines. Turbulence and engine. Aerodynamic heating. Nuclear effects. EM interference. Electrostatic. Lightning. Corrosive Atmosphere. Noise
d. Ship & Submarine	High temperature (Dry/humid). Low temperature/freezing. Rain, hail, snow, ice. Salt mist. Solar radiation. Mould growth. Chemical attack.	Shock due to weapon firing, detonation and wave slam. Vibration due to waves, engine and acoustic noise. Nuclear effects. EM interference. Electrostatic. Lightning. Increased pressure (submarine). Corrosive atmosphere. Underwater weapon detonation.
e. Static Equipment	High temperature (Dry/Humid) Low temperature/freezing. Rain, hail, snow, ice.	Shock due to weapon firing and detonation. Vibration due to engines.

TYPICAL ENVIRONMENTAL FACTORS IN A GENERALISED LIFE CYCLE ENVIRONMENT

SITUATIONS	NATURAL	INDUCED
	Salt mist. Solar radiation. Mould growth. Chemical attack.	Acoustic noise. Nuclear effects. EM interference. Electrostatic. Lightning. Corrosive atmosphere.
f. <u>Projectile Free Flight</u>	Rain and dust erosion. target impact.	Shock due to firing and Acceleration due to firing. Aerodynamic heating. Acoustic noise. Nuclear effects. EM interference. Electrostatic. Lightning.
g. <u>Torpedo Launch</u>	Immersion. Thermal shock. turbulence.	Shock due to launch boost separation and target impact. Vibration due to engine and hydrodynamic and aerodynamic Launch acceleration. Acoustic noise. Nuclear effects. EM interference.
h. <u>Missile Free Flight</u>	Rain and dust erosion. aerodynamic turbulence.	Shock due to launch, boost separation and target impact. vibration due to engine and Launch acceleration. Aerodynamic heating. Acoustic noise. Nuclear effects. EM interference. Electrostatic. Lightning.

ANNEX B - SERVICE LIFE ANALYSIS

The following questionnaire may be used to identify the planned environments and possible induced external influences during the in service life of the materiel. The questionnaire is divided into eight sections, two main tables and six supplemental tables. To ensure no questions are missed it is advised to go through all sections in a sequential manner. Section 1 provides basic information about the materiel and should be used to identify the general purpose of the materiel. The response to the directions in sections 2 through 7 will be dependent upon the way the materiel will be stored, transported or serviced. This response can be filled out in the Tables A and B. Some of the information in these tables will require more detailed information which can be filled out in tables C through H. The final question in section 8 is applicable any time.



Section 1: General

This section contains all questions regarding the identification and purpose of the test item.

No.	Question	Response
1.1	State whether one of the following is applicable for the item: a. detachable components b. practice version available c. in service assembly d. necessary test equipment Will those parts / items be stored and transported separately and/or in a different manner? If so, fill out the questionnaire for each item or component separately.	
1.2	Which of the Services are likely to use this item?	
1.3	State whether the item will be operated from inside an enclosure?	Y/ N (if yes, specify)
1.4	What is the intended total lifetime for this item (including disposal)?	
1.5	May the life be achieved by replacing short-life components during service?	Y / N (if yes, specify)
1.6	What will be done with items that exceed their service life? (see AECTP-600 for evaluating extended life requirements)	
1.7	If packaged, describe the packaging or protection intended for each of the following situations: a. storage b. transit c. during operation d. any other purpose? Specify role.	Specify: a. b. c. d.
1.8	Is the item or packaging required to be water tight or vapour tight? If yes, will a desiccant be used?	Y / N
1.9	Is the item required to be capable of functioning after exposure to an Electro Magnetic Pulse (exo- or endo-atmospheric)?	Y / N
1.10	Could the item be exposed to electromagnetic environments ?	Y / N

Section 2: Storage

No.	Direction	Completed by
2.1	Complete the storage column of Table A. Climatic zones are described in AECTP-230 Leaflet 2311. The storage column of Table A should be completed for all types of storage including storage associated with other phases of the life cycle. See AECTP-230, Leaflet 2310 for guidance on storage categories.	Name: Date:

Section 3: Logistic Transport

For this section it is assumed that the item is in its logistic packaging or configured for logistic transport. Logistic packaging is intended for transport of, mostly larger amounts of, items to or from the National storage locations. This packaging can vary in the degree of protection it provides for the packaged item, and may or may not contain sub packaging. For transport configuration it is possible that the item will be folded (down), disassembled or provided with a cover or protection.

If these instructions do not cover every situation, please go to the tactical transport section.

No.	Direction	Completed by
3.1	Complete the Logistic Transport column of Table A. Although this requires durations, it may be sufficient to merely indicate the climatic category if these are not known.	Name: Date:
3.2	Complete the Logistic Transport column of Table B and the relevant supplemental tables.	Name: Date:

Section 4: Tactical Transport

For this section it is assumed that the item is in its logistic or tactical packaging or configured for tactical transport. If these questions do not cover any situation, please go to operational sections. Tactical packaging is intended for transport, over (multiple) shorter distance(s), just before or during operational use. This packaging, mostly, provides less protection than the logistical packaging.

No.	Direction / Question	Completed by
4.1	Complete the Tactical Transport column of Table A. Although this requires durations, it may be sufficient to merely indicate the climatic category if these are not known.	Name: Date:
4.2	Complete the Tactical Transport column of Table B and the relevant supplemental tables.	Name: Date:

Section 5: Operational Sea

No.	Direction	Completed by
5.1	Complete the Operational Sea column of Table A.	Name: Date:
5.2	Complete the Operational Sea column of Table B and the relevant supplemental tables.	Name: Date:

Section 6: Operational Air

No.	Direction	Completed by
6.1	Complete the Operational Air column of Table A. Indicate respective exposure in each climatic category for the following: a. standby (on the ground/flight deck) b. operating (carriage at altitude)	Name: Date:
6.2	Complete the Operational column of Table B and the relevant supplemental tables.	Name: Date:

Section 7: Operational Land

No.	Direction	Completed by
7.1	Complete the Operational Land column of Table A. Indicate respective exposure in each climatic category for the following: a. standby or installation b. operating or in use	Name: Date:
7.2	Complete the Operational column of Table B and the relevant supplemental tables.	Name: Date:

Section 8: Unique Aspects

No.	Question	Response
8.1	Is there any situation, condition or external influence which might be expected during the lifetime of the item which is not addressed in the questionnaire?	Detail:

Table A : Climatic Exposure

Environment	Climatic Zone	Duration[1] (Indicate the duration of expected exposure for each phase of the Life Cycle)									Other Information
		Storage[2]	Logistic Transport	Tactical Transport	Operational Sea		Operational Air		Operational Land		
					Standby[3]	Operating	Standby[3]	Operating	Standby[3]	Operating	
High Temperature	A1										
	A2										
	A3										
	M1										
	M2										
Low temperature	C0										
	C1										
	C2										
	C3										
	C4										
	M3										
Solar Radiation	A1										
	A2										
	A3										
	M1										
	M2										
Humidity	B1										
	B2										
	B3										
	M1										
	M2										

[1] When considering durations for the climatic zones, include all possible deployments and the potential return to storage.
[2] Storage phase includes long term in conditioned depots or short term in theater.
[3] Standby includes unprotected storage on forward base, upper deck of a ship, or placed on platforms waiting to be used.

Table A (Continued): Climatic Exposure

Environment	Requirement (indicate during which life cycle phase each environment may occur)										Duration (if known)	Other Information
	Storage	Logistic Transport			Tactical Transport			Operational				
		Sea	Air	Land	Sea	Air	Land	Sea	Air	Land		
Thermal shock												
Immersion												
Mould Growth												
Rain												
Snow												
Icing												
Pressure												
Sand and Dust												
Contamination by Fluids												
Freeze/Thaw												

Table A (Continued): Climatic Exposure

Environment	Requirement (indicate during which life cycle phase each environment may occur)										Duration (if known)	Other Information
	Storage	Logistic Transport			Tactical Transport			Operational				
		Sea	Air	Land	Sea	Air	Land	Sea	Air	Land		
Explosive Atmosphere												
Salt Environment												
Acidic Atmosphere												
Wind												
Green Sea Loading												

Table B : Dynamic Exposure

Category	Mechanical environment	Table [1]	Units	Logistic Transport	Tactical Transport	Operational		Details	Other Information / References
			(Indicate the expected exposure for each phase of the Life Cycle)						
Vibration	Wheeled vehicle / 4-wheeled trailer	C	(km)						
	Tracked vehicle		(km)						
	2-wheeled Trailer		(km)						
	Amphibious	D	(km)						
	Rotary wing	E	(hr)						
	Fixed wing	F	(hr)						
	Rail road		(km)						
	Ship-board	G	(days)						
	Submarine		(days)						
	Acoustic		Y/N ?					Severe acoustic environment ? (> 140 dB)	
	Other		(km) or (hr)					Please specify	
Shock	Handling / Drop	H		Y	Y	Y			
	Munition Launch		Y/N ?						
	Air delivery (parachute)		Number ?					Packaged state ?	
	Catapult Launch / Recovery		Y/N ?						
	Adjacent launch		(rounds)					Specify adjacent munition	
	Pyrotechnic		Y/N ?					Specify near / far field	
	Gunfire		(rounds)					Specify gun and distance from muzzle	
	Ballistic		Y/N ?					Survivability of indirect ballistic impact	
	Underwater explosion (UNDEX)	G	Y/N ?					Still safe and/or suitable ?	
	Rail impact		Y/N ?						
Acceleration	Constant		(g)					Max g ?	

Note [1] : Complete Tables for each type / variant identified.

Table C - Tracked or wheeled vehicle / trailer

Type/ Variant [1]		
Terrain	On road	Off road
Logistic		
Distance		
Avg Speed		
Max Speed		
Tactical		
Shock mounting	Y / N ?	Y / N ?
Secured cargo	Y / N / Both ?	Y / N / Both ?
Distance		
Avg Speed		
Max Speed		
Operational		
Shock mounting	Y / N ?	Y / N ?
Secured cargo	Y / N / Both ?	Y / N / Both ?
Distance		
Avg Speed		
Max Speed		

[1] *To be filled out for each type/variant*

Table D : Amphibious vehicle

Type/ Variant [1]			
Terrain	Water	On-road	Off-road
Logistic			
Distance			
Avg Speed			
Max Speed			
Tactical			
Shock mounting	Y / N ?	Y / N ?	Y / N ?
Distance			
Avg Speed			
Max Speed			
Operational			
Shock mounting	Y / N ?	Y / N ?	Y / N ?
Distance			
Avg Speed			
Max Speed			

[1] *To be filled out for each type/variant*

Table E : Rotary Wing

Type/ Variant [1]	
Logistic	
Duration internal [hrs]	
Duration underslung [hrs]	
Delivery at sea (vertical replenishment)	Y / N, Specify maximum sea state
Tactical / Operational	
Duration once [hrs]	
Duration cumulative [hrs]	
Adjacent stores	Y / N, Specify adjacent stores
Projected mission profile	
Number of take off's / landings	
Cruise [% of operational duration]	
Tactical Maneuver [% of operational duration]	
Attack [% of operational duration]	
Show of force [% of operational duration]	

[1] *To be filled out for each type/variant*

Table F : Fixed Wing

Type/ Variant [1]	
Logistic	
Duration [hrs]	
Tactical / Operational	
Duration once [hrs]	
Duration cumulative [hrs]	
Adjacent stores	Y / N, Specify adjacent stores
Projected mission profile	
Number of take off's / landings	
Cruise [% of operational duration]	
Tactical Maneuver [% of operational duration]	
Attack [% of operational duration]	
Show of force [% of operational duration]	

[1] *To be filled out for each type/variant*

Table G : Ship board

Type/ Variant [1]			
	Duration [days]		
	Logistic	Tactical	Operational
Masthead			
Exposed upper deck			
On or adjacent to a flight deck or helicopter landing pad			
On or near a designated vehicle park			
Protected compartment			
Hull, below water line			

[1] *To be filled out for each type/variant*

Table H : Handling / Drop

Handling / Drop category		Logistic transport		Tactical transport / Operational	
		Packaged	Unpackaged	Packaged	Unpackaged
Ship transport	Y / N ?				
Jackstay					
Man carried					
Forklift					
Crane					
Vehicle (un)loading					
Bench handling					
Other	Specify:				

ANNEX C - GENERIC USAGE PROFILES AND THEIR APPLICATIONS

1. DERIVATION OF GENERIC USAGE PROFILES

1.1 Limitations

1.1.1 **It is recommended that programme specific usage profiles be developed as early as possible in accordance with the user requirements. This annex is only to be used preliminarily if usage profile data is not available. As the programme matures the usage profiles should be validated and revised as necessary**.

1.2 Purpose

1.2.1 The purpose of this section is to present a series of generic usage profiles covering the storage, transportation and deployment of materiel. These profiles can be used to derive project specific environmental requirements and to aid the specification of test severities and durations.

1.2.2 Usage profiles and environmental requirements for a specific project should be based on the information provided in the requirements documents and the user must verify that the profiles assumed are applicable to the item under consideration. The generic usage profiles within this section can be used to support production of and aid the validation of the requirements documents to ensure gaps are not present. They also provide added detail to supplement the information in these documents.

1.2.3 The information in this section also provides guidance to the Project Manager when compiling the environmental requirement sections of Invitation-to-Tender (ITT) documentation.

1.2.4 The generic usage profiles are set out for deployment on seven platform types (man carried, wheeled vehicles, tracked vehicles, propeller and jet aircraft, rotary wing and ships). In addition, generic environmental profiles are provided for storage and transportation to the forward base[1)] and to the front line[2)]. Thus a total of nine generic profile groups are considered.

1) The Forward Base (also known as the Forward Operating Base or the Theatre Supply Area) is part of the supply chain and does not cover contractor supply chain storage or distribution.

2) The Front Line is part of the supply chain and applies to materiel used or deployed in the operational field or battlefield environment.

1.2.5 For each of these groups a range of environments discussed, including:

- mechanical e.g. vibration, shock & drop, and acceleration
- climatic (natural) e.g. temperature, humidity, solar radiation, pressure, wind, sand & dust, rain & snow
- climatic (induced) e.g. immersion & spray, thermal shock
- contamination e.g. contamination by fluids
- abnormal conditions e.g. accidents & hostile attack

1.2.6 Generic profiles for individual munition types which indicate the likely transportation modes and durations for a range of common munitions are provided in Appendix 1. If a different profile is more appropriate for a particular munition, then it should be used. Appendix 1 is not prescriptive for all munitions.

1.2.7 The information in this section can also be used to support the process in Annex D for developing a sequential test programme. It is particularly useful when evaluating the environmental inputs (Step 1), compiling the draft list of critical environments (Step 4), and converting the environments to a sequence of test methods and severities (Step 6). In effect, the data in this section can provide a useful start to these three steps in Annex D.

Appendix 1 Generic Usage Profiles for Munitions

This Appendix presents generic usage profiles for a range of munition types.

	Transportation Mode							Operational Mode
Munition Type	Land		Sea		Air			
	Commercial Vehicle	Military Vehicle	Cargo Ship	Naval Ship	Jet Aircraft	Turboprop Aircraft	Helicopter	Combat Platform
Artillery	5,000 km	5,000 km	8 mths	8 mths	20 h	20 h	20 h	Not applicable
Mortar	10,000 km	10,000 km	8 mths	8 mths	100 h	100 h	20 h	5,000 km
Tank Ammunition	5,000 km	5,000 km	8 mths	8 mths	20 h	20 h	20 h	5,000 km
Self-Propelled Gun Ammunition	5,000 km	5,000 km	8 mths	8 mths	20 h	20 h	20 h	2,000 km
Man Portable Missile	10,000 km	10,000 km	8 mths	8 mths	100 h	100 h	50 h	5,000 km
Land Vehicle Mounted Missile	10,000 km	10,000 km	8 mths	8 mths	100 h	100 h	20 h	5,000 km
Anti-Tank Mine	10,000 km	10,000 km	8 mths	8 mths	100 h	100 h	20 h	2,000 km
Cannon Ammunition	10,000 km	10,000 km	8 mths	18 mths	100 h	100 h	50 h	5,000 km
Small Arms Ammunition	20,000 km	20,000 km	8 mths	18 mths	200 h	200 h	50 h	5,000 km
Hand / Rifle Grenade	20,000 km	20,000 km	8 mths	18 mths	200 h	200 h	50 h	5,000 km
Land Forces Pyrotechnics	5,000 km	5,000 km	8 mths	8 mths	100 h	100 h	50 h	2,000 km
Demolitions	20,000 km	20,000 km	8 mths	18 mths	500 h	200 h	50 h	10,000 km
Naval Gun Ammunition	5,000 km	Not applicable	8 mths	12 mths	20 h	20 h	5 h	4 years
Sea Launched Missile	5,000 km	5,000 km	8 mths	8 mths	50 h	50 h	5 h	10 years
Depth Charge	5,000 km	5,000 km	8 mths	8 mths	20 h	20 h	5 h	5 years
Sea Mine	5,000 km	5,000 km	8 mths	8 mths	20 h	20 h	5 h	5 years
Naval Decoys	5,000 km	5,000 km	8 mths	8 mths	20 h	20 h	5 h	5 years

Munition Type	Transportation Mode							Operational Mode
	Land		Sea		Air			
	Commercial Vehicle	Military Vehicle	Cargo Ship	Naval Ship	Jet Aircraft	Turboprop Aircraft	Helicopter	Combat Platform
Medium Calibre Ammunition	10,000 km	10,000 km	8 mths	18 mths	100 h	100 h	50 h	10 years
Naval Pyrotechnics	5,000 km	5,000 km	8 mths	8 mths	50 h	50 h	20 h	5 years
Torpedo	5,000 km	5,000 km	8 mths	8 mths	50 h	50 h	5 h	Fixed Wing 500 h Helicopter 50 h Ship 10 years
Air Launched Missile	10,000 km	10,000 km	8 mths	8 mths *(note 1)*	200 h	100 h	20 h	5 to 500 h
Aircraft Bomb	10,000 km	10,000 km	8 mths	8 mths *(note 1)*	200 h	100 h	20 h	50 h
Aircraft Gun Ammunition	10,000 km	10,000 km	8 mths	18 mths *(note 1)*	100 h	100 h	20 h	200 h
Defensive Aids Pyrotechnics	5,000 km	5,000 km	8 mths	8 mths *(note 1)*	50 h	50 h	20 h	500 h
Ejection Seat Energetics	5,000 km	5,000 km	8 mths	8 mths *(note 1)*	50 h	50 h	20 h	200 h

Note 1: For Naval aircraft significant additional sea transport / operational storage may apply.

2. STORAGE AND TRANSPORTATION OF MATERIEL UP TO FORWARD BASE

2.1 Handling

2.1.1 Handling of the packaged equipment will utilise any commercial handling methods including forklift trucks, cranes & hoists and trolleys. A total of up to 2 hours of forklift truck handling can occur, up to 50 crane or hoist lifts and 2 hours on trolleys.

2.2 Storage

2.2.1 Packaged equipment is held in storage at fixed depots for a period of time prior to issue. The actual duration of storage will be dependent on many factors, however, equipment will normally be packaged to ensure that it will be in a serviceable condition after a period of long term storage. The majority of this storage will occur in permanent, frost-free buildings.

2.2.2 Once issued, equipment may be stored for shorter periods prior to onward shipment or use. This storage will typically occur at forward depots and could occur anywhere in the world. The type and quality of the storage facilities may vary considerably from permanent buildings to a simple tarpaulin covering or no protection at all.

2.2.3 The following criteria are typical of current requirements and should be used as fall back guidance for the storage periods of various types of equipment. The storage period needs to reflect the materiel's design life as stated in the through life plan and / or user requirement. If the actual storage period is known then it should be used in preference to the durations given below:

Long Term Storage	
OME (Ordnance, Munitions and Explosives) (Limited to permanent frost-free buildings)	10 years
Conventional Non-Hazardous Stores (Limited to permanent frost-free buildings)	5 years
Consumable Stores (Limited to permanent frost-free buildings) [1]	1 year

Note 1: Consumable stores are items which are non-returnable and have a set period within which they must be used.

Storage at Forward Depots	
OME (Covered buildings or similar)	600 days
OME (No protection or covered with tarpaulins)	180 days
Conventional Non-Hazardous Stores (Covered buildings or similar)	300 days
Conventional Non-Hazardous Stores (No protection or covered with tarpaulins)	60 days
Consumable Stores (Covered buildings or similar)	60 days

Note that the storage and handling requirements for military packages which do not contain OME or materiel of a hazardous nature are defined by the Military Packaging Levels/Codes. These Levels/Codes are based on specific performance criteria and are designed to ensure that equipment will remain in a serviceable condition during storage and handling in the supply chain.

2.3 Transportation

2.3.1 Transportation to and from the forward depot may occur up to 10 times in the life of the equipment. The likely methods of transportation are by road, rail, sea and air. The transportation environments envisaged are set out in the following paragraphs.

2.3.2 Road transportation may utilise either commercial carriers or service vehicles. Mostly road transportation will utilise reasonable quality roads, although some transport over degraded roads can occur. No significant off-road transportation is expected in this phase. A total of 20,000 km of land (road and rail) transport is possible. The total elapsed time for land transport can be up to 90 days.

2.3.3 Rail transport may utilise “block” trains with good quality wagons (i.e. with hydraulic buffers and good suspension) and no loose shunting or poor quality wagons (i.e. with spring buffers and poor suspension and uncontrolled loose shunting could occur.

2.3.4 Air transportation may be by fixed wing propeller aircraft, fixed wing jet aircraft or helicopter (either internally or as an under slung load). A total of 10 air journeys may occur world wide. Of this total up to 100 hours may be in fixed wing jet aircraft, 50 hours in propeller aircraft, 20 hours internally by helicopter and 5 hours under slung.

2.3.5 Sea transportation may be by commercial carrier or by Naval Transport Ships. A total of 4 months sea transportation is possible. Protracted periods aboard Naval Transport Ships may occur (up to 12 months) if these vessels are used for forward storage purposes. Loading on and off a Naval Transport Ship may adopt military or commercial dockside cranes, derricks or helicopters. Packaged equipment may be carried in unventilated containers as deck cargo for 1 month (of the 4 months for sea transportation).

3. STORAGE AND TRANSPORTATION OF MATERIEL TO THE FRONT LINE

3.1 Handling

3.1.1 Handling of the packaged equipment will utilise any commercial handling methods including forklift trucks, cranes & hoists and trolleys. A total of up to 2 hours of forklift truck handling can occur, up to 50 crane / hoist lift and 2 hours on trolleys. Additionally handling may utilise military field handling equipment or the equipment may be manhandled. At sea the equipment may be transferred using Jackstays or helicopter Vertical Replenishment (VERTREP) up 20 times.

3.2 Storage

3.2.1 Packaged equipment is held in storage at fixed depots for a period of time prior to issue. The actual duration of storage will be dependent on many factors, however, equipment will normally be packaged to ensure that it will be in a serviceable condition after a period of long term storage**.**

3.2.2 Once issued equipment may be stored for shorter periods prior to onward shipment or use. This storage will typically occur at forward depots and could occur anywhere in the world. The type and quality of the storage facilities may vary considerably from permanent buildings to a simple tarpaulin covering or no protection at all.

3.2.3 The following criteria are typical of current requirements and should be used as guidance for the storage periods of various types of equipment. The storage period needs to reflect the materiel's design life as stated in the through life plan and / or user requirement. If the actual storage period is known then it should be used in preference to the durations given below:

Storage at Forward Depots / Field Storage	
OME (Covered buildings or similar)	600 days
OME (No protection or covered with tarpaulins)	180 days
Conventional Non-Hazardous Stores (Covered buildings or similar)	300 days
Conventional Non-Hazardous Stores (No protection or covered with tarpaulins)	60 days
Consumable Stores (Covered buildings or similar) [1]	60 days
Consumable Stores (No protection or covered with tarpaulins)	30 days

Note 1 : Consumable stores are items which are non-returnable and have a set period within which they must be used

Note that the storage and handling requirements for military packages which do not contain OME or materiel of a hazardous nature are defined by the Military Packaging Levels/Codes. These Levels/Codes are based on specific performance criteria and are designed to ensure that equipment will remain in a serviceable condition during storage and handling in the supply chain.

3.3 Transportation

3.3.1 Transportation to and from the front line may occur up to 20 times in the life of the equipment. The expected methods of transportation are by road, rail, sea and air. The transportation environments envisaged are set out in the following paragraphs.

3.3.2 Road transportation may utilise either commercial carriers or service vehicles. Mostly road transportation will utilise reasonable quality roads, although transport over degraded roads and off-road transportation can occur. A total of 24,000 km of land (road and rail) transport are expected. The total elapsed time for land transport can be up to 120 days. Of this total, 4,000 km may occur off-road or on degraded roads over a period of 30 days.

3.3.3 Operational rail transport may utilise “block” trains of with good quality wagons (i.e. with hydraulic buffers and good suspension) and no loose shunting. or poor quality wagons (i.e. with spring buffers and poor suspension) and uncontrolled loose shunting could occur.

3.3.4 Air transportation may be by fixed wing propeller aircraft, fixed wing jet aircraft or helicopter (either internal or as under slung load). A total of 10 air journeys may occur world wide. Of this total up to 100 hours may in fixed wing jet aircraft, 50 hours in propeller aircraft, 20 hours internally by helicopter and 5 hours under slung.

3.3.5 Sea transportation may be by commercial carrier or by Naval Transport Ships. A total of 12 months sea transportation is possible. Protracted periods aboard Naval Transport Ships may occur (up to 24 months) if these vessels are used for field storage purposes. Loading on and off a Naval Transport Ship may adopt dockside cranes, derricks or helicopters. Packaged equipment may be carried in unventilated containers as deck cargo for 12 months (of the 24 months for sea transportation).

3.3.6 Transportation at the front line may utilise any available means some of which would not normally used for transport to forward depot. These include tracked vehicles (particularly APCs and command vehicles) for up to 500 km, small wheeled vehicles and trailers (4 hours) and small helicopters (included in air transport total above). All land vehicles may be utilised in off road conditions or on degraded roads.

4. MAN CARRIED

4.1 The equipment may be deployed and used world-wide during its required service life. A typical battlefield deployment "War fighting - Single Rifle Company" or "Outdoor Training Day" is given below:

Activity	Duration (h)	Notes
Preparation	10	including rehearsal & checking of equipment either on land or sea
Tactical Move	4	either: • 100% land vehicle [1] or • 50% land vehicle [1] and 50% helicopter or • 50% landing craft and 50% land vehicle [1]
Infiltration	6	dismounted tactical movement including 12 km cross country
Attack	18	
Replenishment	10	including checking of equipment
TOTAL	48	

Note 1 : wheeled or tracked.

A typical battlefield deployment "Peace Support Operations – Single Rife Company" including day patrol, night patrol & manning a checkpoint is given below:

Activity	Duration (h)	Notes
Preparation	4	including rehearsal & checking of equipment
Patrol	4	day patrol on foot
Post Patrol	2	including checking of equipment
Preparation	4	including rehearsal & checking of equipment
Patrol	4	night patrol on foot
Post Patrol	2	including checking of equipment
Preparation	8	including rehearsal & checking of equipment
Move to checkpoint	4	land vehicle [1] 75% road & 25% cross-country
Occupation of checkpoint	10	
Recovery	4	land vehicle [1] 75% road & 25% cross-country
Post Patrol	2	including checking of equipment
TOTAL	48	

Note 1 : wheeled or tracked.

5. WHEELED VEHICLES

5.1 Wheeled vehicles may be deployed and used world-wide during their required service lives. Typical usage profiles for a range of vehicle types are given below:

Vehicle Type	**Mission Type**	**Distance (km)**
Self Propelled Gun or Rocket Launcher	Battlefield Operations	6,000
	Battlefield Training	6,000
	Shoot & Scoot	6,000
	Command	6,000
	Convoy	2,000
	Maintenance	2,000
APC or Light Wheeled Tank or Command Vehicle	Battlefield Operations	6,000
	Battlefield Support	6,000
	Shoot & Scoot	6,000
	Training	6,000
	Command	6,000
	Convoy	2,000
	Maintenance	2,000
Logistic Battlefield Support Vehicle	Battlefield Support	20,000
	Rear Line Support	20,000
	Convoy (degraded roads)	20,000
	Road Operations	100,000
Commercial Support Vehicle	Rear Line Support	20,000
	Convoy (degraded roads)	20,000
	Road Operations	100,000

Typical usage profiles for materiel installed or deployed in wheeled vehicles are given below:

Materiel Type	**Vehicle Type**	**Mission Type**	**Distance (km)**	**Duration (h)**
Man Portable Anti-Tank Weapon	Wheeled Fighting Vehicle	Battlefield Deployment & Training (cross country or degraded roads)	4,000	80
		Convoy & Training (metalled roads)	1,500	30
		Idling & Maintenance (quasi-stationary)	-	20
	Wheeled Armoured Personnel Carrier	Battlefield Deployment & Training (cross country or degraded roads)	3,000	60
		Convoy & Training (metalled roads)	2,500	50
		Idling & Maintenance (quasi-stationary)	-	20
Vehicle Radio	Logistic Battlefield Support Vehicle	Battlefield Deployment & Training (cross country or degraded roads)	20,000	400
		Convoy & Training (metalled roads)	40,000	800
		Idling & Maintenance (quasi-stationary)	-	50
Vehicle Radio	Commercial Support Vehicle	Battlefield Deployment & Training (cross country or degraded roads)	40,000	800
		Convoy & Training (metalled roads)	80,000	1,600
		Idling & Maintenance (quasi-stationary)	-	100

Note that the duration only indicates the time for which the vehicle is moving or stationary with the engine idling. An average speed of 50 km/h has been assumed.

An example mission profile for a wheeled fighting vehicle is given below:

Terrain	**% Time**	**Speed (kph)**	**Distance (km)**	**Duration (h)**
Pavé	6	< 30	5	0.2
		30 - 40	3	0.1
		> 40	4	0.1
Cross Country	22	< 30	15	1.0
		> 30	10	0.3
Rough Road	30	< 30	20	1.0
		> 30	25	0.8
Main Roads	42	< 30	8	0.5
		30 - 40	18	0.5
		40 - 50	42	1.0
		> 50	30	0.5
TOTAL			180	6

An example mission profile for a medium mobility transport vehicle is given below:

Terrain	**% Time**	**Speed (kph)**	**Distance (km)**	**Duration (h)**
Pavé	5	< 30	5	0.2
		> 30	7	0.2
Cross Country	21	< 20	10	1.0
		20 - 40	30	0.8
Rough Road	18	< 20	8	0.5
		20 - 60	40	1.0
Main Roads	56	< 30	20	1.0
		30 - 50	50	1.5
		50 - 70	120	2.3
TOTAL			290	8.5

6. TRACKED VEHICLES

6.1 Tracked vehicles may be deployed and used world-wide during their required service lives. Typical usage profiles for a range of vehicle types are below:

Vehicle Type	Mission Type	Distance (km)
Main Battle Tank	Battlefield Operations	4,200
	Training	4,200
	Command	4,200
	Convoy	2,000
	Maintenance	500
Self Propelled Gun or Rocket Launcher	Battlefield Operations	4,200
	Battlefield Training	4,200
	Shoot & Scoot	4,200
	Command	4,200
	Convoy	2,000
	Maintenance	2,000
APC or Light Tank or Command Vehicle	Battlefield Operations	4,200
	Battlefield Support	4,200
	Command	4,200
	Convoy	2,000
	Maintenance	2,000
Logistics Vehicle	Battlefield Support	14,000
	Rear line Support	5,000
	Convoy (degraded road)	5,000
	Road Operations	5,000

Typical usage profiles for materiel installed or deployed in tracked vehicles are given below:

Materiel Type	**Vehicle Type**	**Mission Type**	**Distance (km)**	**Duration (h)**
Main Gun Ammunition	Main Battle Tank	Battlefield Deployment & Training (cross country or degraded roads)	4,200	120
		Convoy & Training (metalled roads)	1,000	30
		Idling & Maintenance (quasi-stationary)	-	30
	Self Propelled Gun	Battlefield Deployment & Training (cross country or degraded roads)	5,600	160
		Convoy & Training (metalled roads)	2,100	60
		Idling & Maintenance (quasi-stationary)	-	40
Man Portable Anti-Tank Weapon	Armoured Personnel Carrier	Battlefield Deployment & Training (cross country or degraded roads)	4,200	120
		Convoy & Training (metalled roads)	2,800	80
		Idling & Maintenance (quasi-stationary)	-	30
Vehicle Radio	Logistic Vehicle	Battlefield Deployment & Training (cross country or degraded roads)	14,000	400
		Convoy & Training (metalled roads)	15,000	430
		Idling & Maintenance (quasi-stationary)	-	100

Note that the duration only indicates the time for which the vehicle is moving or stationary with the engine idling. An average speed of 35 km/h has been assumed.

An example mission profile for a self-propelled gun is given below:

Terrain	**% Time**	**Speed (kph)**	**Distance (km)**	**Duration (h)**
Pavé	8	< 30	2	0.1
		30 - 40	7	0.2
		> 40	5	0.1
Cross Country	32	< 30	15	0.7
		> 30	35	0.9
Rough Road	24	< 30	15	0.7
		> 30	20	0.5
Main Roads	36	< 30	10	0.5
		30 - 40	15	0.4
		40 - 50	20	0.4
		> 50	30	0.5
TOTAL			174	5

An example mission profile for an armoured personnel carrier is given below:

Terrain	**% Time**	**Speed (kph)**	**Distance (km)**	**Duration (h)**
Pavé	6	< 30	2	0.1
		30 - 40	3	0.1
		> 40	4	0.1
Cross Country	29	< 30	15	1.0
		30 - 40	20	0.6
Rough Road	41	< 20	10	0.5
		20 -30	20	0.8
		30 - 40	20	0.6
		40 - 50	15	0.3
Main Roads	24	< 30	5	0.2
		30 - 40	10	0.3
		40 - 50	14	0.3
		> 50	25	0.5
TOTAL			163	5.4

7. FIXED WING JET AIRCRAFT

7.1 Aircraft may be deployed and used world-wide during their required service lives. Typical usage profiles for a range of aircraft types are given below:

Aircraft Type	Mission Type	% of Flight Life
Attack Aircraft	Low-low-low	25
	High-low-high	15
	Close Support	15
	High-high-high	5
	High-low-low-high	10
	Ferry / loiter	30
Anti-Submarine Warfare Aircraft	Seek & Attack	20
	Surface Surveillance	20
	Investigate / attack	10
	Investigate only	10
	Mine laying	5
	High-high-high	20
	Ferry / loiter	15
ECM Aircraft	Penetration	30
	Stand-off	40
	Ferry / loiter	30
Fighter Aircraft	Low-low-low	5
	Escort	8
	High-low-low-high	8
	Close support	8
	High-high-high	8
	Air defence / capture	8
	Low-low-high	15
	Intercept	10
	Ferry / loiter	30
Reconnaissance Aircraft	Low-low-low	5
	High-low-high	30
	High-high-high	30
	High-supersonic	15
	Ferry / loiter	20
Tanker Aircraft	Low-low-low refuel	30
	Strike refuel	30
	High-low-high refuel	40

Typical usage profiles for materiel installed in or deployed on aircraft are given below:

Materiel Type	Aircraft Type	Mission Type	Max Dynamic Pressure (kPa)	Duration (minutes)
Free Fall Bomb	High Performance Attack Aircraft	Low-low-low	30.6	140
		High-low-high	49.5	142
		Close support	41.4	226
		High-high-high	13.0	156
		High-low-low-high	42.2	168
		Ferry / loiter	9.2	305
Air to Air Missile	High Performance Fighter Aircraft	Low-low-low	33.5	150
		Escort	48.9	204
		High-low-low-high	49.5	187
		Close support	42.7	233
		High-high-high	13.6	115
		Air defence / capture	30.7	119
		Low-low-high	53.4	152
		Intercept	33.2	50
		Ferry / loiter	8.2	260
Torpedo	Low Performance Anti-Submarine Warfare Aircraft	Seek & attack	5.6	415
		Surface surveillance	24.7	460
		Investigate / attack	34.1	445
		Investigate / intermediate	33.5	430
		Mine laying	33.5	315
		High-high-high	7.1	245
		Ferry / loiter	5.3	600
Externally Mounted Reconnaissance Equipment	Reconnaissance Aircraft	Low-low-low	33.5	145
		High-low-high	55.4	215
		Low-low-high	53.4	143
		High subsonic	13.6	160
		Ferry / loiter (High subsonic)	28.3	100
		Ferry / loiter (High supersonic)	8.0	275
Externally Mounted ECM Equipment	High Performance Aircraft	Penetration	49.5	159
		Stand-off	10.4	160
		Ferry / loiter	8.2	275
Externally Mounted ECM Equipment	Tanker Aircraft	Low-low-low refuel	21.3	147
		Strike refuel	14.5	112
		High-low-high refuel	28.9	186

An example of a 'high-low-high' mission for a 30 hour materiel air carriage life is given below:

Segment	Altitude (ft) / (m)	Mach No	Dynamic Pressure (kPa)	Duration (h)	Duration (%)
1	32,000 / 9750	0.68	8.9	12.6	42
2	1,000 / 300	0.85	49.5	1.9	6
3	1,000 / 300	0.70	33.5	1.1	4
4	40,000 / 12200	0.68	5.9	14.4	48

8. FIXED WING PROPELLER AIRCRAFT

8.1 Aircraft may be deployed and used world-wide during their required life service lives. A typical usage profile is given below:

Aircraft Type	Mission Type	% of Flight Life
Transport Aircraft	Short range transport (< 2h)	25
	Medium range transport (2-5h)	20
	Long range transport (> 5h)	20
	Personnel parachute drop	5
	Equipment parachute drop	10
	Training	20

Typical usage profiles for materiel installed in or deployed on fixed wing propeller aircraft are given below:

Materiel Type	Aircraft Type	Mission Type	Indicated Air Speed (kts)/ (km/hr)	Duration (hours)
Defensive Aids Suite Flares	Transport Aircraft	Short range transport (< 2h)	200 / 370	50
		Medium range transport (2-5h)	200 / 370	50
		Long range transport (> 5h)	200 / 370	50
		Personnel parachute drop	110 / 200	15
		Equipment parachute drop	120 / 220	25
		Training	200 / 370	N/A
Radio	Transport Aircraft	Short range transport (< 2h)	200 / 370	1,200
		Medium range transport (2-5h)	200 / 370	1,200
		Long range transport (> 5h)	200 / 370	1,200
		Personnel parachute drop	110 / 200	300
		Equipment parachute drop	120 / 220	600
		Training	200 / 370	1,200

9. ROTARY WING AIRCRAFT

9.1 Helicopters may be deployed and used world-wide during their required life service lives. Typical usage profiles for a range of aircraft types are given below:

Aircraft Type	Mission Type	% of Flight Life
Transport Helicopter	Transport – Internal Load	35
	Transport – Under Slung Load	20
	Trooping Mission	30
	Fighter Evasion	1
	Training	14
Anti-Submarine Warfare Helicopter	Anti-submarine search and strike	40
	Anti-surface search and over the horizon targeting	15
	Trooping Mission	5
	Transport of equipment	10
	Vertical Replenishment	5
	Reconnaissance	10
	Training	10
	Casualty Evacuation / Search and Rescue	5
Attack Helicopter	Anti-armour	15
	Ground suppression	15
	Reconnaissance	10
	Ferry	10
	Training	50

Examples of generic usage profiles for materiel installed in or deployed on helicopters are given below:

Materiel Type	**Aircraft Type**	**Mission Type**	**Duration (hours)**
Defensive Aids Suite Flares	Transport Helicopter	Transport – Internal Load	100
		Transport – Under Slung Load	65
		Trooping Mission	80
		Fighter Evasion	5
		Training	0
Torpedo	Anti-Submarine Warfare Helicopter	Anti-submarine search and strike	150
		Reconnaissance	35
		Training	5
		Casualty Evacuation / Search and Rescue	10
Missile	Attack Helicopter	Anti-armour	20
		Ground suppression	15
		Reconnaissance	10
		Ferry	3
		Training	2
Cannon ammunition	Attack Helicopter	Anti-armour	70
		Ground suppression	70
		Reconnaissance	30
		Ferry	20
		Training	10

Example mission profiles for a transport, ground attack and anti-submarine warfare helicopter are given below:

	Transport helicopter	**Ground attack helicopter**	**Anti-submarine warfare helicopter**
Flight Condition	**% Time**	**% Time**	**% Time**
Take-off	5	2	2
Taxi	5	1	NA
Ground ops	NA	NA	10
Straight & Level	50	45	45
Turns	5	15	5
Dash	NA	10	NA
Approach	5	5	5
Transition to hover	5	5	3
Climb & descent	10	5	10
Hover	10	10	18
Land	5	2	2

10. SHIPS & SUBMARINES

10.1 The ships and submarines may be deployed and used world-wide during their required life service lives. Typical lives for a range of ship and submarine types are given below:

Ship Type	Life (years)
Frigate	20
Destroyer	25
Aircraft Carrier	25
Royal Fleet Auxiliary	40
Hunter-Killer (SSN)	20
Ballistic Missile Submarine (SSBN)	25

Typical speeds and ranges for ships and submarines are given below:

Type	Typical Speed (kts) / (km/hr)	Top Speed (kts) / (km/hr)	Typical Range (nm) / (km)
Frigate	15 / 28	28 / 52	6,750 / 12,500
Destroyer	18 / 33	30 / 56	3,460 / 6,400
Aircraft Carrier	19 / 35	28 / 52	6,050 / 11,200
Royal Fleet Auxiliary	20 / 37	22 / 41	8,640 / 16,000
Hunter-Killer (SSN)	30 / 56	-	21,600 / 40,300 [1]
Ballistic Missile Submarine (SSBN)	25 / 46	-	18,000 / 33,000 [1]

Note 1 : Normalised to a 1 month deployment

Typical usage profiles for materiel installed in or deployed on ships and submarines are given below:

Materiel Type	Ship / Submarine Type	Total Duration (years)
Anti-ship missile	Frigate	10
Anti-missile missile	Destroyer	10
Decoy system	Aircraft Carrier	2
Torpedo	Hunter-Killer Submarine	10

ANNEX D - PROCESS FOR DEVELOPING A SEQUENTIAL TEST PROGRAMME

1. PURPOSE

1.1 This chapter describes a ten step process for developing a sequential test programme. The process presented in this chapter is essentially a framework document supported by example. The purpose of this framework document is to demonstrate the engineering principles involved when evaluating the environmental, design, programme and laboratory inputs necessary to develop a sequential test programme. The process is comprehensive and systematically addresses the issues to be resolved.

1.2 The process is applicable to all materiel projects. It is especially applicable to munitions of advanced design, such as air carried guided weapons.

1.3 It is acknowledged that experienced environmental engineers when developing sequential test programmes may tend to address several steps simultaneously. Nevertheless, the process as presented does indicate a logical approach to the task which should offer assistance to the less experienced practitioner.

1.4 The application of the process as presented in this chapter is limited to the development of sequential environmental test programmes. A demonstration of the process is presented as Appendix 1.

2. INTRODUCTION TO THE PROCESS

2.1 The process is derived from the internationally developed Ten Step Method used for evaluating the ability of materiel to meet extended life, role and deployment changes. It is based on the premise that the materiel is to be developed and qualified to an accepted best practice environmental control and management process such as that presented in AECTP-100.

2.2 The following paragraphs provide a brief introduction to the process. A demonstration of the process through examples can be found in the appendixes to this chapter. The inter-relationship between the steps is shown in Figure 1, while the required input information and the expected outputs for each of the steps are shown in Table 1.

2.2.1 In Step 1, Step 2 and Step 3 the three generic sources of inputs to the process, namely: environmental, programme and design are reviewed to ensure that the information required for the process is satisfactory. The outputs from these three steps should as a minimum enable Step 4 and Step 5 to be completed with appropriate confidence. The reviews and evaluations associated with the three steps are therefore far from trivial. Moreover, it is often a challenging task to extract sufficient information on design weaknesses from design teams.

2.2.2 The purpose of Step 4 is to compile a provisional list of critical environments based on the knowledge gained from Step 1, Step 2 and particularly Step 3. The list is expected to be largely based upon personal experience and knowledge of similar systems and testing thereof. The output is likely to be the result of several iterations to form a credible list of environments placed broadly in sequence according to the appropriate phases of the Life Cycle Environmental Profile (LCEP). In Step 5 the list is refined to sets of sequential environments, during which the purpose of each environmental requirement and the potential failure modes of the materiel are addressed in more detail. Consequently this step is best achieved systematically with the aid of a matrix or tabular format, such as those used for the figures in Appendix 1 and as detailed in Appendix 3. Such a matrix can also be used as the basis of a safety case compliance document to provide assurance that appropriate environmental consideration has been applied. The decision at this stage to omit an environment listed in the matrix from further consideration should be validated and traced to provide an audit trail.

2.2.3 In Step 6 the refined sets of sequential environments are converted to test methods and severities. The detail of this step will be driven by the strategy stated in the General Environment Management Plan for the project (see paragraph 5.2 of AECTP 100). The complexity of the resulting test methods and severities will be a function of the sensitivity of the materiel to the specified environments. The use of combined environments testing is addressed in Step 7, which also deals with the integration of the non-sequential tests into the programme. Complementary modelling, analysis and assessment evidence is dealt with by the process at Step 7.

2.2.4 The purpose of Step 8 is to balance systems and sub-systems testing to reflect project environmental strategy requirements and the availability of test facilities especially for system level testing. Consequently the major output from Step 8 is a technically credible environmental sequential test programme which needs to be researched in depth with the project cost and time constraints. This consideration is the purpose of Step 9. The final task within the process (Step 10) is to complete and issue the pre-test documentation.

3. PROVISIONS AND BENEFITS

3.1 The process provides a structured and economic method to aid conformity and traceability when developing an environmental sequential test programme, including the integration of the associated non-sequential tests and the complementary analyses, modelling and assessments. It facilitates the generation of a common baseline test and assessment plan for use in competitive tender procurement without being prescriptive in the testing methodology used by the competing tenderers. This reduces the risks associated with cost or timescale overrun for the procurement team and provides a firmer basis of competitive and commercial off-the-shelf / military off-the-shelf (COTS/MOTS) procurement.

3.2 Historically, sequential environmental test programmes have been developed mainly through the pragmatism of environmental engineers engaged on materiel projects. However, in recent years fewer specialists are available for such tasks, and even fewer are in a position to develop sufficient experience to become specialists. Therefore the format of the process is designed as both a management and training tool to guide engineers systematically through the more important technical aspects of developing sequential environmental test programmes.

4. INDIVIDUAL STEPS

4.1 <u>Step 1: Evaluate Environmental Inputs</u>

4.1.1 An essential precursor to this process is to evaluate thoroughly the environmental inputs which are usually defined in the Life Cycle Environment Profile (LCEP). The purpose and usage of the LCEP document is defined in AECTP-100 Paragraph 5.3. It is vital that evidence is available to support any data presented in the LCEP. If this is not possible then test methods/severities supported in AECTP-300/400 may be applicable. When deriving a programme of tests leading to materiel design qualification it is very important that the environmental inputs are complete and stable, i.e. finalised and unlikely to change, as it would of course be ‘disastrous’ in terms of programme costs and time-scales if these inputs were changed during the environmental qualification programme.

4.1.2 Establish that the environmental inputs are fit for purpose, i.e. they are of a form that describes the environment in sufficient detail to enable subsequently the derivation of appropriate test severities. Examples of typical environmental inputs are presented in AECTP-100 Annex C – Generic Usage Profiles and their Application. Develop acceptable inputs for those that are not fit for purpose.

4.1.3 For sensitive assemblies and for many assemblies containing energetic materials it may be necessary to conduct environmental data gathering trials to verify the environmental conditions and to achieve sufficient confidence in the environmental inputs for design qualification.

4.2 Step 2: Review Programme Inputs

4.2.1 Review the strategy for environmental design qualification of the materiel in the General Environmental Management (or Strategy) Plan (GEMP). The purpose and usage of the GEMP document is defined in AECTP-100 Paragraph 5.2.

4.2.2 The content of the GEMP should define how the range of environmental testing elements contributes to the total design qualification for the materiel. For example, how much of the evidence will rely on full scale or live demonstration testing in the field, and how much on full scale or live testing in the laboratory. These statements will indicate the degree of sub-system laboratory testing necessary to support the full scale testing to demonstrate compliance with the LCEP. This information is an important input for evaluating the scope of the sequential environmental test programme. Develop strategy statements for the GEMP to cover any shortcomings.

4.2.3 Other important inputs to consider at this step (although they are covered again and in depth at Step 9) are the constraints imposed by the programme costs and timescales, and also by the work breakdown structure particularly if it involves multi-national design teams and test facilities.

4.3 Step 3: Evaluate Design Inputs

4.3.1 The purpose of this step is to attain knowledge on the robustness, or conversely the sensitivity or design weaknesses of the materiel to the specified environmental inputs. It is unlikely that such information will be reliably recorded. Consequently, considerable effort is usually required to draw out this information from the design teams. Document the knowledge attained.

4.3.2 Of particular interest are the major potential failure modes of the material at full assembly, sub-assembly and component hardware levels. Information on potential failure modes is required so that an appropriate series of tests can be derived to exercise these modes to the verified levels stated in the LCEP (see Step 1).

4.3.3 In addition to potential tensile and classical fatigue failure modes of the materials used to manufacture equipment assemblies, equally damaging modes are generated by climatic, chemical and other mechanical conditions. Sources of identification for these modes include AECTP-230 (i.e. the ‘effects’ chapters) for potential climatic and chemical failure modes, and AECTP-240 for potential mechanical failure modes.

4.4 Step 4: Compile Provisional Lists of Critical Environments

4.4.1 Compile provisional lists of critical environments based on the evaluation of the environmental inputs, the programme environmental strategy and the design weaknesses of the materiel, i.e. from the outputs of Step 1, Step 2 and Step 3.

4.4.2 A separate list should be compiled for each phase of the life cycle, depicted in the LCEP, e.g. transportation and storage, deployment, operational use and disposal. Due notice should be taken of materiel configuration and/or state changes that could affect the number of lists required to initiate the sequential process.

4.4.3 Each list of provisional critical environments for each life cycle phase would be expected to include:

- vibration;
- shock (pulse and/or drop);
- high temperature (dry and/or damp heat);
- low temperature;
- thermo-mechanical stresses caused by thermal shock or thermal (diurnal) cycling;
- sand and dust;
- water (natural and induced).

4.4.4 It would normally be expected that each list is drawn up with only generic knowledge of potential failure modes such as that available to designers from past experience on devices manufactured from similar materials and using similar assembly techniques. Potential failure modes for project specific materiel are addressed in Step 5.

A typical list for a Line Replacement Unit (LRU) to be installed on a wheeled vehicle is shown in Appendix 1 Figure 1.

4.5 Step 5: Refine to Sets of Sequential Environments

4.5.1 Using a systematic approach by adopting a tabular or matrix format such as that shown in Appendix 1, Figure 2 and as described in Appendix 3, develop the provisional lists of critical environments into a refined set of sequential environments.

4.5.2 An early consideration within this step is to re-examine the environmental conditions in the LCEP and the associated content of the strategy plan to ascertain the purpose of each requirement. For example,

a. if the requirement is to demonstrate only the operational capability of the materiel, then the environmental conditions that need to be considered are those that may occur during operation.

b. if the requirement is to demonstrate that the materiel will survive specified environmental conditions and will subsequently operate in relatively less severe environmental conditions, then the conditions that will occur before operation of the materiel need to be included in the sequence. The duration of the exposure for both sets of conditions needs to replicate that which the materiel might experience in Service.

c. if the requirement is to demonstrate that the equipment will survive and subsequently operate after a 'life time' exposure to the environmental conditions, then representative environmental ageing will need to be induced in the materiel prior to demonstrating its operating characteristics.

4.5.3 A key activity within this step is to examine the design details of the materiel to ascertain the potential critical failure modes for this specific materiel design. The success of this sequential process could depend upon the diligence employed in researching potential failure modes and the subsequent development of the sequential test programme to exercise the failure modes in a representative manner.

4.5.4 From the detailed information acquired within this step develop the list of critical environments to form a sequence for each phase of the life cycle and materiel configurations and/or state changes. Guidance on the development of the sequence of environments, i.e. Step 5, is given in Appendix 1.

4.6 Step 6: Convert to a Set of Test Methods and Severities

4.6.1 The General Environmental Management (or Strategy) Plan should indicate the degree of simulation of the environment to be achieved during testing based on the sensitivity of the materiel. For example, assemblies comprising energetic materials will need to be tested to a high level of confidence that the materiel is both safe and serviceable. Consequently such assemblies may require a tailored testing methodology with test severities derived from measured (field) data.

4.6.2 As the conversion from environments to test severities is very dependant upon the sensitivity of the materiel, this step is illustrated by an example; see Appendix 1, Figure 3. It is important that the supporting evidence to accompany the test results, to demonstrate compliance with the Environmental Requirement Specification, should be indicated at this stage so that the requirements for this evidence can be developed at Step 7 or possibly Step 8.

4.7 Step 7: Refine the Sequence and Complete the Test Programme

4.7.1 Refine the sequence of test methods developed in Step 6 by the use of combined environments testing (such as vibration plus temperature) into the test programme where considered to be advantageous, and particularly where such testing would exercise potential failure modes more effectively.

4.7.2 Where relevant, for assemblies containing energetic materials, and/or considered as ‘one shot’ devices, develop a cascade of sequential tests of a form similar to that shown in Appendix 2.

4.7.3 It may be possible to combine tests and/or omit certain tests altogether where it can be demonstrated that a combined test fully embraces the potential damage mechanisms of the constituent tests, without generating new, artificial failure mechanisms. Such combinations are usually, but not always limited to those environments where the packaging state is common between the environments under consideration. Where the packaging state is not common appropriate transfer functions would have to be demonstrated and taken into account. An appropriate methodology for combining tests within the mechanical environments is shown in leaflet 2410 of AECTP-240.

4.7.4 Complete the test programme by integrating as appropriate the non-sequential tests to the sequential test programme.

4.7.5 At this stage the complementary modelling, analytical and assessment evidence necessary to support the demonstration of compliance with the LCEP should also be developed in conjunction with the relevant test programme elements to ensure that there are no significant voids in the compliance plan.

4.7.6 The completion of this step should provide sufficient information for the Environmental Test Specification to be compiled; see AECTP-100 Paragraph 5.5 for the purpose and usage of this specification.

4.8 Step 8: Balance System Level and Sub-System Level Testing

4.8.1 Having developed a provisional complete environmental test programme, reconsider the balance of system and sub-system testing and associated analytical and assessment activities that support the demonstration of compliance with the LCEP. Sufficient guidance on the relevant strategies to be applied for system and sub-system testing should be stated in the project specific Environmental Management (or Strategy) document.

4.8.2 A factor that often influences this balance is the availability of acceptable test facilities, particularly for system level testing. If the confidence in the results from system testing is unlikely to be fully satisfactory then more emphasis may need to be placed on improved representation of the environmental conditions at sub-system level to mitigate the shortfall.

4.8.3 Where sub-system testing is utilised to provide evidence of a system meeting its environmental requirements then appropriate knowledge of the sub-system severity or the relevant transfer functions and other safety factors used to derive the sub-system test levels must be demonstrated with appropriate evidence. Care must also be taken that the sub-system test uses the same interfaces as would be used in the complete system and is sufficiently similar to the service materiel that dynamic and thermal behaviour is representative and thus any potential failure modes are replicated.

4.8.4 On completion of this step it should be possible to initiate the Environmental Test Specification which is driven by technical rather than programme requirements.

4.9 Step 9: Re-consider Programme Constraints

4.9.1 It is acknowledged that programme time and cost constraints should have been considered throughout the preceding steps of this process. Nevertheless, having now established a technically credible path to demonstrate compliance with the environmental requirements, it is necessary to review the entire environmental test programme again in depth to ascertain what savings in both time and costs can be achieved by technically acceptable modification.

4.9.2 Any modifications should be within the bounds of the strategy contained within the Environmental Management Plan, and of course should not degrade the technical confidence in meeting the Environmental Compliance Matrix or Plan.

4.9.3 On completion of this step it should be possible to issue the Environmental Test Specification in draft form.

4.10 Step 10: Complete Pre-Test Documentation for Issue

4.10.1 Having completed the environmental sequential and associated non-sequential test programmes the Environmental Test Specification can be issued. A remaining task is to complete and issue the Environmental Test Programme which will include the sequential test programme developed using this ten step process. This ten step process for developing a sequential environmental test programme can then be considered complete.

4.10.2 On completion of this ten step process an outstanding task prior to the tests being undertaken is to compile the subsidiary test documentation such as Environmental Test Instructions and associated Functional Test Specifications.

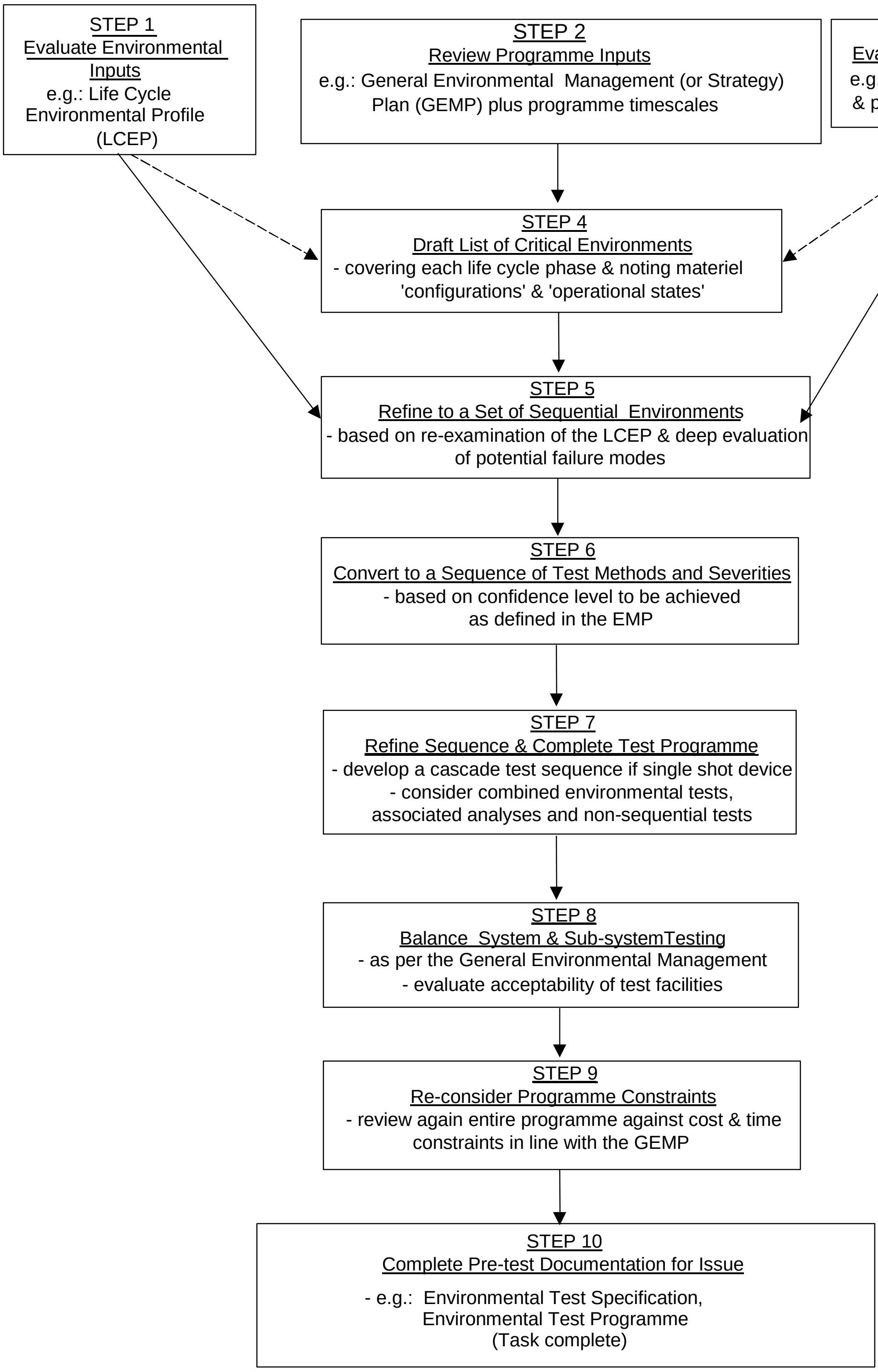


Figure1 Process for developing a sequential test programme.

Step	Action	Input information	Output information
1	Evaluate environmental inputs	Life Cycle Environmental Profile (LCEP)	LCEP that is fit for purpose

2	Review programme inputs	General Environmental Management (or Strategy) Plan (GEMP), usually part of the Design Assurance or Qualification Plan	GEMP and/or authorised statements that provide sufficient environmental strategy to proceed
3	Evaluate design inputs	Materiel design and development data	Document design weaknesses including potential failure modes
4	Compile provisional lists of critical environments	Fit for purpose environmental, programme and design data from Step 1, Step 2 and Step 3	List of critical environments for each life cycle phase and/or materiel state/configuration
5	Refine to sets of sequential environments	Lists of critical environments from Step 4 plus more detailed information from the LCEP and on materiel potential failure modes	Sets of sequential environments for the MTDS phases and materiel states/configurations
6	Convert to a set of test methods and severities	Sets of sequential environments from Step 5 plus strategy guidance from the GEMP	Provisional set of sequential test methods and severities
7	Refine the sequence and complete the test programme	Provisional sets of sequential test methods and severities plus list of non-sequential tests plus details of supporting analyses, assessments, etc	Full set of sequential and non-sequential tests plus list of supporting assessments (including combined environments tests)
8	Balance system and sub-system testing	Full set of tests and assessments from Step 7 plus the Environmental Management Plan	Balanced technical set of system and subsystem tests available for initiating the Environmental Test Specification (ETS)
9	Reconsider programme constraints (again)	Balanced set of tests from Step 8, plus latest programme details for reconciliation, plus details of suitable test facilities	Balanced set of system and sub-system tests that meet the technical and programme requirements. ETS available as a draft issue
10	Complete pre-test documentation for issue	Draft ETS document from Step 9 plus functional test requirements	Set of issued pre-test documentation

Table 1 Inputs and expected outputs for each of the ten steps.

Appendix 1 Derivation of a sequential Test Programme – A demonstration of the process

1. A demonstration of the Process

1.1 The purpose of this appendix is to provide a demonstration of the process to derive a sequential test programme. An electronic subassembly of a recovery vehicle has been chosen for this demonstration. Although the choice of electronic assembly is sufficient to demonstrate the principles of the process, other more elaborate examples would be necessary to demonstrate the full capabilities of the process.

1.2 The ten steps have been divided into four stages:

Stage 1: Review inputs and compile a provisional list of critical environments (Step 1-4).

Stage 2: Refine critical environments and develop a set of sequential tests and severities (Step 5-6).

Stage 3: Refine the set to a set of test methods and severities (Step 7-8).

Stage 4: Address facility and programme constraints and complete documentation (Step 9-10).

1.3 This appendix focuses on providing additional guidance on Stage 2 (Step 5 and Step 6). It primarily addresses the relatively complicated activity of refining the critical environments to a set of sequential environments and their conversion and refinement to a sequence of test methods and severities.

1.4 It is stressed that this is a worked example and the test levels are not to be used generally, rather test levels must be derived from the various requirements for the particular materiel under consideration.

2. Review inputs and compile provisional list of critical environments (Step 1-4)

2.1 The aim of Steps 1-4, as described in Annex D – Chapter 4, is to identify provisional critical environments (Step 4) after having reviewed the environmental requirements (Step 1), the programme constraints such as the General Environmental Management Plan (Step 2), and evaluated the potential design weaknesses (Step 3).

2.2 A list of provisional critical environments for the electronic subassembly on the recovery vehicle is shown in Figure 1 for both the transportation and storage phase of the life cycle and for the deployment or operational use phase. Comments and provisional potential materiel failure modes are included at this stage.

3. Refine critical environments and develop a list of sequential tests and severities (Step 5-6)

3.1 The first task in Stage 2 is to refine the provisional critical environments listed in Figure 1 as shown in Figure 2 (i.e. Step 5). For this example, the refined critical environments are shown in Column 1 of Figure 2.

3.2 Assembly of sequential environmental conditions

3.2.1 When refining the sequence of critical environments, the environmental requirements and the strategy plan (see Step 1 and Step 2) need to be reconsidered in detail. For example:

a. If the requirement is to demonstrate the operational capability of the equipment, then the environmental conditions that need to be considered are those that could occur during operation.

b. If the requirement is to demonstrate that the equipment will survive and subsequently operate in the environmental conditions, the conditions that will occur before operation need to be included. Additionally, the exposure needs to replicate that which typical equipment might experience in Service.

c. If the requirement is to demonstrate that the equipment will survive and subsequently operate after a 'life time' exposure to the environmental conditions, representative environmental ageing will need to be induced in the equipment.

3.2.2 This aspect is demonstrated in Column 2 of Figure 2. The success of the whole process may well depend on the diligence involved in identifying and examining the potential critical failure modes for this specific materiel design. The summary should be recorded in Column 3 of Figure 2. Based on the evidence gathered (as summarised in Columns 1, 2 and 3 the sequence can be refined (as summarised in Column 4).

3.2.3 The next task in Stage 2 is to convert the refined critical environments to a provisional sequence of test methods and severities (i.e. Step 6). The General Environmental Management Plan should be consulted to establish the degree of simulation of the environment to be achieved by testing and aspects that are to be covered by analysis and testing. For this example it is assumed that the testing strategy advocated minimum integrity testing where possible.

3.2.4 The nature of the treatment for this example to exercise potential failure modes is indicated in Column 2 Figure 3. Provisional test conditions and alternative treatments (such as assessments) are indicated in Column 3. Comments with respect to achieving full compliance with the Environmental Requirements Specification are presented in Column 4.

4. Refine the set of test methods and severities (Step 7-8)

4.1 The next task is to refine the provisional set of test methods and severities (i.e. Step 7). A particular consideration is the applicability of combined environments testing. For this example combined vibration with temperature may prove advantageous and cost effective for the deployment environments. The outputs from this step are shown in Figure 4.

4.2 Another task at this stage is to integrate subsystem level testing with system level testing. Guidance on this topic for a particular item of materiel should be found in the project specific Environmental Management Plan. For this example it is considered that any trade-offs in system level with subsystem level testing or vice-versa would be limited, as the overriding requirement in this instance is simply to provide sufficient confidence to proceed with system level testing for the assembled vehicle.

5. Address facility and programme constraints (Step 9-10)

5.1 A task at this stage (i.e. at Step 9) is to address any test facility constraints. For this example, as the electronic subassembly is likely to be relatively small, there are unlikely to be any significant test facility constraints. Consequently, there will be no need to conduct any risk assessments for technically inferior test facilities.

5.2 Next and, most importantly, review once again the programme constraints, which in practice tend to shift continuously.

5.3 The final task for this example is to complete the pre-test documentation (Step 10), such as the Environmental Test Specification and the Environmental Test Programme.

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1. Transportation and storage
(assuming that the electronic subassembly is packaged as a line replacement unit (LRU)

Provisional critical environmental conditions	Comments on the environmental conditions	Provisional potential materiel failure modes
Normal		
Vibration – restrained cargo	Aim for a single (composite) vibration environment	Low cycle fatigue from dynamic magnification
Loose cargo – wheeled vehicles	Consider relevance of this condition	Brittle fractures, low cycle fatigue
Shock (vertical and horizontal)	Aim for minimum integrity environments	Permanent deformation, brittle fracture
Dry heat	Consider constant or diurnal conditions	Failure of packaging insulation,
Humid heat	Consider constant or diurnal conditions	Swelling/deterioration from water absorption
Low temperature	Consider constant or diurnal conditions	Failure of bonding materials, freezing (expansion) of water
Thermal shock	Probably not relevant to this LRU	Probably not relevant to this LRU
Pressure (altitude)	Probably not relevant to this LRU	Probably not relevant to this LRU
Rain	Full specified conditions	Swelling/deterioration from water absorption
Induced water	Full specified conditions	Swelling/deterioration from water absorption
Lifting (acceleration)	Consider applicability of this condition	Permanent deformation, brittle failure (if fails in-service)
Abnormal (hostile)		
Acceleration (UNDEX)	Consider applicability of this condition	Permanent deformation, brittle failure

Figure 1 Provisional critical environments (Step 4)

2. Deployment or operational use

Provisional critical environmental conditions	Comments on the environmental conditions	Provisional potential materiel failure modes
Normal		
Vibration	Worst case conditions occur during battlefield transit	Microphony, impacts from dynamic magnification
Shock (pulse)	Vehicle shock conditions (could be significant)	Permanent deformation, brittle fracture
Dry heat	Specified conditions (Climatic Category A1)	Melting and exudation
Humid heat	Specified conditions (Climatic Category B3)	Electrical short cuts from condensation
Low temperature	Specified conditions (Climatic Category C2)	Brittle fractures, freezing (expansion) of water
Thermal shock	Ambient – either A1 or C2	Fracture, delamination, bond failure
Pressure (altitude)	Probably not relevant to this assembly	Probably not relevant to this assembly
Salt atmosphere	Full specified conditions (significant exposure assumed)	Corrosion of insulating materials
Sand and dust	Full specified conditions (significant exposure assumed)	Clogging of cooling fans
Induced water	Full specified conditions (significant exposure assumed)	Electrical short cuts from entrapped water
EMC	Full specified conditions	Induced spurious voltages
Abnormal (hostile)		
Blast (overpressure & acceleration)	Full specified conditions	Permanent deformation, brittle fracture
NBC decontaminants	Full specified conditions	Corrosion of insulating materials
Abnormal (accident)		
Shock (pulse)	Shocks arising from vehicle impacts	Permanent deformation, brittle fracture
Immersion	Full specified conditions	Electrical short cuts from entrapped water

Figure 1- Continued Provisional critical environments (Step 4)

1. Transportation and storage
(assuming that the electronic subassembly is packaged as a line replacement unit (LRU)

(1) Potentially critical environments		(2) Aspect of mission criticality affected: a. Performance operate b. Performance survive c. Structural integrity and safety	(3) Potential failure modes driving the sequence and treatment action	(4) Sequence refinements
	Normal			
1.1	Dry heat (transportation) (eg: Climatic category A1)	Performance survive		
1.2	Humid heat (transportation) (eg: Climatic category B3)	Performance survive		
1.3	Cold (transportation) (eg: Climatic category C2)	Performance survive		
1.4	Vibration – restrained cargo	Performance survive	Fatigue of components/ attachments after application of limit thermal (hot and cold) stressing	In sequence after transportation conditioning
1.5	Shock (drop – vertical and horizontal)	Performance survive		
1.6	Loose cargo–wheeled vehicles	Performance survive		
1.7	Rain	Performance survive		
1.8	Induced water	Performance survive		
1.9	Lifting (acceleration)	Performance survive		
	Abnormal hostile			
1.10	UNDEX (acceleration)	Performance survive		

Figure 2 Sequential critical environments (Step 5)

2. Deployment or operational use

(1) Potentially critical environments		(2) Aspect of mission criticality affected: a. Performance operate b. Performance survive c. Structural integrity and safety	(3) Potential failure modes driving the sequence and treatment action	(4) Sequence refinements
	Normal			
2.1	Dry heat	Performance operate		Conduct prior to (or preferably combine with), vibration shock testing (see Step 7)
2.2	Humid heat	Performance operate		
2.3	Low temperature	Performance operate		
2.4	Thermal shock	Performance survive		
2.5	Vibration	Performance operate	Fatigue of components/ attachments after application of limit thermal (hot and cold) stressing	In sequence after transportation conditioning
2.6	Shock pulse	Performance survive		
2.7	Salt atmosphere	Performance operate		Position in relation to one another is not critical
2.8	Dust and Sand	Performance operate		
2.9	Induced water	Performance operate		
2.10	Pressure (at altitude)	Performance operate		
2.11	EMC	Performance operate		Do not need to be in sequence but preferably after shock and vibration
2.12	Biological hazards	Performance operate		
	Abnormal hostile			
2.13	NBC decontaminants	Performance operate		
2.14	Blast (overpressure)	Performance survive		
	Abnormal accident			
2.15	Shock pulse (crash)	Performance survive		
2.16	Immersion	Performance survive		

<u>Figure 2 – Continued Sequential critical environments (Step 5)</u>

1. Transportation and storage
(assuming that the electronic subassembly is packaged as a line replacement unit (LRU)

(1) Sequence of critical test methods and severities		(2) Nature of treatment required to exercise potential failure modes	(3) Provisional test procedure (or alternative treatments) and severities	(4) Comments with respect to achieving full compliance with the Environmental Requirement Spec
	Normal			
1.1	Dry heat	Lab Test – diurnal cycling test preferred	Test Method 302	Compliant
1.2	Humid heat	Lab Test – diurnal cycling test preferred	Test Method 306	Compliant
1.3	Low temperature	Lab Test – diurnal cycling test preferred	Test Method 303	Compliant
1.4	Thermal shock	Deleted	-	-
1.5	Vibration (random)	Lab Test – composite mode test preferred	Test Method 401	Compliant
1.6	Shock (vertical and horizontal)	Lab Test – vertical and lateral impact	Test Method 414	Compliant
1.7	Loose cargo	Lab Test – Circular synchronous motion	Test Method 406	Compliant
1.8	Pressure (altitude)	Deleted	-	-
1.9	Rain	Lab Test	Test Method 310	Compliant
1.10	Induced water	Lab Test	Test Method 310	Compliant
1.11	Lifting	Cover by assessment	Stress attachments	Compliant
	Abnormal hostile			
1.12	UNDEX	Cover by test plus assessment	Test Method 419	Combination should provide sufficient confidence

Figure 3 Provisional sequence of test methods and severities (Step 6)

2. Deployment or operational use

(1) Sequence of critical test methods and severities		(2) Nature of treatment required to exercise potential failure modes	(3) Provisional test procedure (or alternative treatments) or severities	(4) Comments with respect to achieving full compliance with the Environmental Requirement Specification
	Normal			
2.1	Dry heat	Lab Test – diurnal cycling temperature	Test Method 302	Compliant
2.2	Humid heat	Lab Test – diurnal cycling temperature	Test Method 306	Compliant
2.3	Low temperature	Lab Test - diurnal cycling temperature	Test Method 303	Compliant
2.4	Thermal shock	Lab Test	Test Method 304	Compliant
2.5	Vibration	Lab Test – wide band random	Test Method 401	Compliant
2.6	Shock pulse	Lab Test – shock pulse	Test Method 403	Compliant
2.7	Dust and Sand	Test – blowing sand	Test Method 313	Compliant
2.8	Salt atmosphere	Lab Test	Test Method 309	Compliant
2.9	Induced water	Lab Test	Test Method 310	Compliant
2.10	Pressure (altitude)	Test deleted, cover by assessment	-	Compliant
2.11	EMC	Assessment	AECTP-500	Compliant
2.12	Biological hazards	Assessment	-	Compliant
	Abnormal hostile			
2.13	NBC decontaminants	Assessment	-	Compliant
2.14	Blast (overpressure)	Assessment	-	Compliant
	Abnormal accident			
2.15	Shock pulse (crash)	Assessment and/or test	Test Method 403	Combination should provide sufficient confidence
2.16	Immersion	Assessment and/or test	Test Method 307	Combination should provide sufficient confidence

Figure 3 – Continued Provisional sequence of test methods and severities (Step 6)

1. Transportation and storage
(assuming that the electronic subassembly is packaged as a line replacement unit (LRU)

(1) Refined sequence of critical test methods and severities		(2) Sequential/non-sequential element	(3) Revised or combined environments testing	(4) Complementary modelling/analysis treatments	(5) Remarks
	Normal				
1.1	Dry heat	Sequential as shown	Test Method 302	N/A	-
1.2	Humid heat	Sequential as shown	Test Method 306	N/A	-
1.3	Low temperature	Sequential as shown	Test Method 303	N/A	-
1.4	Vibration (random)	Sequential as shown	Unchanged	N/A	-
1.5	Shock (vertical and horizontal)	Sequential as shown	Unchanged	N/A	-
1.6	Loose cargo	Sequential as shown	Unchanged	N/A	-
1.7	Rain	Non-sequential	Unchanged	N/A	-
1.8	Induced water	Non-sequential	Unchanged	N/A	-
1.9	Lifting	Non-sequential	Unchanged	Unchanged	-
	Abnormal hostile				
1.10	UNDEX	Non-sequential	Unchanged	Unchanged	-

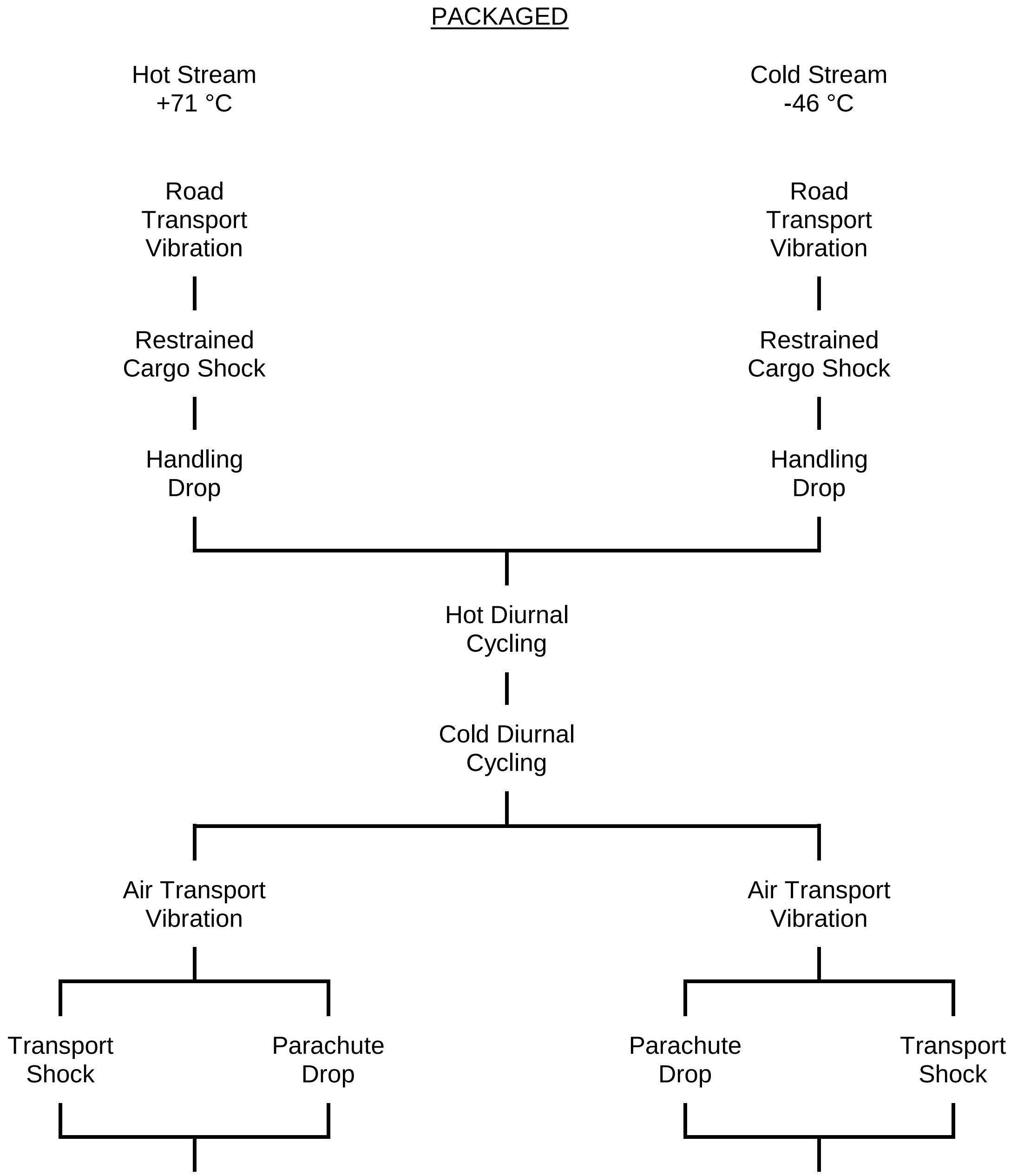
Figure 4 Refined sequence of test methods and severities (Step 7)

2. Deployment or operational use

(1) Refined sequence of critical test methods and severities		(2) Sequential/non-sequential element	(3) Revised or combined environments testing	(4) Complementary modelling/analysis treatments	(5) Remarks
	Normal				
2.1	Dry heat	Sequential as shown	Unchanged	N/A	-
2.2	Humid heat	Sequential as shown	Unchanged	N/A	-
2.3	Low temperature	Sequential as shown	Unchanged	N/A	-
2.4	Vibration	Sequential as shown	Unchanged	N/A	-
2.5	Thermal shock	Sequential as shown	Unchanged	N/A	-
2.6	Shock pulse	Sequential as shown	Unchanged	N/A	-
2.7	Dust and Sand	Non-sequential	Unchanged	N/A	-
2.8	Salt atmosphere	Non-sequential	Unchanged	N/A	-
2.9	Induced water	Non-sequential	Unchanged	N/A	-
2.10	EMC	N/A	Unchanged	Unchanged	-
2.11	Biological hazards	N/A	Unchanged	Unchanged	-
	Abnormal hostile				
2.12	NBC decontaminants	N/A	Unchanged	Unchanged	-
2.13	Blast (overpressure)	N/A	Unchanged	Unchanged	-
	Abnormal accident				
2.14	Shock pulse (crash)	N/A	Unchanged	Unchanged	-
2.15	Immersion	N/A	Unchanged	Unchanged	-

Figure 4 – Continued Refined sequence of test methods and severities (Step 7)

Appendix 2
An example of a sequential test programme
(Air to ground guided missile)



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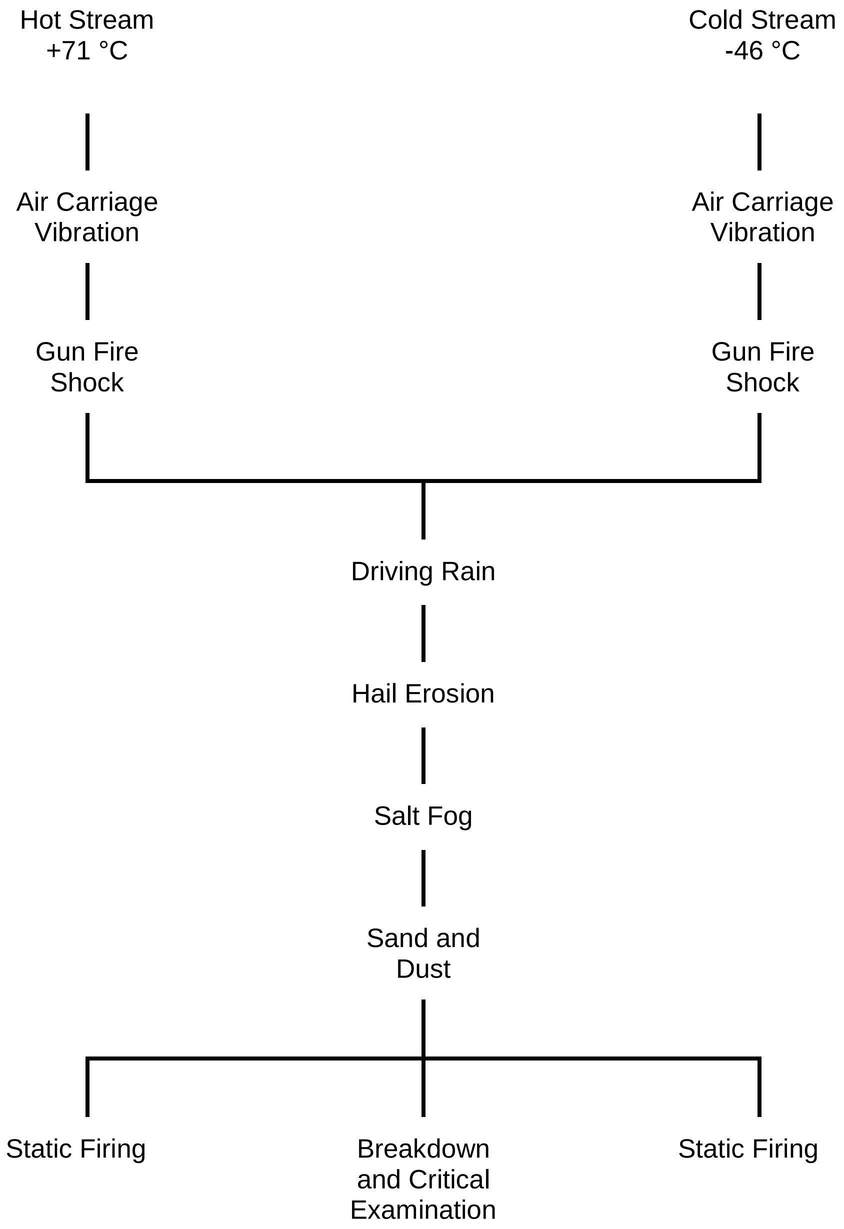
Hot Stream
+71 °C
Cold Stream
-46 °C
Air Carriage
Vibration
Air Carriage
Vibration
Gun Fire
Shock
Gun Fire
Shock
Driving Rain
Hail Erosion
Salt Fog
Sand and
Dust
Static Firing
Breakdown
and Critical
Examination
Static Firing

Appendix 3
LCP Environmental checklist

Note that this checklist is intended as a guide and is not exhaustive (see sub-paragraph 2.2.2 of Annex D).

LCP Phase	Critical Environment Type	Environmental Detail	Typical Test Method
Logistic Transport (Logistic Packaging)	High temperature (dry and/or humid heat)	Storage & Transport Temperatures for climatic zone	302
	Low temperature	Storage & Transport Temperatures for climatic zone	303, 317
	Thermo-mechanical stresses caused by thermal shock or thermal (diurnal) cycling	Transfer from hot vehicle to ambient Met temp. e.g. A3 S&T to A3 Met	304
	Solar	Heating and actinic effects	305
	Icing	Ice accretion and freeze thaw	311, 315
	Water (natural and induced)	Rain, immersion etc	307, 310
	Pressure	Sustained pressure and rapid decompression	312
	Sand and dust	N/A	313
	Chemical	Contaminants, acid and salt	309, 314, 319
	Biological	Mould growth	-
	Shock (pulse and/or drop)	Handling, crane lift & fork lift pick up/put down, vehicle associated (restrained cargo, rail shunting etc..)	403, 406, 414, 416, 417
	Vibration	Logistic wheeled vehicle, air transport, sea transport, fork lift	401
	Acoustic	Engine noise and blast	402, 413
	Other environments	Induced environment from other equipment	

LCP Phase	Critical Environment Type	Environmental Detail	Typical Test Method
Storage (Logistic Packaging/ tactical Packaging)	High temperature (dry and/or humid heat)	Deep storage & forward area permanent & temporary (poor) storage	302
	Low temperature	Deep storage & forward area permanent & temporary (poor) storage	303, 317
	Thermo-mechanical stresses caused by thermal (diurnal) cycling	Diurnal effects. e.g. A3 Met	302, 303
	Solar	Heating and actinic effects	305
	Icing	Ice accretion and freeze thaw	311, 315
	Water (natural and induced)	Rain, immersion etc	307, 310
	Pressure	Sustained pressure	312
	Sand and dust	Forward area permanent & temporary (poor) storage.	313
	Chemical	Contaminants, acid and salt	309, 314, 319
	Biological	Mould growth	-
	Shock (pulse and/or drop)	Handling, crane lift & fork lift pick up/put down,	403, 414, 417
	Vibration	Fork lift, local wheeled vehicle	401
	Acoustic	Probably not applicable	402, 413
	Other environments	Induced environment from other equipment	

LCP Phase	Critical Environment Type	Environmental Detail	Typical Test Method
Tactical Transport (Tactical packaging / unpackaged)	High temperature (dry and/or humid heat)	Storage & Transport Temperatures for climatic zone	302
	Low temperature	Storage & Transport Temperatures for climatic zone	303, 317
	Thermo-mechanical stresses caused by thermal shock or thermal (diurnal) cycling	Transfer from ambient vehicle internal temperature to local ambient temp.	304
	Solar	Heating and actinic effects	305
	Icing	Ice accretion and freeze thaw	311, 315
	Water (natural and induced)	Rain, immersion etc	307, 310
	Pressure	Sustained pressure and rapid decompression	312
	Sand and dust	Depends on local conditions and vehicles	313
	Chemical	Contaminants, acid and salt	309, 314, 319
	Biological	Mould growth	-
	Shock (pulse and/or drop)	Handling, crane lift & fork lift pick up/put down, vehicle associated (restrained cargo degraded road, DROPS vehicle, rail shunting etc.), UNDEX - safe for disposal and safe & suitable for use.	403, 406, 414, 416, 417
	Vibration	Air (fixed wing prop & jet & rotary wing), sea, rail, road, local specialist vehicles (DROPS, S-Trolley, etc.)	401
	Acoustic	Engine noise and blast	402, 413
	Other environments	Induced environment from other equipment	

LCP Phase	Critical Environment Type	Environmental Detail	Typical Test Method
Operational Deployment (unpackaged or tactical packaging)	High temperature (dry and/or humid heat)	Storage & Transport Temperatures for climatic zone	302
	Low temperature	Storage & Transport Temperatures for climatic zone	303, 317
	Thermo-mechanical stresses caused by thermal shock or thermal (diurnal) cycling	Transfer from ambient storage to induced temp, e.g. from hot storage to high altitude (cold) or from cold storage to high speed low altitude flight (kinetic heating).	304
	Solar	Heating and actinic effects	305
	Icing	Ice accretion and freeze thaw	311, 315
	Water (natural and induced)	Rain, immersion etc	307, 310
	Pressure	Sustained pressure and rapid decompression	312
	Sand and dust	Depends on local conditions and vehicles	313
	Erosion	Particulate and ice	-
	Kinetic heating	High speed jet	-
	Chemical	Contaminants, acid and salt	309, 314, 319
	Biological	Mould growth	-
	Shock (pulse and/or drop)	Handling, operational vehicle associated (restrained cargo shocks), adjacent weapon launch, UNDEX - safe for disposal and safe & suitable for use.	403, 405, 406, 414, 415, 416, 417, 419
	Vibration	Air (fixed wing prop & jet & rotary wing), sea, rail, road, local specialist vehicles (S-Trolley, etc.)	401
	Acoustic	Engine noise and blast	402, 413
	Other environments	Induced environment from other equipment	

LCP Phase	Critical Environment Type	Environmental Detail	Typical Test Method
Use (unpackaged)	Thermo-mechanical stresses caused by thermal shock or thermal (diurnal) cycling	Transfer from hot ambient vehicle to cold environment, e.g. vehicle temp to cold seawater or internal bomb bay (hot) release to cold air.	304

LCP Phase	Critical Environment Type	Environmental Detail	Typical Test Method
	Water (natural and induced)	Immersion	307
	Pressure	Sustained pressure and rapid change of pressure	312
	Erosion	Particulate and ice	-
	Kinetic heating	High speed missiles	-
	Shock (pulse and/or drop)	Usage related shocks including Launch shocks (safe & suitable for use)	403, 417
	Vibration	Flight vibration	401
	Acceleration	Prolonged acceleration during launch or flight	404
	Acoustic	Motor / engine noise	402, 413
	Other environments	Induced environment from other equipment	
Disposal (Packaged or unpackaged)	High temperature (dry and/or humid heat)	Storage for long enough to dispose of normally at least 2 years (safe for disposal).	Assessment
	Shock (pulse and/or drop)	Handling, accident and carriage to storage & disposal site (safe for disposal).	Assessment
	Vibration	Transport to storage & disposal site (safe for disposal).	Assessment
	Other environments	Not normally relevant as normally benign compared to deployment environment (safe for disposal).	Assessment

ANNEX E

GLOSSARY OF TERMS

This list gives definitions for some of the terminology used in climatic and mechanical testing.

Note that the meanings of these terms are given for the particular fields within the series of AECTP-100 through 600. The official (general) explanation will be different in some cases.

Abnormal Environment: An environment resulting from an unplanned but nevertheless credible event, such as fire, and including those related to combat vulnerability.

Absolute Humidity: The mass of water vapour per unit volume of a mixture of dry air and water vapour; usually expressed in g/m^3. This is inversely proportional to the absolute temperature of the mixture, and it decreases from its saturation value as the temperature increases above the dew point (see dew point).

Accelerated Test: A test in which the applied stress level is selected to shorten the time required to observe the stress response of the test item or magnify the response in a given time. To be valid, an accelerated test must not alter the basic failure modes and/or mechanisms.

Acceleration: A vector that specifies the rate of change of velocity (with time). Acceleration levels are often measured in terms of (g).

Acceleration Due to Gravity (g): The acceleration produced by the force of gravity at the surface of the Earth. It varies with the latitude and elevation of the point of observation and is then referred to as g_n. By international agreement, the value of g is 9.80665 m/s^2.

Accelerometer: A transducer which converts an input acceleration to an output (usually electrical) that is proportional to the input acceleration.

Activation Energy: The amount of energy required to initiate a chemical reaction, such as the chemical degradation of materials. If the Arrhenius Equation is used to calculate possible durations for thermal ageing, then specific values of activation energy must be identified for each likely failure mode.

Ambient Conditions: The surrounding conditions. Where ambient conditions are specified no pre-conditioning of the test specimen is required.

Amplitude: The magnitude of a vector or a scalar quantity, which may be expressed in terms of peak, peak to peak, rms or average value.

Amplitude Distributions: Statistical parameters characterise time history data in terms of a few numbers. In some cases, more details of the amplitude characteristics are required and this can be obtained from amplitude probability or level crossing distributions. The range of amplitudes of the data is subdivided into intervals and the data examined to determine the number of occurrences in each interval. Typically this is tabulated and the number of occurrences in each interval is then plotted against amplitude in the form of a histogram. The values of Mean, Standard Deviation, Minimum, Maximum, Peak and Zero crossing periods are generally provided for assessment.

Analysers: There are many forms of frequency analyser, and their complexity is generally dependent on the level of flexibility demanded by the user. The general requirement for a frequency analyser is to convert time history data into its frequency components. In this way, the frequency domain characteristics of the system being studied can be evaluated.

Anti-Resonance: Anti-resonance of a system in forced oscillation exists at a point when any change, however small, in the frequency of excitation causes an increase in a response at this point. Where a system with constant excitation, decreases in its response.

Applied Shock (Shock Excitation): An excitation applied to a system, which produces a mechanical shock.

Arrhenius Equation: This is a theoretical definition of the relationship between chemical reaction and temperature, developed by Svent Arrhenius. It can be used to compare the relative effects, upon a test specimen, of one thermal environment to another.

$$k = Ae^{\frac{-E_a}{RT}}$$

where: k = rate constant
A = Frequency factor used to describe frequency and orientation of collisions between molecules. Taken as a constant across all temperatures.
E_a = Activation energy.
R = Universal Gas Constant (8.314×10^{-3} kJ mol^{-1} K^{-1}).
T = Absolute Temperature (K)

This equation is often used in the following form during environmental testing to calculate possible durations for thermal ageing.

$$\frac{k_1}{k_2} = e^{\left[-\frac{E_a}{R}\left(\frac{1}{T_1}-\frac{1}{T_2}\right)\right]}$$

where: k_1, T_1 refer to the test condition and k_2, T_2 refer to the reference condition

ASD (Acceleration Spectral Density): ASD is the limiting mean square value of acceleration per unit bandwidth (see PSD).

Auto Correlation Function: The auto correlation function $R_{xx}(\tau)$ of a signal x(t) is the average of the product of the value of the signal at time t with the value t + τ for an appropriate averaging time T. It provides a means of separating random from periodic variations in the time domain.

Autospectral Density: For a stationary (Ergodic) random process the finite Fourier transform of x(t) is given by:

$$X(f,T) = \int_0^T x(t)e^{-j2\pi ft}\,dt$$

where f = frequency
T = record length
j = complex variable

Bandwidth: The bandwidth is the differences in start and end frequency values. A usage is excitation bandwidth. This bandwidth is the frequency interval that is used for the excitation in an environmental test. A further use of bandwidth is to define the width of a peak or plateau in a frequency response function. In the case of a resonance, the peak is sharp and the bandwidth is related to the damping. In the case of a filter, the bandwidth is usually a plateau region. The bandwidth is given in hertz or radians per second. The start and end frequencies of a bandwidth are defined as the frequencies where the function has dropped to 1/2 of the maximum value. This ratio is equivalent to 0.707 or 3dB (dB defined as 20 Log_{10} of ratio). These frequencies are known as the half power points.

Bias Error: is a systematic error independent of record length. It is a function of the bandwidth and the sharpness of the peaks in the data.

Broadband Random Vibration: Random vibration having its frequency components distributed over a broad frequency band, typically 0-2kHz.

Calibration Factor (of a transducer): The average sensitivity within a specified frequency range or *bandwidth*. [See sensitivity].

Centre Frequency: The geometric mean of the nominal cut-off frequencies of a pass-band.

Centre of Gravity: That point through which the resultant of the weights of the component particles of a body pass with respect to a gravitational field, for all orientations.

Classical Pulse: A short duration transient time history, having the form of a half-sine, a square wave, a triangular wave, a ramp with a terminal peak amplitude, a ramp with an initial peak amplitude, or a general trapezoid.

Clipping: Clipping is the result of overloading of some part of the instrumentation chain and can be rectified by proper setting up.

Coherence: Coherence is the ratio of the maximum energy in a combined output signal due to its input components and the total amount of energy in the output signal. Therefore, it is a relative indication of causality between the output and input signals and a measure of the fraction of one signal (input) that is directly related to another (output). A high value (near 1) indicates high causality so that the output is due almost entirely to the input. A value (near 0) indicates a problem such as extraneous input signal not being measured i.e. noise, non-linearity or time delays in the system.

Common Mode Rejection: A measure of how well a differential amplifier rejects a signal simultaneously and in phase at both terminals. CMR is normally expressed as a dB ratio at a given frequency. The ratio tends to fall at high frequencies and low voltages.

Compliance: The reciprocal of stiffness.

Control Strategy (also see Vibration Control): The accuracy in providing and measuring vibration environments. This is highly dependent on fixtures and mounting of the test item, the measuring system and the exciter control strategy. A control strategy will need to provide the required vibration at the required location(s) in or on the test item. This selection can be based on the characteristics of the vibration to be generated and platform / materiel interaction. Generally a single control strategy is appropriate. However, there are cases where multiple control strategies are used simultaneously e.g. acceleration and force limit control.

Critical Damping: Minimum viscous damping that will allow a displaced system to return to its original position without oscillation in the shortest time possible. For a single degree-of-freedom system, the amount of viscous damping which corresponds to the limiting condition between an oscillatory and a non-oscillatory transient state of free vibration.

Cross Correlation: is a measure of the similarity between two functions in the time domain, with the time lag between the two used as an independent variable.

Cross Spectral Density: The two sided cross spectral density function of x(t) and y(t) is defined by:

$$S_{xy} = \lim E\left[X^*(f,T)Y(f,T)\right]$$

Cut-Off Frequency: The frequency or frequencies above and / or below the frequency of maximum response of a filter at which the response to a sinusoidal signal is 3 dB below the maximum response.

Cycle: The complete range of states or values through which a periodic phenomenon or function passes before repeating itself identically.

Cyclic Frequency: The reciprocal of the fundamental period.

Damping: The dissipation of vibration energy with time. Such dissipation may vary spatially. Damping in a structure converts potential and kinetic energy to heat or noise or some other form of energy. Damping is a generic term ascribed to the numerous energy dissipation mechanisms in a system. In practice, damping depends upon many parameters, such as the structural system, mode of vibration, strain, applied forces, velocity, materials, joint slippage etc.

Damping (Critical): is the minimum viscous damping that will allow a displaced system to return to its initial position.

Damping (Structural Damping): Hysteretic damping is sometimes known as structural damping. Hysteretic damping is defined for sinusoidal motion and is only appropriate for frequency domain models. The force exerted by a hysteretic damper has a magnitude that is proportional to the displacement but is in phase with the velocity. The magnitude of the force is independent of frequency.

Damping Ratio (Fraction of Critical Damping): For a system with linear viscous damping, the ratio of the actual damping coefficient to the critical damping coefficient. [See *critical damping*].

Data Processing: A general term for the electronic or mechanical processing of original information.

Decade: A decade is the interval between two frequencies having a 10:1 ratio (10, 100, 1000. 10000 etc.) The number of decades is given by:

Number of Decades = Log (Upper Frequency / Lower Frequency)

Decibel (dB): The decibel (one tenth of a bel) is the logarithm of a ratio of two values. For power quantities (e.g. noise, pressure, PSD, etc) it is given by:

$$dB = 10 \log_{10} P_2/P_1$$

For linear quantities (e.g. acceleration, velocity, etc) it is given by:

$$dB = 20 \log_{10} L_2/L_1$$

Degrees of Freedom (Coordinate): The number of degrees of freedom of a structure is the number of coordinates needed to define its location in space as it moves. The number of degrees of freedom of a mechanical system is equal to the minimum number of independent generalised coordinates required to define completely the configuration of the system at any instant of time. A rigid body requires six coordinates (three for translations and three for rotations). A structure made of several rigid bodies, or which is flexible, requires many coordinates to define its configuration and thus has many degrees of freedom. A particle requires three coordinates to locate it (the x, y and z coordinates).

Deterministic: is when the value of a function at any time can be predicted from its value at any other time.

Dew Point: The temperature to which air must be cooled, for water vapour to condense.

Direct Control: Direct control is where measured data is played directly in to the actuators or servo-controllers. A rig control and simulation computer is not used.

Displacement (Relative Displacement): A vector quantity (sense and magnitude) that specifies the change of position of a body, or particle with respect to a reference frame. A distance travelled.

Distortion (of a Signal): An undesired change in an output waveform compared to that at the point of origin.

Dominant Frequency: A frequency at which a maximum value occurs in a spectral density curve.

Drift: All measurement systems suffer from drift, which may be regarded as a very low frequency noise. A common cause is thermal effects on electronic components.

Duration (of Shock Pulse): The time-interval between the instant the motion rises above some stated fraction of the maximum value and the instant it decays to this fraction.

Dynamic Range: All items in the measurement system have a restricted range of allowable amplitude, the lower limit being set by inherent noise, and the upper limit being set by electrical overloading or excessive non-linearity or, even possibly, by mechanical limits in the transducer. It is important for the user to arrange all the various items in the instrumentation chain to work within their dynamic range and, preferably, as near to the top of the range as can be accommodated without overloading.

Earth Loop (Ground Loop): The closed electrical circuit formed by the connection of a ground wire to several ground terminals at different locations.

Electromechanical Transducer: A transducer, which is actuated by energy from a mechanical system (strain, force, motion, etc.), and supplies energy to an electrical system.

Ensemble (Vibration): A collection of sample time history records from a single random process where each of the time history records is defined over the same duration time interval.

Enveloping: This is where the test item dynamic response measured during operational duty (usually under various conditions) is encompassed by and below a line drawn throughout the frequency range of interest. This line can be the result of a curve fit or engineering judgment. Often a factor is added to the line to take account of statistical variations in the measured data.

Environment: The aggregate of all (physical, chemical and biological) conditions and influences to which materiel is subjected. For the purposes of this standard, these have been subdivided into Natural, Induced and Abnormal environments.

Environmental Engineering Specialist: One who is skilled in one or more environmental engineering areas. These include, but are not necessarily limited to: natural and induced environments and their effects on military materiel; expertise in measuring and analysing field environmental conditions; formulating environmental test criteria; determining when environmental laboratory tests are appropriate/valid substitute for natural field/fleet environmental tests, and evaluating the effects of specific environments on materiel.

Environmental Project Tailoring: The process of assuring that materiel is designed, developed and tested to requirements which are directly derived from the anticipated Service use conditions.

Environmental Requirement: A detailed statement of the environmental conditions for which specified materiel is to be exposed.

Environmental Test Chamber (Enclosure): An enclosure capable of simulating, with required accuracy, natural or induced climatic environments, either singly or in combination.

Environmental Test Equipment: The laboratory and/or test equipment that is used (in whole or part) to produce, monitor or record environmental conditions necessary to stress the test item.

Environmental Test Instruction: A set of detailed procedures including the parameters, levels and instructions for the conduct of a particular test or series of tests on a specific test item. This plan governs test control, data analysis and administrative aspects.

Environmental Test Specification: A detailed statement of the parameters and their ranges to which the test item is to be subjected and the criteria against which the test item will be assessed.

Environmental Testing: Testing of materiel under specified environmental conditions likely to affect the performance or safety of that materiel.

Excitation (Stimulus): An external force (or other input) applied to a system that causes the system to respond in some way.

Excitation Techniques: Vibration excitation techniques, which are less common and generally more specific to a particular type of testing. The following systems are all specialist systems which are listed for reference.

- Acceleration testing using a centrifuge type exciter.
- High velocity shock and impact testing using rocket powered test tables or sleds.
- Acoustic excitation using loudspeakers or sirens.
- Shock testing using explosive or pyrotechnic excitation.
- Fluid jet excitation.
- Vibration excitation using a rotating or translational reaction mass.

Factors: Provide conservatism with measured data. Due to limitations in numbers of transducers, accessibility of measurement points, linearity of data at extreme conditions, and other causes, measurements do not include all extreme conditions. Further, there are test limitations such as single axis versus multi-axis, and practical fixtures versus platform support. Factors are applied to measured data in deriving test criteria to account for these variables.

Failure Modes: Vibration results in dynamic deflections of and within materiel. These dynamic deflections and associated velocities and accelerations may cause or contribute to structural fatigue and mechanical wear of structures, assemblies, and parts. In addition, dynamic deflections may result in impacting of elements and/or disruption of function. Some typical symptoms of vibration-induced problems are given below (this list is not intended to be all-inclusive):

- Brittle Fracture
- Fatigue
- Plastic Collapse
- Leakage & Corrosion
- Wear - e.g. Chafed wiring.
- Loose fasteners/components.
- Fretting
- Broken & Deformed Seals
- Cracking
- Debonding
- Optical & Mechanical Misalignment
- Powdering & Migration of Energetic Materials into Screw Threads etc.
- Distortion
- Friction
- Loosening
- Electrical shorts.
- Intermittent Electrical Contact
- Spark Discharge & Static Electrical Build-up
- Creep

Fast Fourier Transform (FFT): A process where the computing times of complex multiplications / additions in the discrete Fourier transform are greatly reduced.

Fatigue Damage Spectrum (FDS): The fatigue damage spectrum is a curve that represents the variation of damage, as defined by Miners Law, as a function of the natural frequency of the system with one degree of freedom, for a given damping factor ξ.

Filtering: Measured data must be filtered to remove any frequencies higher than the maximum frequencies of interest otherwise aliasing errors may occur. It is recommended that filters be used at a frequency of about 1.5 times the maximum frequency of interest. All channels must be filtered in the same way to avoid changes of phase between channels.

Filter: A device for separating oscillations on the basis of their frequency. It introduces relatively small attenuation to wave oscillations in one or more frequency bands and relatively large attenuation to oscillations of other frequencies.

Finite Fourier Transform: Experimentally acquired periodic or transient data only have a finite duration T seconds. This limits the Fourier Transform to the Finite Fourier Transform.

$$F_{(\omega)} = \int_{0}^{T} f(t) e^{-j\omega t} dt$$

where: ω= angular frequency
T = record length
t = time
j = complex variable

Fixing Point: Part of the materiel in contact with the fixture or vibration table at a point where the materiel is normally fastened in service.

Fixtures: Fixtures attach the actuators to the test specimen and may provide reaction points for the specimen. They transmit loads to the specimen. They are an integral and important part of the test rig design.

Flexible Drive Rod (Stinger): A rod, which connects the shaker to the structure, which is stiff in the direction of excitation, but flexible in all other directions.

Flow Down Process: The environmental engineering process that provides a procedure for determining environmental conditions, test methods and severity's from the defined life cycle, in conjunction with the knowledge of the materiel's possible failure modes.

Force: The agency that tends to change the momentum of a (massive) body (see Newton's 2nd law of motion).

Force (System): Defines the maximum force a vibration system can provide. It is normally derived from the product of the maximum permitted acceleration (rms or pk) and armature mass.

Forced Vibration (Oscillation): When a time-varying force acts on a structure it induces vibration. This is forced vibration. If a structure is released with initial conditions and a time-varying force then the vibration is a combination of free vibration and forced vibration. Some time-varying forces continue indefinitely. In this case, when the initial starting transient has died away, and only the effects of the force are present, the structure is said to be experiencing steady-state forced vibration.

Foundation: A structure that supports a mechanical system. It may be fixed in a specific reference frame or it may undergo a motion that provides excitation for the supported system.

Fourier Series: A series, which expresses the values of a periodic function in terms of discrete frequency components that are harmonically related to each other.

Fourier Transform:

(a) **Direct Fourier Transform:** The transformation of a non-periodic function of time (or other variable such as distance) into a continuous function of frequency (or other variable such as wave number).

(b) **Inverse Fourier Transform:** The transformation of a continuous function of frequency (or other variable such as wave number) into its corresponding function of time (or other variable such as distance).

Frequency (Hz): The frequency of an oscillation is the number of cycles of oscillation in a given time period. Frequencies are usually specified by the number of cycles per second. The SI unit for cycles per second is Hertz, which is abbreviated to Hz. The frequency may also be expressed in radians per second.

Frequency Profile: The magnitude associated with each spectral line within the 'Test Frequency Range' combined to form a profile.

Frequency Range of Interest: The span, in Hertz, from the lowest frequency to the highest frequency at which, say, which an environmental test is specified.

Frequency Resolution: The smallest increment of frequency for which an analysis system is capable of differentiating between the input data.

Frequency Response: The output signal expressed as a function of the frequency for a given signal. The frequency response is usually given graphically by curves showing the relationship of the output signal and, where applicable, phase shift or phase angle as a function of frequency.

Frequency Response Function (FRF): Defines the magnitude and phase of the relationship between the output and input as a function of frequency. The response vector (output spectrum) divided by the excitation force vector (input spectrum) for a range of frequencies. The FRF contains amplitude and phase information and when plotted is normally shown as response / force vs. frequency and phase vs. frequency in two separate plots. The amplitude and phase can be shown together on an Argand diagram with frequency values marked along the curve.

Frequency Sweep: Either step or continuous frequency change between set frequency limits.

Fundamental Frequency: The lowest natural frequency of an oscillating system. The normal mode of vibration associated with this frequency is known as the fundamental mode.

Gaussian Distribution: The Gaussian distribution (also known as a Normal distribution) is given by:

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[\frac{-(x-\mu_x)^2}{2\sigma^2}\right]$$

Where: μ_x and σ^2_x is the true value of the mean and variance of x(t) respectively.

Gaussian Process: A Gaussian process is a stationary random process that obeys the probability density function of a *Gaussian Distribution*.

Harmonic: A sinusoid, the frequency of which is an integral multiple of the fundamental frequency.

High-Pass Filter: A filter, which has a single transmission band extending from some critical or cut-off frequency, not zero, up to infinite frequency or, in practice, above the highest frequency of interest.

Histogram: A histogram is a measure of the fractional amount of time per unit time that magnitude levels associated with a quantity *x(t)* will fall into specified ranges.

Homogeneity: A structure is homogeneous if a force produces a response which, when the magnitude of the force is changed by a factor, the output undergoes a change also of the same factor. Another way of viewing this principle in the frequency domain is to say that the output divided by the input (referred to as the Frequency Response Function) will remain unchanged, regardless of any change in the input.

Impedance: The ratio of a harmonic excitation of a system to its response (in consistent units), both of which are complex quantities and both of whose arguments increase linearly with time at the same rate. The term generally applies only to linear systems. [See *mechanical impedance*].

Impulse Response: is the Inverse Fourier Transform of the Transfer Function (also referred to as weighting function).

$$h_{(\tau)} = \int_{-\infty}^{\infty} \overline{H}(j\omega).e^{j\omega t} d\omega$$

where: $\overline{H}$ = Fourier Transfer
j = complex variable
ω = angular frequency
t = time

Induced Environment: Those mechanical, climatic, chemical and biological conditions that occur because of the materiel's operation, transportation, deployment, configuration, modes of storage and handling. Induced environments can also be generated as a result of other co-located materiel.

Input Impedance (of an Electronic Device): The electrical impedance between the input terminals.

Instantaneous Value (Value): The value of a variable quantity at a given instant.

Kurtosis: A measure of the 'peakedness' or 'spikiness' of a signal.

$$Kurtosis = \frac{1}{N}\sum_{i=1}^{N}(x_i - \overline{x})^4.\frac{1}{\sigma^4}$$

Laboratory Simulation Testing: The reproduction in a laboratory of the actual conditions which an engineering structure / materiel will experience in service.

LCEP (Life Cycle Environment Profile): Defines all the expected (natural and induced) climatic, mechanical and electrical environments, along with expected duration and probability of exposure, to which materiel is likely to be subjected from time it leaves the factory until it is removed from service. The LCEP includes transport, handling, storage, and maintenance operations with respect to their frequency (See MTDS).

Leakage: The error inherent in any Finite Fourier Transform of non-periodic signals is called Leakage.

Life Cycle: The life cycle defines all of the events to which the materiel will be subjected from the time it leaves the factory until it is removed from service.

Linear System: A system in which the magnitude of the response is directly proportional to the magnitude of the excitation.

Loading: The number, type, magnitude and position of the main loads applied to materiel.

Mass: The amount of material in an object. A measure of a body's inertia i.e. its resistance to acceleration.

Materiel: A generic term covering military systems, sub-systems, equipment, supplies and associated packaging.

Maximum Value: The value of a function when any small change in the independent variable causes a decrease in the value of the function.

Maximum Response Spectrum (MRS): When a vibration excitation is applied to a mechanical system with one degree of freedom, the maximum value of the response of this system for a deterministic signal, or the probability of a maximum value for a random signal, can be calculated. This value is called the 'maximum' or the 'extreme' value. The maximum response spectrum is the curve that represents variations of the 'maximum' response value as a function of the natural frequency of the system with one degree of freedom for a given damping factor.

Mean Value: The mean value $\bar{x}$ of a quantity *x(t)* is the time average of the quantity for an appropriate averaging time *T.*

$$\bar{x} = \frac{1}{T}\int_0^T x(t)dt$$

For an ergodic process, the true mean value μ_x can be obtained by letting *T* approach infinity.

Mean Square Value: the mean square value $\overline{x^2}$ of a quantity *x(t)* is the average of the square of the quantity for an appropriate average time *T*.

$$\overline{x^2} = \frac{1}{T}\int_0^T x^2(t)dt$$

For an ergodic process, the true mean square value can be obtained by letting *T* approach infinity.

Measurement Points: Specific points at which data are gathered for conducting a test. These points are of three types, namely:

a. Check point – point located on a fixture, on a vibration table or on a specimen as close as possible to one of its fixing points, and in any case rigidly connected to it.
b. Reference Point – This is chosen from the checkpoints whose signal is used to control the test so that the requirements of the standard are satisfied.
c. Response Point – Point on the specimen used for measurement of the response during vibration response investigations or during testing.

Mechanical Impedance (Z): At a point in a mechanical system, the complex ratio of force to velocity where the force and velocity may be taken at the same or different points in the same system during simple harmonic motion. The reciprocal of Mobility.

Mechanical Shock (Shock): A sudden change of force, position, velocity or acceleration that excites transient disturbances in a system.

Mechanical System: An aggregate of matter comprising a defined configuration of mass, stiffness and damping.

Meteorological Temperature: This is the ambient air temperature measured under standard conditions of ventilation and radiation shielding in a meteorological screen (such as a ‘Stevenson Screen’) at a height of 1.2 to 2.0m above ground level.

Miner's Rule: Is a commonly used technique for comparing the equivalent fatigue damage of different vibration spectra. (see Leaflet 2410).

Mobility (Y): The complex ratio of the velocity, taken at a point in a mechanical system, to the force, taken at the same or another point in the system, during simple harmonic motion.

This technique involves the use of modal parameters derived from testing. Here the structural modal analysis provides information relating to resonant frequencies (ω_r), modal constants (A_{ij}), modal stiffness (k_r), modal mass (m_r), phase (ϕ) and structural damping (η).

Mode of Vibration: In a system undergoing vibration, a mode of vibration designates the characteristic pattern of nodes and antinodes assumed by the system in which the motion of every particle, for a particular frequency, is simple harmonic (for linear systems) or has corresponding decay patterns.

Mode Shape: When a structure vibrates with a single sinusoidal frequency each point may have a different amplitude and phase. The values of amplitude and phase that describe this motion are called the operating deflections and they depend, amongst other factors, on the location and magnitude of the excitation. All possible operating deflections for a structure may be expressed as a weighted sum of mode shapes. The mode shapes are special distributions of amplitude and phase that are characteristics of the structure and are independent of the excitation. There is one mode shape associated with each natural frequency. The amplitude of each mode shape is scaled in a convenient manner.

Mounting: All shock and vibration test specifications should state both the method of mounting the materiel on the test apparatus and whether the effect of gravity is important. BS 2011 discusses the requirements for mounting in terms of tests on components and tests on equipment.

MTDS (Manufacture to Target or Disposal Sequence): The sequence of events and associated environments throughout the life of the materiel from manufacture until it is removed from service (see LCEP).

Narrow Band Random Vibration: is random vibration having frequency components within a narrow frequency band around its centre frequency. It has the appearance of a sine wave whose amplitude varies in an unpredictable way. The narrow band random vibration level is constrained within a tight frequency range and provides the amplitude of vibration at specific frequencies. Such vibration can have instantaneous amplitude values which follow a Gaussian distribution while its peak values follow a Rayleigh distribution.

Natural Environment: Those environmental conditions which are directly attributable to the forces of nature. These typically consist of meteorological, climatic, chemical and biological conditions that material directly experiences at its external surfaces due to its global location.

Natural Frequency: is the frequency of a free vibration of a system. For multi degree of freedom systems the natural frequencies are the frequencies of the normal modes of vibration.

Node: A point, line or surface in a standing wave where some characteristic of the wave field has essentially zero amplitude.

Noise: The term *noise* is generally referred to as any signal corrupting the required 'perfect' signal, which truly represents the structural motion. Any disagreeable or undesired sound. Sound, generally of a random nature, the spectrum of which does not exhibit clearly defined frequency components.

Normal Mode: A natural mode of an un-damped mechanical system.

Nyquist Frequency: A frequency equivalent to half of the sampling rate.

Octave: The interval between two frequencies, which have a frequency ratio of two. (ie. 20 to 40 Hz, 500 to 1000Hz).

Oscillation: The variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than some mean value.

Output Impedance (of an electronic device): The electrical impedance between its output terminals.

Overshoot (Undershoot): If the output of a system is changed from a steady value ***A*** to a steady value ***B*** by varying the input, such that value ***B*** is greater (less) than ***A***, then the response is said to overshoot (undershoot) when the maximum (minimum) transient response exceeds (is less than) value ***B***.

Partial Coherence: Indicates whether one output is correlated with one of the inputs.
The partial coherence function between a quantity $y(t)$ and any subset of a larger set of known quantities $x_i(t),\ i = 1,2,\ldots,q$ measures the extent to which y(t) may be predicted from this subset by optimum linear-least square relationships. Such partial coherence functions will be bounded between zero and unity.

Parts and Components: A part or component is any item incapable of useful function at a lower level of assembly. They may be electronic, electrical, mechanical, explosive, optical etc.

Peak Value (Peak Magnitude, Positive (Negative) Peak Value): The maximum or minimum value of a vibration during a given interval. [See also *maximum value*]. A peak value of a quantity x(t) is the value of x(t) at a maximum or minimum value. Peak counts per unit time can indicate the number of maxima only, the number of minima only or both.

Periodic excitation: A pattern which repeats exactly after a given interval or period.

Periodic (Complex): is a non-sinusoidal time varying waveform, which exactly repeats itself at regular intervals.

Pre-Conditioning: The exposure of a test specimen to predetermined conditions required by the test specification such that the properties of the specimen are stabilised before measurement and test.

Probability Density Function: Describes the relative occurrences of any given signal amplitude level contained within a time waveform.

PSD (Power Spectral Density): PSD is the limiting mean square value of a parameter per unit bandwidth. This is a measure of the average power within a specified frequency band. The Power Spectrum is computed using the Fourier Transform. The linear spectrum is displayed in terms of the frequency component modulus plotted against frequency.

$$G_x(f) = 2S_x(f) = \frac{2}{T} X(f).X(f)^*$$

where:

Gxf = Power Spectral Density in terms of the ‘single side’ spectrum
Sxf = Power Spectral Density in terms of the ‘double sided’ spectrum
* denotes complex conjugate

Pulse: A pulse is a finite duration deterministic or random time history. In cases in which the pulse is related to the response in testing of materiel, the duration is generally no longer than five times the period of the lowest natural frequency of the materiel under consideration, and may be substantially shorter.

Q: Q **factor:** A quantity which is a measure of the sharpness of a resonance, or frequency selectivity, of a resonant oscillatory system having a single degree of freedom, either mechanical or electrical.

Quality Assurance: Quality assurance is a management responsibility, with quality being achieved by analysis of the tasks to be performed, identification of the skills required, selection and training of personnel, use of appropriate equipment, creation of a satisfactory environment in which the activity can be performed, and recognition of the responsibility of the individual who is to perform the task. Quality assurance provides for a disciplined approach to each task, including verification that each task has been satisfactorily performed, and production of documentary evidence to demonstrate that the required quality has been achieved.

Random Error: is defined as:

Normalised Random Error = 1 / √Bandwidth x Record Length

$$e = \frac{1}{\sqrt{B_e T}}$$

Random Noise: A noise the magnitude of which cannot be precisely predicted for any given instant of time. [See *random vibration*].

Random Process (Stochastic Process): A set (ensemble) of time functions that can be characterised through statistical properties, such as the average properties of these records at a number of fixed times.

Random Vibration: A vibration whose instantaneous magnitude is not specified for any given instant of time. A random vibration does not contain any periodic components.

Rattling: Many complex structures rattle when excited, and the contribution of the rattles to the control / measurement signals is often significant, due to their normally high frequency.

Relative humidity: A ratio of the amount of water in the air at a particular temperature and pressure to the maximum amount it could hold at that temperature and pressure; expressed as a percentage.

Resolution: The resolution of a system for measuring motions is the smallest change in input (displacement, velocity, acceleration, strain, or other input quantity) for which a change in output is discernible. The resolution of the digitising process depends upon the number of bits in the Analogue to Digital Converter. It is recommended that this is at least 12 bits, equivalent to a resolution of 1 part in 4096 of the full-scale range.

Resonance: At or near resonance the amplitude of oscillation of a mechanical system exposed to a periodic force, whose frequency is equal or very close to one of it's natural un-damped frequencies, increases. Any change in excitation frequency, however small, causes a decrease in a response of the system.

Resonance Frequency: A frequency at which resonance exists.

Response Control: A form of vibration system control that attempts to match the response of materiel at one or more points with measured or specified vibration data at one or more points on the materiel.

Response (of a System): A quantitative expression of the output of the system.

Response Spectrum: In both shock and vibration, a response spectrum is a plot of the maximum response (acceleration, velocity or displacement) of a family of damped, single-degree-of-freedom bodies (oscillators) as a function of their natural frequency (or period) to a vibratory motion input at their supports.

Rise Time (Pulse Rise Time): The interval of time required for the value of the pulse to rise from some specified small fraction of the maximum value to some specified large fraction of the maximum value.

Root-Mean-Square Value (rms Value): The root-mean-square (rms) value is the positive square root of the mean-square value. The rms value is equal to the standard deviation if the mean value is zero.

Sampling: To obtain the values of a function for regularly or irregularly spaced distinct times.

Sampling interval: The time interval between two samples.

Sampling Rate (Vibration and Shock): The time interval between the digitised points is called the sampling period. The number of digitised points per second is the sampling rate. The maximum frequency in the data that can be examined is one half the sampling rate. Sampling must be performed at equal time intervals and at a data acquisition rate adequate to fully characterise the data without the introduction of avoidable errors. Normal practice is to select the sampling frequency based on the maximum frequency of interest in the data. It is recommended that for simulation applications it is at least four times the maximum frequency of interest for vibration and 10 times the maximum frequency for shock events.

Scaling: Analog signals should be scaled (amplified) to utilise the full range of the ADC (without saturation) to make maximum use of the resolution available.

Sensitivity (of a Transducer): The ratio of a specified output quantity to a specified input quantity.

Shock Pulse: A form of shock excitation characterised by a sudden rise and/or sudden decay of time-dependent parameter (such as motion, force or velocity).

Shock Response Spectrum: In vibration testing a response spectrum is an envelope of the maximum response of a family of single-degree-of-freedom bodies (oscillators) during the test excitation whereas, in shock, which has the excitation applied for a short duration, the shock response spectrum may be defined as:

a. An envelope of the maximum response of the oscillator masses whenever it occurs –the so-called *maxi-max* shock response spectrum
b. An envelope of the maximum responses of the oscillator masses occurring during the period of the applied shock - the initial or primary shock response spectrum;
c. An envelope of the maximum responses of the oscillator masses occurring after the applied shock duration - the residual shock response spectrum.

Unless otherwise stated, the shock response spectrum is always the maxi-max shock response spectrum and the damping is assumed to be zero.

Shock Tests: are generally required to demonstrate pyrotechnic event resistance (rocket motors, gunfire, UNDEX (a non-contact underwater explosion) etc), impact resistance and strength of components or systems. The specified shock can take the form of a classical waveform in the time domain or a frequency domain specification known as the Shock Response Spectrum.

a. Classical shock specifications will usually give the required pulse shape, magnitude of the pulse, duration of the pulse, number and directions of pulses to be applied, tolerances on pulse shape/magnitude and either the velocity change or tolerance on the pulse duration.

b. Response spectrum – the test level is given in the form of response amplitude against frequency curve and may include a requirement for a given number of peaks in the time history to exceed a certain value.

Shock Testing Machine (Shock Machine): A device for subjecting a system to controlled and reproducible mechanical shock.

Signal: A disturbance or variation of a physical quantity used to convey information. The information to be conveyed over a communication system.

Signal to Noise Ratio: The signal/noise (S/N) ratio sets a limit to the accuracy of measurement, there being two aspects of importance. The first aspect is the S/N ratio in the frequency band of interest. The S/N ratio of the instrumentation chain tends to be dominated by the input pre-amplifier, and some care should be exercised in its choice/use to obtain an adequate S/N ratio. The in-band S/N ratio sets the ultimate accuracy, and the target value that should be estimated during the system analysis. The second aspect is the possible presence of relatively large amounts of out-of-band noise. Because the rejection of out-of-band signals is never infinite, the spill-over from such noise may be significant. It may also be that amplifiers, analyser etc have to be used on scale settings, which are less than optimum from the point of view of analysis of the signal of interest, in order to avoid overloading from the out-of-band noise. If the out-of-band noise arises from earth loops or other avoidable sources, these should be eliminated. If the noise is unavoidable, then appropriate filtering should be employed, though care has to be taken if shock measurements are in progress, because of the associated phase shifts.

Sine Sweep: is obtained by continuously varying the frequency of a sine wave. Dynamic test specifications will give the amplitude as either a constant level of maximum displacement, velocity and acceleration over the specified frequency range, or constant levels of maximum displacement, velocity and acceleration over different portions of the frequency range.

Skewness: A measure of the symmetry of the signal about the mean.

$$Skewness = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^3 . \frac{1}{\sigma^3}$$

Smoothing: An averaging process in which a data block is shifted and averaged. Smoothing can be applied in the time domain, the frequency domain and to histograms.

Solar Radiation: The infra-red, visible and ultra-violet radiation emitted from the sun.

Specimen: An item of materiel to be tested in accordance with the test procedures contained within this standard. This includes any auxiliary parts or systems that are integral features of the materiel (e.g. heating, cooling or anti-icing systems).

Spectral Density: See ‘autospectral and cross-spectral density function’.

Spectrum: A description of a quantity as a function of frequency or wavelength.

Stability: A stable structure is one in which every bounded input produces a bounded output. This means that if the input is finite in magnitude then the output must also be finite in magnitude.

Standard Deviation: The standard deviation is the positive square root of the variance. The standard deviation is equal to the rms value if the mean value is zero.

Stationary Random Process: is where an ensemble of signals such that an average of values over the ensemble at any given time is independent of time.

A stationary random process is a collection of time history records having statistical properties, which are invariant with respect to translations in time. Stationary processes may either be ergodic or non-ergodic.

Stiffness, *k*: The ratio of change of force (or torque) to the corresponding change in translational (or rotational) displacement of an elastic element.

Storage and Transit Conditions: This is an induced environment. Storage and transit conditions refer to the air temperature and humidity often induced in temporary field conditions. This could include unventilated conditions giving rise to accelerated effects of solar radiation (e.g. under tarpaulin covers, within a vehicle, or in a railway boxcar in hot climates) or exposed conditions accelerating the effects of wind and rain (e.g. no cover in cold climates).

Sub-System: A subsystem is defined as a group of assemblies, designed together to form a major part of a system, complete in its own right performing a specific function or functions; for example a radar scanner within a radar system.

Superposition: The principle of superposition is often used to calculate the response of a structure when several forces are acting either at one location or at several differing locations. The calculation is performed by determining the response when each force is acting alone. The response when all the forces are acting is the sum of all the individual responses. Superposition follows from the idea of linearity.

Sweep: (as applied to the operation of a vibration generator): The process of traversing continuously through a range of values of an independent variable, usually frequency. A sweep can be in one direction only, or one direction followed by a reverse direction. In a vibration test including swept components the sweep direction must be specified.

Sweep Rate: The rate of change of the independent variable, usually frequency, for example *df /dt* where is *f* is frequency and *t* is time.

System: A system is a combination of subsystems and/or parts/components organised to perform a function or functions.

Temporal Moments: Provide a method to characterise shock in a time / frequency framework. The i^{th} temporal moment about time, $m_i\,(a)$ of a time history, *x(t)* about a time location, *a* will be defied as:

$$m_i(a) = \int_{-\infty}^{\infty} (t-a)^i \left[f(t) \right]^2 dt$$

Test Categories: The following presents types of tests. A typical materiel development might include development testing and durability testing, while another might include qualification and reliability testing. Environmental worthiness testing is included when needed. All of the tests consume life. It should be assumed that a qualification test, a durability test, or a reliability test consumes the test article such that it is not subsequently suitable for field deployment. Development tests and worthiness tests may or may not consume a complete life depending on the specific test goals. In all cases it is vital to tailor test methodology, requirements, and success or failure criteria to achieve the desired results.

a. **Acceptance Test:** Examination and verification of products against contract specification requirements.

b. **Development Test -** Development testing is used to determine characteristics of materiel, to uncover design and construction deficiencies, and to evaluate corrective actions. It begins as early as practical in the development and continues as the design matures. The ultimate purpose is to provide confidence that developed materiel will be compatible with the environmental life cycle and that formal testing does not result in failure. The tests have a variety of specific objectives and therefore, allow considerable freedom in selecting test severities for example vibration levels, excitation, frequency ranges, and durations. Typical programs might include modal analysis to verify analytical mode shapes and frequencies, and sine dwell, swept sine, transient, or random excitation transient vibration to evaluate function, fatigue life, or wear life. The test types, levels, and frequencies are selected to accomplish specific test objectives. Levels may be lower than life cycle environments to avoid damage to a prototype, higher to verify structural integrity, or raised in steps to evaluate performance variations and fragility.

c. **Environmental Stress Screen (ESS):** ESS is not an environmental test. It is a production or maintenance acceptance inspection technique. Materiel may be subject to multiple ESS cycles and maintenance ESS exposure severities may differ from production acceptance severities.

d. **Functional Test:** Functional testing is conducted to verify that the materiel functions as required while exposed to worst case operational vibration.

e. **Hardening Test:** The use of environmental testing methods to provide failure mode data for the improvement of materiel reliability. Specific environments simulated during hardening tests may not occur in the actual materiel life cycle.

f. **Operational Test:** A range of testing and experimentation conducted in realistic operational environments, with military personnel that are representative of those expected to operate, maintain and support the system when fielded or deployed.

g. **Qualification Test -** Qualification testing is conducted to determine compliance of a materiel with specific environmental requirements and will normally be part of a sequential test programme.

h. **Reliability Test:** Reliability testing is accomplished to obtain statistical definitions of materiel failure rates. These tests may be development tests or qualification tests. The accuracy of the resulting data is improved by improving realism of the environmental simulation. Multiple test items are exposed to segments of a life cycle.

Test, Configuration: A detailed description of the test item state (i.e. in a storage/shipping container, operational configuration, etc.), and its interface and/or orientation with any associated materiel and the test equipment during the test.

Test Frequency Range: The frequency bandwidth, having a lower and upper frequency limit, over which the test is conducted. Also see ‘Frequency Range of Interest’.

Test Report: Test reports may vary from a simple test certificate to a formal test report giving all details, results, assessments, discussion, conclusions and recommendations.

Thermal Stability: Thermal stability is attained when that part of the test specimen considered to have the longest thermal lag reaches the nominal test temperature within specified tolerances. If no tolerances are specified, thermal stability is achieved when all parts of the test specimen are within 2°C of the specified test temperature.

Time Constant (Relaxation Time): The time taken by an exponentially decaying quantity to decrease in magnitude by a factor of 1/e = 0.3679.

Time History: The magnitude of a quantity expressed as a function of time.

Time Waveform: The time waveform is defined as the display of the vibration time history that includes all the frequencies capable of being detected by the transducer.

Tracking Filter: A band-pass filter (usually narrow-band) the centre frequency of which can be made to follow a signal of varying frequency.

Transducer: A device designed to receive energy from one system and supply energy, of either the same or of a different kind, to another in such a manner that the desired characteristics of the input energy appear at the output.

Transfer function (of a system): A mathematical relation between the output (or response) and the input (or excitation) of the system. The ratio of the output to the input of a system. Where the quantity is complex in nature the real and imaginary parts must both be used in the comparison.

Transfer Function = Output Response / Input Signal

Transient Vibration: The vibratory motion of a system other than steady state or random. Transient vibration is a temporarily sustained vibration of a mechanical system. Transient vibration is vibration of limited duration which may be either deterministic or random.

Transmissibility: The non-dimensional ratio of the response amplitude of a system in steady-state forced vibration to the excitation amplitude. The ratio may be one of forces, displacements, velocities or accelerations.

Transverse Axis (of a Transducer): Any nominal direction perpendicular to the sensitive axis.

Transverse Sensitivity (of a Rectilinear Transducer): The sensitivity of a transducer to excitation in a nominal direction perpendicular to its sensitive axis.

Unit or Assembly: A unit or assembly is defined as any part which is less than a subsystem, but whose performance can be independently assessed in terms of the overall performance of the subsystem.

Validation: The process of determining the degree to which a model, simulation results set or data set is an accurate representation of the real world, from the perspective of the intended purpose of the model, simulation or real data.

Vapour Pressure (Water): Vapour pressure is that part of the total atmospheric pressure which is exerted by water vapour.

Variance (Signal): The variance s^2_x of a quantity $x(t)$ is the average of the square of the deviation from the mean value $\bar{x}$ for an appropriate averaging time T.

$$S_x^2 = \frac{1}{T}\int_0^T \left[x(t) - \bar{x}\right]^2 dt$$

Vector: A quantity that is completely determined by its magnitude and direction.

Velocity (Relative Velocity): A vector that specifies the time-derivative of displacement. The rate of change of distance travelled (ms^{-1})

Verification: The process of determining the degree to which a model, simulation results set or data set, accurately represent the conceptual model description and its specifications.

Vibration: The variation of time of the magnitude of quantity which is descriptive of the motion or position of mechanical system, when the magnitude is alternately greater and smaller than some average value or reference. [See *oscillation*]. A body, or point is said to vibrate when it follows an oscillatory motion about a position of equilibrium.

Vibration Generator (Vibration Machine): A machine that is specifically designed for and is capable of generating vibrations and of imparting these vibrations to other structures or devices.

Vibration Generator System: The vibration generator and associated equipment necessary for its operation.

Vibration Isolator: A flexible passive device designed to attenuate the transmission of vibration in a frequency range.

Wavelength (of a Periodic Wave): The distance measured perpendicular to the wave front in the direction of propagation, between two successive points on the wave, which are separated by one period.

Wavelet: A time history with a single frequency that is a component of the synthesised time history for an SRS.

Wear: The unwanted removal of material from contacting solid surfaces as a result of mechanical action. This does not account for other forms of surface damage such as those arising from impact/overload where there is no sliding motion or from cavitation where the counter body is a fluid. Some examples are:

a. **abrasive wear:** Abrasive wear occurs when material is removed from surfaces due to sharp hard projections from one surface cutting into a softer surface (2-body abrasion), or due to hard particles rolling or sliding between contacting surfaces (3-body abrasion) under the action of load/pressure.
b. **adhesive wear:** Due to the extremely high contact pressures between two surfaces, they undergo localised plastic deformation and become micro-welded. Continued relative motion between the surfaces causes one side of the ‘welded’ junction to fracture.
c. **brinelling:** True Brinelling occurs as a result of material deformation due to excessive operating loads, impact, dropping or hammering. False Brinelling has the appearance of True Brinelling in that small indentations of the surfaces are formed; however in this case these are produced by the mechanisms described for fretting.
d. **corrosive wear:** Corrosive wear occurs when there is a combination of a wear situation and an environment likely to cause chemical or electrochemical reaction.
e. **fretting:** It occurs when contacting surfaces undergo oscillatory displacements of small amplitude such as in vibration situations. This small motion is sufficient to cause micro-welding of asperities on both surfaces like that observed in adhesive wear, but any wear debris which forms then becomes trapped between the surfaces causing subsequent 3-body abrasive wear.
f. **plastic deformation:** This occurs when a material is taken past its yield strength, resulting in burrs, dimension changes and potentially work hardening (depending upon the material).
g. **surface fatigue:** Surface fatigue wear occurs during repeated sliding or rolling that initiates surface or sub-surface fatigue cracks, eventually leading to break up of the surface and the formation of relatively large wear particles. Unlike other forms of wear, fatigue wear does not require the surfaces to be in direct physical contact, only for a load-path to be present.

Wideband Random Vibration: Wideband random vibration is vibration whose spectrum is significant over a wide frequency range relative to the centre of this band.

Working Space (in a Test Chamber): That part of the test chamber in which the test conditions can be maintained within specified tolerances.

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