

CEN workshop 10
Standardisation for Defence Procurement
Expert Group 8 Environmental Engineering

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Report of Expert Group 8
Environmental Engineering
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Contents

1	References	4
2	Introduction	5
2.1	CEN Workshop 10	5
2.2	Expert Group 8 Environmental Engineering	5
2.3	Historical Background of Environmental Test Procedures	6
2.4	Limitation of the Work of Expert Group 8	8
3	Scope	10
3.1	Standards Considered	10
3.2	Equivalent Management Processes	17
3.3	Equivalent Test Methods	17
4	The Reduction Process	21
4.1	Criteria Used in Review of Test Procedures	21
4.2	Criteria Used in Review of Fallback Test Severities	22
5	Recommendations for Best Practice	25
5.1	Environmental Management Procedures	25
5.2	Environmental Test Procedures	28
5.3	Environmental Test (Fallback) Severities	34
6	Recommendations For Standardisation Process	45
6.1	Environmental Management Process	46
6.2	Environmental Definitions	46
6.3	Derivation of Test Severities From Measured Data	47
6.4	Environmental Test Procedures	47
6.5	Environmental Test (Fallback) Severities	47
7	Conclusions	49
Annex A	Detailed Comparative Review Between Standards	A-1
A.1	Review and Comparison of Environmental Management Standards	A-3
A.2	Review and Comparison of Vibration Test Methods	A-15
A.3	Review and Comparison of Shock Test Methods	A-27
A.4	Review and Comparison of Miscellaneous Mechanical Test Methods	A-41
A.5	Review and Comparison of Temperature, Humidity and Pressure Test Methods	A-47
A.6	Review and Comparison of Natural & Man Made Contaminate Test Methods	A-59
Annex B	Overview Of Each Standard Group	B-1
B.1	International Civil Standard EN / IEC 60068 & 60721	B-3
B.2	National Defence Standard Def Stan 00-35 (UK)	B-3
B.3	National Defence Standard GAM-EG-13 (F)	B-4
B.4	National Defence Standard MIL STD 810 (US)	B-4
B.5	International Defence Procedure STANAG 4370 (NATO)	B-5
Annex C	Additional Information on Environmental Standards	C-1
C.1	The Environmental Control and Management Process	C-3
C.2	The Environmental Test Tailoring Process	C-3
C.3	Environmental Engineering and Reliability Tests	C-6
C.4	Environmental Engineering and Safety Tests	C-7

1 References

CEN/WS010 N0018, General Framework Paper, 10th October 2007.

CEN/WS010 N0022, Template for Drafting Recommendations, 3rd November 2007.

Terminology

NATO STANAG 4370, AECTP-100, Edition 4, Annex C, Glossary of Terms

Def Stan 00-35 Issue 3, Environmental Handbook for Defence Materiel, Part 3 Environmental Test Methods, Section 1 General, Chapter 1-06 Glossary of Terms

Mil Std 810G, Environmental Engineering Considerations and Laboratory Tests, Part 1, Section 3, Definitions, 3.1 Terms and 3.2 Acronyms.

2 Introduction

2.1 CEN Workshop 10

The European Commission requested that the European Committee for Standardization establish Workshop 10 to improve the efficiency and enhance the competitiveness of European Defence Industry.

The European Handbook for Defence Procurement, EHDP, has been prepared by Experts Groups reporting to CEN Workshop 10. This European handbook is a guide designed as a tool for anyone involved in the European defence procurement. The primary target users for the Handbook are:

- The staff in the ministries of defence who are producing procurement specifications and invitations to tender.
- The staff in defence companies who are responding to those requirements.

The European Handbook for Defence Procurement is designed to provide defence procurement agencies and defence industries with a preferential list of selected recommended standards qualified as best practice ones to be included in armament contracts together with concise recommendations for an optimum use of those standards in such a defence procurement context. Those types of resulting informative data could be used in the acquisition process by MoD and in the development process by industry such that system will be built faster, better and cheaper.

The aim of a recommendation is to develop good practices in the domain addressed by the Expert Group and to assist the final user in using recommended best practices standards in the best cost-effective way.

- Increasing the controlled use of existing standardization, a necessity to harmonise European practices used by defence procurement stakeholders.
- The objective is to deploy a common approach through Nations Procurement agencies about an optimized utilization of standards: civil ones and military ones, the possible limitations of civilian standards with respect to military applications, to provide a useful guide to all stakeholders involved in defence procurement process.
- Description of how to implement standards successfully in armament contracts.
- The overall result will be a better use of standards in armament contracts.

Recommendations are, during the drafting process, designed to allow EHDP final users to be provided with the right information for timely and quickly acquiring the best control in writing standards clauses related to the selected material, in armaments contracts. That is why the volume of recommendations will be accordingly fully compatible with respect to EHDP vocation and purpose.

2.2 Expert Group 8 Environmental Engineering

Expert Group 8 was constituted to review all environmental engineering and associated testing standards relating to the procurement of defence materiel. This has included management and test strategy relating to all aspects of environment engineering concerning the environmental immunity of equipment. Environmental engineering is considered as a horizontal process (“process related”) encompassing all defence materiel and equipment including weapons and sensors utilised in all theatres. Supporting information on Environmental standards and how they relate to a number of other horizontal standards is set out in Annex C.

The exceptions to the work of Expert Group 8 are the electromagnetic environment and aspects of NBC Indicators (nuclear, biological, chemical weapons), both of which are addressed by other

expert groups. The work of Expert Group 8 also did not directly address defence space environments.

Expert Group 8 has reviewed environmental requirements, test procedures, test severities as well as the methodologies necessary to manage the environmental demonstration process. The Expert Group has identified a preferential list of best practice environmental test procedures, severities and methodologies. This document presents the recommendations and rationale as to on the best use of those best practice standards in armament contracts.

The environmental test procedures, severities and methodologies addressed by the Expert Group are listed herein. The review undertaken separately addressed the environmental management process, environmental test procedures and environmental test severities. The latter are specifically those that may be used as defaults or fallbacks when no other information is available. In general the use of test severities derived from actual conditions is recommended. A summary of the extent of each of the three reviews is indicated below.

- From a wide range of documents, four aspects of the environmental management process are separately reviewed namely; the environmental engineering process, environmental conditions, the derivation of test profiles and default (fallback) severities. The presentation of material in this report allows the user to evaluate the different processes use by different standards. Each is compared and recommendations given, based upon a defined set of discriminatory selection criteria.
- Approximately 250 individual test procedures were collected into forty five different types of test for comparison. Purely for organizational purposes these were further collected into five groups namely; vibration tests, shock tests, miscellaneous mechanical tests, climatic tests and natural & man made contaminate tests. Together the forty five different types of test procedure encompass the environmental test requirements for most defence systems. The presentation of material in this report allows the user to identify similar test procedures from within different standards. Each is compared in detail and recommendations given, based upon a defined set of discriminatory selection criteria.
- For each of the forty five different types of test procedure, the appropriate fallback severities are addressed. Again the presentation of material in this report allows the user to identify similar test severities from within different standards. Recommendations given, based upon a defined set of discriminatory selection criteria.

2.3 Historical Background of Environmental Test Procedures

Many environmental engineering test procedures started as test equipment specific procedures. However, by the 1960's, the more common test methods began to be written into national and international standards. Although much updated since then, the layout, approach and limitations of some of those early specifications are still apparent today. In the early days most environmental engineering standards were little more than a cook book of test procedures with embedded severities. Relatively little choice of test procedure was available as this was frequently dictated by available test equipment. Moreover, severities were, by necessity, generally simplistic and frequently had only minimal relationship with actual conditions. Environmental testing was expensive and facilities existed at only a few locations.

From the late 1960s to the mid 1990s the main environmental test standard, in the defence sector, was the US Mil Std 810 which was adopted in some European countries often without any change. In the UK the main defence standard was Def Std 07-55 (now replaced by Def Stan 00-35) and in France GAM EG 13. In Germany there were some environmental engineering standards in the sector of the defence equipment standards (VG) and of the technical supply conditions (TL). In the civil sector, the first of the family of procedures that are now IEC 60068 (but then known by different numbers in different countries) become available.

By the mid 1970's test facilities were rapidly improving, new test control, monitoring and instrumentation were also becoming available. As a consequence many of the older test procedures were subject to significant update. Also the ability to make field measurements was starting to indicate deficiencies in the generic and crude test severities used in the 1960s and 1970s. In some military areas the need for a revision of the test severities had become critical as the existing tests were significantly affecting product design, mass, cost or performance. The main area of concern was with so called induced environments, as opposed to the natural environment. Induced environments are those created by the system itself often in-conjunction with its operational conditions. In some cases in-service failures were not been reproduced in test or testing was causing failures not found in operation. A number of empirical methodologies to determine improved severities originate from this time as does initial work to better understand the mechanism causing induced environmental conditions.

The IEC EN 60068 series of test procedures are frequently first choice for civil products that contain electro-technical or electronic components. Various goods of this type are also embedded in defence products. Therefore the IEC 60068 series of procedures can be regarded as basic standard for dual use products. Civil product test procedures are unlikely to fulfil all the requirements needed by military environmental requirements. This is because specific defence environmental conditions Any civil test procedure will at best need to be supplemented by tests which unique original military requirements. The IEC EN 60068 series of test procedures are frequently adopted by vertical (product) standards and appear as the base test procedure other applications in a variety of guises.

By the early 1980s it was becoming clear that purchasing authorities, defining fixed cook book test severities, were effectively taking all the risk and consequences of inappropriate tests. However, they rarely have sufficient information to judge the extent of the risk they were taking. Whilst, some environmental standards included processes to partly alleviate this problem, the real debate, on risk arising from the lack of severities and the need to improve severities, were only widely addressed with the issue of US Mil Std 810 issue D. This turned around previous approaches and put the onus on the equipment supplier to establish an environmental strategy as well as the actual environmental conditions. This allowed suppliers to adopt representative severities, a process which became known as "tailoring". In fact this is a particularly ambiguous description as it tends to be used to mean different parts of the process.

The Mil Std 810D process was supposed to be managed by a series of specified formal documents. These documents were intended to allow the equipment supplier to manage the environmental engineering process by agreeing and demonstrating the approach they were adopting. It should be remembered up to that point requirement contracts were frequently based upon a set of firmly written contractual requirements allowing the supplier little scope for deviation. The process of Mil Std 810 D was allowing suppliers greater responsibility, scope and flexibility. However, the Mil Std 810 D documents rarely interfaced with the procurement process used by European countries. Indeed experience would suggest it was not exclusively used in US defence procurements either.

The above notwithstanding the Mil Std 810 D concept of "tailoring" process was widely adopted by the European Defence industry as it gave clear advantage when environmental conditions were design drivers. The process also extended to many areas of commercial work. The adoption of the process increased the need for in-service measurements and an increase in measurement exercises occurred allowing further improvements to the severities embedded within standards. However, the quality of these measurements was not always that good nor were they always matched by an understanding of the mechanisms involved in generating the conditions. In short the methodology for deriving test severities from in-service measurements was not defined and, as a consequence, derived test severities varied enormously. This has been demonstrated within Europe by several Round Robin exercises.

By the mid 1980's significantly improved, service based, environmental severities were available and many of the national Defence Standards were starting to incorporate these improvements.

Some, notably the French Defence Standard were also starting to incorporate methodologies for deriving test severities from in-service data. However, the different approaches adopted for severity derivation in the various national standards meant that they were diverging and the need for an international approach for convergence became pressing. The only real international commercial standard was the procedures & severities of EN IEC 60068 & 60721. However, the severities of these documents were not self consistent nor did they appeared to benefit from any credible measurement exercises. As a consequence even for areas where commercial / military environments overlapped those documents were not considered a credible base for international defence agreement.

The solution adopted by the NATO STANAG organisation was to initiate an environmental test standard based upon available national standards. The majority of the work on this standard occurred in the early 1990's and in effect encompassed aspects of the US standard, Mil Std 810, the French standard, GAM EG 13 standard and the UK standard, Def Stan 00-35.

During the 1990s, in parallel with the generation of the first NATO horizontal environmental testing standard, the three main national standards were also revised. In the case of the French GAM standard, significant additional information and advice was included on the derivation of test severities from measurement and for user defined in-service equipment life cycles. The UK standard additionally included information on induced mechanical and climatic environments as well setting out an environmental management process compatible with the design process and consistent with the UK procurement. The US Mil Std had been updated in the late 1980's and again in the late 1990's these revisions included updated test severities as well as a revised environmental management process. In this period no similar changes either to severities or the management process were made to EN IEC 60068 or 60721. It was not till the late 1990's that, long overdue, work to update the environmental and test severities of the two documents occurred. Even then that update was restricted to severity reconciliation between the two documents rather than a fundamental review of severities.

In recent years commonality of the national standards with that of NATO STANAG has increased. The French GAM EG 13 is no longer supported, in favour of the NATO STANAG. However, both the US Mil Std and the UK Def Stan continue to be updated. The IEC EN 60068 series of test procedures also continues to be updated and new tests introduced. However, these new tests are almost always introduced later than in the defence standards.

2.4 Limitation of the Work of Expert Group 8

Although Expert Group 8 has focused on environmental testing and engineering, many specifications of products include environmental requirements affecting quality, reliability and service life. There is a huge amount of these standards out on the market. Very often those standards are related to a branch or a group of equipment such as electronics, telecommunication equipment, vehicles, weapons, missiles, ammunitions, aerospace, and personal equipment for the soldier. These specifications and standards are often referred to as 'vertical standards' compared to those standards which describe the test procedures independent of the tested products. These standards are often referred to as 'horizontal standards' because they can be applied for various groups of products.

The limitation of this investigation is delineated by military needs. Many similar standards have been developed in the past for civilian products and quite a large number of standards exist for specific purposes and equipment.

This report clearly focuses on universal standards in the area of military hardware and important civilian standards dealing with environmental testing. Many so called 'dual-use-products' or 'commercially-of-the-shelf-products' (COTS) are to be tested according to these basic test procedures. Due to a limited time schedule and resources not all existing test standards have been evaluated. There are a lot of specific environmental testing standards available, e.g.

related to automotive application, aerospace application, optical instruments, telecommunication equipment which could not been addressed in detail.

The experience and knowledge of the experts involved in the field of environmental engineering has ensured that the most important standards have been included in this study. The history of environmental engineering tells us that most testing standards have the same roots. Quite often the newly established standards in a specific branch can be traced back to the basic environmental testing procedures of the area of defence application.

Certain aspects of environmental testing are closely related to, and overlap with, areas of safety and reliability testing. Indeed many test procedures used for these purposes are either based upon or similar to environmental test procedures. The environmental testing to space vehicles and spacecraft equipment was identified as including some unique requirements. To explain these relationships the following paragraphs refer to some specific considerations.

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3 Scope

This section sets out the primary standards considered and compared by Expert Group 8. All the environmental standards considered are substantial documents which exist either as single publications or as a group of publications under a common designation. When the latter occurs individual documents may have different publication and revision dates. Each standard group adopts its own layout, numbering and titling scheme. As a consequence it is not always easy for a user to identify notionally similar test procedures from one standard to another. The (approx. 250) individual publications considered by Expert Group 8 are listed (in sub-section 3.1).

To facilitate both the comparison process the publications have been grouped into similar procedures. This process was mostly undertaken during the Phase 1 work, was updated at the start of the Phase 3 work. Essentially each of the publications has been collected into one of 49 groups. Four of these groups relate to aspects of the environmental management process and the remaining 45 groups relate to different types of environmental test procedure. Tabulated in this section (sub-section 3.2) are the notionally similar publications which form the 4 groups which relate to aspects of the environmental management process. Also tabulated in section (sub-section 3.3) are the notionally similar publications which form the 45 groups which relate to different types of environmental test procedure. An overview of the five groups of standards is set out in Annex B.

3.1 Standards Considered

The primary environmental standards considered and compared by Expert Group 8 are listed below. Some of the standards considered are issued as separate component parts whilst others are issued as an entity. For this reason each of the test procedures has been considered separately for the purpose of the work of Expert Group 8.

EN 60068 **Environmental Testing** (International Standard for Civil Electro-technical equipment generated by IEC and issued by CEN and most National standard Agencies. Listed sections issued and sold separately in English, French, German and many other languages. Updates are on a rolling basis and occur at different times).

- 60068-1 Part 1: General and guidance
- 60068-2 Environmental testing Basic environmental testing procedures
- 60068-2-1 Part 2-1: Tests A: Cold
- 60068-2-2 Part 2-2: Tests B: Dry heat
- 60068-2-5 Part 2-5: Test Sa: Simulated solar radiation at ground level
- 60068-2-6 Part 2-6: Test Fc: Vibration (sinusoidal)
- 60068-2-7 Part 2-7: Test Ga and guidance: Acceleration, steady state
- 60068-2-9 Part 2-9: Guidance for solar radiation testing
- 60068-2-10 Part 2-10: Test J and guidance: Mould growth
- 60068-2-11 Part 2-11: Test Ka: Salt mist
- 60068-2-13 Part 2-13: Test M: Low air pressure
- 60068-2-14 Part 2-14: Test N: Change of temperature
- 60068-2-17 Part 2-17: Test Q: Sealing
- 60068-2-18 Part 2-18: Test R and guidance: Water
- 60068-2-27 Part 2-27: Test Ea and guidance: Shock
- 60068-2-29 Part 2-29: Test Eb and guidance: Bump
- 60068-2-30 Part 2-30: Test Db and guidance: Damp heat, cyclic (12 +12-hour cycle)
- 60068-2-31 Part 2-31: Test Ec: Drop and topple, primarily for equipment-type specimens
- 60068-2-32 Part 2-32: Test Ed: Free fall (Procedure 1)
- 60068-2-33 Part 2-33: Guidance on change of temperature tests
- 60068-2-38 Part 2-38: Test Z/AD: Composite temperature/humidity cyclic test
- 60068-2-39 Part 2-39: Test Z/AMD: Combined sequential cold, low air pressure, and damp heat test
- 60068-2-40 Part 2-40: Test Z/AM: Combined cold/low air pressure tests
- 60068-2-41 Part 2-41: Test Z/BM: Combined dry heat/low air pressure tests
- 60068-2-45 Part 2-45: Test XA and guidance: Immersion in cleaning solvents
- 60068-2-47 Part 2-47: Mounting of components, equipment and other articles for dynamic tests including shock (Ea), bump (Eb), vibration (Fc and Fd) and steady-state acceleration (Ga) and guidance
- 60068-2-48 Part 2-48: Guidance on the application of the tests of IEC 68 to simulate the effects of storage

CEN workshop 10
Standardisation for Defence Procurement
Expert Group 8 Environmental Engineering

- 60068-2-50 Part 2-50: Tests Z/AFc: Combined cold/vibration (sinusoidal) tests for both heat-dissipating and non-heat dissipating specimens
- 60068-2-51 Part 2-51: Tests Z/BFc: Combined dry heat/vibration (sinusoidal) tests for both heat-dissipating and non-heat dissipating specimens
- 60068-2-52 Part 2-52: Test Kb: Salt mist, cyclic (sodium, chloride solution)
- 60068-2-53 Part 2-53: Guidance to Tests Z/AFc and Z/BFc: Combined temperature (cold and dry heat) and vibration (sinusoidal) tests
- 60068-2-55 Part 2-55: Test Ee and guidance: Bounce
- 60068-2-57 Ed 2 Part 2.57: Test Ff: Vibration - Time-history method
- 60068-2-59 Part 2-59: Test Fe: Vibration – Sine-beat method
- 60068-2-60 Part 2-60: Test Ke: Flowing mixed gas corrosion test
- 60068-2-61 Part 2-61: Test methods - Test Z/ABDM: Climatic sequence
- 60068-2-64 Part 2-64: Test methods - Test Fh: Vibration, broad-band random (digital control) and guidance
- 60068-2-65 Part 2-65: Methods of test - Test Fg: Vibration, acoustically induced
- 60068-2-66 Part 2-66: Test methods - Test Cx: Damp heat, steady state (unsaturated pressurized vapour)
- 60068-2-67 Part 2-67: Test Cy: Damp heat, steady state, accelerated test primarily intended for components
- 60068-2-68 Part 2-68: Test L: Dust and sand
- 60068-2-74 Part 2-74: Test Xc: Fluid contamination
- 60068-2-75 Part 2-75: Test Eh: Hammer tests
- 60068-2-76 Part 2-78: Test Cab : Damp heat steady state
- 60068-2-80 Part 2-80: Test Fi: Vibration – Mixed mode
- 60068-2-81 Part 2.81: Test Ei: Shock – Shock response spectrum synthesis
- 60068-3 Supporting documentations and guidance - Background information
- 60068-3-1 Part 3-1: Cold and dry heat tests
- 60068-3-2 Part 3-2: Combined temperature/low air pressure tests
- 60068-3-3 Part 3-3: Guidance. Seismic test methods for equipment
- 60068-3-4 Part 3-4: Supporting documentation and guidance – Damp heat tests
- 60068-3-5 Part 3-5: Supporting documentation and guidance – confirmation of the performance of temperature chambers
- 60068-3-6 Part 3-6: Supporting documentation and guidance – confirmation of the performance of temperature/humidity chambers
- 60068-3-7 Part 3-7: Supporting documentation and guidance – Measurement in temperature chambers for tests A and B (with load)
- 60068-3-8 Part 3-8: Supporting documentation and guidance – Selecting amongst vibration tests
- 60068-4- Information for specification writers
- 60068-5 Guide to drafting of test methods

EN 60721 **Classification of Environmental Conditions** (International Standard for Civil Electro-technical equipment generated by IEC and issued by CEN and most National standard Agencies. Sections issued and sold separately, in English, French, German and other languages. Section are updated at different times and are at different issue).

- 60721-1 Part 1-1: Environmental parameters and their severities
- 60721-2 Part 2: Environmental conditions appearing in nature
- 60721-2-1 Part 2.1: -Temperature and humidity
- 60721-2-2 Part 2.2: -Precipitation and wind
- 60721-2-3 Part 2.3: -Air pressure
- 60721-2-4 Part 2.4: -Solar radiation and temperature
- 60721-2-5 Part 2.5: -Section 5: Dust, sand, salt mist
- 60721-2-6 Part 2.6: -Earthquake vibration and shock
- 60721-2-7 Part 2.7: -Fauna and flora
- 60721-2-8 Part 2.8: -Section 8: Fire exposure
- 60721-3 Part 3: Classification of groups of environmental parameters and their severities
- 60721-3-0 Part 3.0: Introduction
- 60721-3-1 Part 3.1: Storage
- 60721-3-2 Part 3.2: Transportation
- 60721-3-3 Part 3.3: Stationary use at weather Protected locations
- 60721-3-4 Part 3.4: Stationary use at non-weather Protected locations
- 60721-3-5 Part 3.5: Ground vehicle installations
- 60721-3-6 Part 3.6: Ship environment
- 60721-3-7 Part 3.7: Portable and non-stationary use
- 60721-3-9 Part 3.9: Microclimates inside products
- 60721-4- TR Guidance for the correlation and transformation of the environmental condition classes of IEC 60721 - 3 to the environmental tests of IEC 60068-2
- 60721-4-0 Part 4.0: Introduction
- 60721-4-1 Part 4.1: Storage

60721-4-2 Part 4.2: Transportation
60721-4-3 Part 4.3: Stationary use at weather Protected locations
60721-4-4 Part 4.4: Stationary use at non-weather Protected locations
60721-4-5 Part 4.5: Ground vehicle installations
60721-4-6 Part 4.6: Ship environment
60721-4-7 Part 4.7: Portable and non-stationary use

Def Stan 00-35 Environmental Handbook for Defence Materiel (UK National Defence Standard.
Each Part is issued by the UK DStan organisation, free of charge. The document is available only in English. Updated as an entire document, currently issue 4).

Part 1 Control and Management
Section 1 Introduction To This Standard
Section 2 Control And Management
Section 3 Procurement Options
Section 4 Related Test Types And Processes
Part 2 Environmental Trials Programme Derivation and Assessment Methodologies
Section 1 General
Section 2 Process For Developing A Sequential Test Programme
Section 3 Generic Usage Profiles And Their Applications
Section 4 Related Processes
Part 3 Environmental Test Methods
Section 1 General
Chapter 1-01 General
Chapter 1-02 Selection and Sequence of Tests
Chapter 1-03 General Environmental Test Conditions and Tolerances
Chapter 1-04 Test Apparatus/Jigs/Fixtures and Test Control
Chapter 1-05 Examination and Performance Evaluation
Chapter 1-06 Glossary of Terms
Section 2 Mechanical
Chapter 2-01 Test M1 - General Purpose Vibration Test
Chapter 2-02 Test M2 - Multi-Exciter Vibration and Shock Test
Chapter 2-03 Test M3 - Classical and Sine Waveform Shock
Chapter 2-04 Test M4 - Drop, Topple and Roll Test
Chapter 2-05 Test M5 - Impact (Vertical and Horizontal) Test
Chapter 2-06 Test M6 - Operational Shock Simulation Test
Chapter 2-07 Test M7 - Shock Testing for Warship Equipment and Armament Stores
Chapter 2-08 Test M8 - Acoustic Noise Test Using a Reverberation Chamber
Chapter 2-09 Test M9 - Acoustic Noise Test using a Progressive Wave Tube
Chapter 2-10 Test M10 - Combined Acoustic, Temperature and Vibration
Chapter 2-11 Test M11 - Wheeled Vehicle Transportation Bounce Test
Chapter 2-12 Test M12 - Bump Test
Chapter 2-13 Test M13 - Steady State Acceleration Test
Chapter 2-14 Test M14 - Test Track Trial
Chapter 2-15 Test M15 - Lifting Test
Chapter 2-16 Test M16 - Stacking Static Load Test
Chapter 2-17 Test M17 - Bending Test
Chapter 2-18 Test M18 - Racking Test
Chapter 2-19 Test M19 - General Time History Replication Test
Section 3 Climatic
Chapter 3-01 Test CL1 - Constant High Temperature - Low Humidity Test
Chapter 3-02 Test CL2 - High Temperature, Low Humidity and Solar Heating Test
Chapter 3-03 Test CL3 - Solar Radiation Test
Chapter 3-04 Test CL4 - Constant Low Temperature Test
Chapter 3-05 Test CL5 - Low Temperature Test
Chapter 3-06 Test CL6 - High Temperature, Humidity and Solar Heating Diurnal Cycle Test
Chapter 3-07 Test CL7 - Constant High Temperature - High Humidity Test
Chapter 3-08 Test CL8 - Kinetic (Aerodynamic) Heating DEF STAN 00-35 Part 3 Issue 4 iv
Chapter 3-09 Test CL9 - Rapid and Explosive Decompression
Chapter 3-10 Test CL10 - Icing
Chapter 3-11 Test CL11 - High Temperature - Low Pressure
Chapter 3-12 Test CL12 - Low Temperature - Low Pressure Test
Chapter 3-13 Test CL13 - Low Temperature - Low Pressure - High Humidity
Chapter 3-14 Test CL14 - Thermal Shock and Rapid Rate of Change of Temperature
Chapter 3-15 Test CL15 - Air Pressure (above Standard Atmospheric)
Chapter 3-16 Test CL16 - High Winds

CEN workshop 10
Standardisation for Defence Procurement
Expert Group 8 Environmental Engineering

Chapter 3-17 Test CL17 - Elevated Ground-Temperature/Humidity Diurnal Cycles
Chapter 3-18 Test CL18 - Driving Snow
Chapter 3-19 Test CL19 - Erosion and Structural Damage in Flight by Rain, Hail, Dust or Sand
Chapter 3-20 Test CL20 - Rapid Change of Pressure
Chapter 3-21 Test CL21 - Low Air Pressure and Air Transportation Tests
Chapter 3-22 Test CL22 - Snow Load
Chapter 3-23 Test CL23 - Impact Icing
Chapter 3-24 Test CL24 - Freeze - Thaw
Chapter 3-25 Test CL25 - Dust and Sand
Chapter 3-26 Test CL26 - Mist, Fog and Low Cloud
Chapter 3-27 Test CL27 - Driving Rain
Chapter 3-28 Test CL28 - Dripproofness
Chapter 3-29 Test CL29 - Immersion
Chapter 3-30 Test CL30 - Sealing (Pressure Differential)
Section 4 Chemical And Biological
Chapter 4-01 Test CN1 - Mould Growth
Chapter 4-02 Test CN2 - Salt (Corrosive) Atmospheres
Chapter 4-03 Test CN3 - Acid Corrosion
Chapter 4-04 Test CN4 - Contamination by Fluids
Chapter 4-05 Test CN5 - Corrosion Test for Materiel Immersed in Salt Water
Section 5 – Abnormal (Accidental & Hostile)
Chapter 5-01 Test FX1 - Bullet Attack Test for Munitions
Chapter 5-02 Test FX2 - Standard Liquid Fuel Fire
Chapter 5-03 Test FX3 - Safety Impact Test for Munitions
Chapter 5-04 Test FX4 - Slow Heating Tests for Munitions
Chapter 5-05 Test FX5 - Sympathetic Reaction, Munition Test
Part 4 Natural Environments
Section 1 – General
Section 2 – Temperature
Section 3 – Solar Radiation
Section 4 – Humidity
Section 5 – Wind
Section 6 – Rain
Section 7 – Hail, Snow And Ice
Section 8 – Deleterious Atmospheres
Section 9 – Dust And Sand
Section 10 – Atmospheric Pressure
Section 11 – Biological Hazard
Section 12 – Atmospheric Electricity
Part 5 Induced Mechanical Environments
Section 1 - General
Section 2 - Transportation
Section 3 - Handling And Storage
Section 4 - Man Mounted And Portable
Section 5 - Non-Mobile And Fixed Installations
Section 6 - Deployment On Land Vehicles
Section 7 - Deployment On Fixed Wing Aircraft
Section 8 - Deployment On Rotary Wing Aircraft
Section 9 - Deployment On Ships
Section 10 - Weapons
Section 11 - Measurement And Assessment
Part 6 Induced Climatic, Chemical and Biological Environments
Section 1 – General
Section 2 – Transportation
Section 3 – Handling And Storage
Section 4 – Man-Mounted And Man-Portable
Section 5 – Deployment Or Installation In Non-Mobile And Fixed Installations
Section 6 – Deployment Or Installation On Vehicles
Section 7 – Deployment Or Installation On Fixed-Wing Aircraft
Section 8 – Deployment Or Installation On Rotary Wing Aircraft
Section 9 – Deployment Or Installation On Ships
Section 10 – Munitions (Bombs, Missiles, Torpedoes, Etc)

STANAG 4370 Environmental Guidelines for Defence Materiel (NATO Sector Defence Standard. Issued by NATO Standards Agency free of charge in AECTP groups. Documents are available in English and French. Mostly the current issue is 3).

AECTP-100 Edition 4: Environmental Guidelines for Defence Materiel
AECTP-200 Edition 4: Environmental Conditions
AECTP-200 Edition 4: Introduction
AECTP-200 Edition 4: Related Sources Of Information
AECTP-230 Edition 1: Climatic Conditions
AECTP-240 Edition 1: Mechanical Conditions
AECTP-300 Edition 3: Climatic Environmental Tests
AECTP-301 Edition 3: General Requirements
AECTP-302 Edition 3: High Temperature
AECTP-303 Edition 3: Low Temperature
AECTP-304 Edition 3: Thermal Shock
AECTP-305 Edition 3: Solar Radiation
AECTP-306 Edition 3: Humid Heat
AECTP-307 Edition 3: Immersion
AECTP-308 Edition 3: Mould Growth
AECTP-309 Edition 3: Salt Fog
AECTP-310 Edition 3: Rain/Watertightness
AECTP-311 Edition 3: Icing
AECTP-312 Edition 3: Low Pressure
AECTP-313 Edition 3: Sand And Dust
AECTP-314 Edition 3: Contamination By Fluids
AECTP-315 Edition 3: Freeze/Thaw
AECTP-316 Edition 3: Explosive Atmosphere
AECTP-317 Edition 3: Temperature/Humidity/Altitude
AECTP-318 Edition 3: Vibration/Temperature/Humidity/Altitude
AECTP-319 Edition 3: Acidic Atmosphere
AECTP-400 Edition 3: Mechanical Environmental Tests
AECTP-401 Edition 3: Vibration
AECTP-402 Edition 3: Acoustic Noise
AECTP-403 Edition 3: Classical Waveform Shock
AECTP-404 Edition 3: Constant Acceleration
AECTP-405 Edition 3: Gunfire
AECTP-406 Edition 3: Loose Cargo
AECTP-407 Edition 3: Materiel Tiedown
AECTP-408 Edition 3: Large Assembly Transport
AECTP-409 Edition 3: Materiel Lifting
AECTP-410 Edition 3: Materiel Stacking
AECTP-411 Edition 3: Materiel Bending
AECTP-412 Edition 3: Materiel Racking
AECTP-413 Edition 3: Acoustic Noise Combined With Temperature And Vibration
AECTP-414 Edition 3: Handling
AECTP-415 Edition 3: Pyroshock
AECTP-416 Edition 3: Rail Impact
AECTP-417 Edition 3: SRS Shock
AECTP-418 Edition 3: Motion Platform
AECTP-419 Edition 3: Undex
AECTP-420 Edition 3: Buffet Vibration
AECTP-421 Edition 3: Multi-Exciter Vibration And Shock Testing
AECTP-422 Edition 3: Ballistic Shock
AECTP-600 Edition 2: The Ten Step Method For Evaluating The Ability Of Materiel To Meet Extended Life, Role
And Deployment Changes

MIL-STD-810 Environmental Engineering Considerations And Laboratory Tests (US
National Defence Standard. Issued by the US DoD as an entity. Available in English
only and the current issue is G).

Part One -- Environmental Engineering Program Guidelines
Part Two -- Laboratory Test Methods
500.5 Low Pressure (Altitude)
501.5 High Temperature
502.5 Low Temperature
503.5 Temperature Shock
504.1 Contamination by Fluids
505.5 Solar Radiation (Sunshine)
506.5 Rain
507.5 Humidity

CEN workshop 10
Standardisation for Defence Procurement
Expert Group 8 Environmental Engineering

- 508.6 Fungus
- 509.5 Salt Fog
- 510.5 Sand and Dust
- 511.5 Explosive Atmosphere
- 512.5 Immersion
- 513.6 Acceleration
- 514.6 Vibration
- 515.6 Acoustic Noise
- 516.6 Shock
- 517.1 Pyroshock
- 518.1 Acidic Atmosphere
- 519.6 Gunfire Shock
- 520.3 Temperature, Humidity, Vibration, and Altitude.
- 521.3 Icing/Freezing Rain
- 522.1 Ballistic Shock
- 523.3 Vibro-Acoustic/Temperature
- 524 Freeze / Thaw
- 525 Time Waveform Replication
- 526 Rail Impact
- 527 Multi-Exciter
- 528 Mechanical Vibrations of Shipboard Equipment (Type I – Environmental and Type II – Internally Excited
Part Three -- World Climatic Regions – Guidance

CIN-EG-01 **Guidelines for Management Of The Environment In A Military Program**
(French National Defence Standard Originally issued by F MoD, no longer supported
but partly represented by NFX50-144-1. Available in French and English)

PR-NORM DEF 01-01 **Guidance for tailoring material to its life cycle environment
profile. Mechanical environment**

GAM-EG-13 **Basic Environmental Test Procedures** (French National Defence Standard
Originally issued by F MoD but no longer supported. Available in French with the parts
listed below also available in English)

- Part 1 Compendium of Test Methods
- Method 01 Cold
- Method 02 Dry heat
- Method 03 Damp heat
- Method 04 Salt fog
- Method 05 Altitude and temperature
- Method 06 Temperature variations
- Method 07 Thermal shocks
- Method 08 Climatic cycles
- Method 09 Solar radiation
- Method 10 Transient thermal vacuum
- Method 11 Long term thermal vacuum
- Method 12 Rain
- Method 13 Mildew
- Method 14 Ice
- Method 15 Immersion
- Method 16 Contamination by fluids
- Method 18 Dust
- Method 19 Gas tightness with internal overpressure
- Method 20 Water Jet
- Method 21 Gas tightness with external overpressure
- Method 22 Icing, freezing, thawing
- Method 23 Explosive atmosphere
- Method 41 Sinusoidal vibrations
- Method 42 Random vibrations
- Method 43 Shocks
- Method 45 Constant acceleration
- Method 48 Acoustic vibrations
- Method 49 Acoustic disturbance

3.2 Equivalent Management Processes

To assist in the selection process, Expert Group 8 partitioned the available standards into those parts setting out process and those setting out test procedures. The equivalent environmental processes, from each of the five primary groups of standards addressed are set out below.

Matrix of Environmental Management Process					
	NATO STANAG's	International EN IEC	UK Def Stan	France GAM & CIN	US Mil Std's
The Environmental Engineering Process	STANAG 4370 AECTP 100	Not Addressed by Standard	Def-Stan 00-35 Part 1	CIN-EG 01	Mil-Std 810 Part 1
Environmental Conditions (either linked to the life cycle of the materiel or otherwise)	STANAG 4370 AECTP 200 (STANAGs 2895, 2914, 4242 are now merged in AECTP 200)	EN IEC 60721-2 (Natural only) EN IEC 60721-3	Def-Stan 00-35 Part 4, 5 & 6	GAM EG 13 Annex for environmental data <i>(ASTE – PR-01-02 not published as standard)</i>	Mil-Std 810 Part 1 & 2 Mil-Hdbk 310 (climatic)
Guidelines For Deriving Test Profiles (Tailoring)	STANAG 4370 AECTP 200	Not addressed by Standard	Def Stan 00-35 Part 4, 5 & 6	Mechanical; PR-NORM DEF 01-01 climatic: <i>(ASTE – PR-01-02 not published as standard)</i>	Mil Std 810 (some elements but within test procedures)
Default or 'Fall Back' Test Severities	STANAG 4370 AECTP 300 & AECTP 400	EN IEC 60721-4 rationalises severities in EN IEC 60721-3 and EN IEC 60068 Part 2	Def-Stan 00-35 Part 3	Guidance documents for specific applications (GAM EG 13 A, B, C, D and E)	Mil-Std 810 Part 2

3.3 Equivalent Test Methods

The equivalent environmental test procedures, from each of the five groups standards addressed by Expert Group 8, are set out below. These are grouped into 45 different test types. Some of the test types are in fact not test procedures but rather environments that have historically considered. In most cases this historic anomaly arose because of specific difficulties in simulating the actual conditions. The test procedure groups set out below were initially used to compare and recommend test procedures. However, the groupings were also separately used to review and recommend fall back test severities.

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068- 2-xx)	UK Def Stan 00- 35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Vibration	401	6 57 59 64 80	2-01 / M1	514 528	1st Part methods 41, 42
Vibration (Incl. combined with temperature and/or humidity)		53		520	
Gunfire	405		2-19 / M19	519	Included in general vibration procedures
Time History Replication		57		525	
Acoustic Tests (Incl. combined with temperature & vibration)	402 413	65	2-08 / M8 2-09 / M9 2-10 / M10	515 523	1st Part method 48
Aircraft Buffet Vibration	420		Encompassed in general vibration procedures		
Multi - Exciter Vibration & Shock	421		2-02 / M2	527	
Classical Waveform Shock	403	27	2-03 / M3	516	Method 43
Handling And Drop	414	31 32	2-04 / M4 2-05 / M5	516 Proc II,III,IV & VI	Method 43 Proc 3, 4 & 5
Safety Drop Test	STANAG 4375	UN Transportation requirements for Dangerous cargo ST/SG/AC.10	5-03 / FX3 BR8541		
Shock Response Spectra	417	57 81	2-06 / M6	516	Method 43
Pyroshock	415			517	Method 43 Proc 7
Rail Impact	416	(within 27)	(within 2-03 /M3)	516 Proc VII	Method 43 Proc 6
Undex Test	419		2-07 / M7		

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068- 2-xx)	UK Def Stan 00- 35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Ballistic Shock	422			522	
Catapult			(Severity only in Part 5)	516 Proc VIII	Method 43 Proc 8
Bump		29	2-12 / M12		Method 43 Proc 9
Constant Acceleration	404	7	2-13 / M13	513	1st Part method 45
Bounce / Loose Cargo	406	55	2-11 / M11	514 Procedure II	1st Part method 42 - procedure 5
Materiel Tiedown	407				
Motion Platform	418				
Large Assembly Transport	408		2-14 / M14	514 Procedure III	1st Part method 42 - procedure 4
Materiel Lifting	409		2-15 / M15		
Materiel Stacking	410	UN Transportation requirements for Dangerous cargo ST/SG/AC.10	2-16 / M16		
Materiel Bending	411		2-17 / M17		
Materiel Racking	412		2-18 / M18		
High Temperature	302	2 Test B Dry Heat 14 Change of Temperature	3-01 / CL1 3-02 / CL2 3-11 / CL11	501	Part 1 Method 02 Hot
Low Temperature	303	1 Test A Cold 14 Change of Temperature	3-04 / CL4 3-05 / CL5	502	Part 1 Method 01 Cold
Thermal Shock	304	14 Change of Temperature	3-14 / CL14	503	Part 1 Method 7 Thermal Shock
Solar Radiation	305	5 Test Sa 9 Guidance	3-03 / CL3	505	Part 1 Method 9 Solar Radiation

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068- 2-xx)	UK Def Stan 00- 35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Humidity	306	30 Damp Heat Cycle 38 Temperature Humidity Cycle	4-07 / CL7 4-06 / CL6	507	Part 1 Method 03 Humid Heat
Pressure	312	13	3-21 / CL21 3-20 / CL 20 3-09 / CL 09	500	
Temperature, Humidity Altitude	317	39 40 41	3-11 / CL 11 3-12 / CL 12 3-13 / CL13	520	05 10 11
Icing	311		3-10 / CL 10	521	14
Freeze Thaw	315		3-24 / CL 24		22
Immersion	307	17 18	3-29 / CL29 4-05 / CN5	512	1st Part method 15
Mould Growth	308	10	4-01 / CN1	508	1st Part method 13
Salt Fog	309	11 52	4-02 / CN2	509	1st Part method 04
Rain and Water Tightness	310	18	3-27 / CL27	506 Procedure I & II	1st Part methods 12, 20
Condensation and Dripproofness	310 Procedure III	18 Test R & Ra Method 2	3-28 / CL28	506 Procedure III	
Sand And Dust	313	68	3-25 / CL25	510	1st Part method 18
Contamination By Fluids	314	74	4-04 / CN4	504	1st Part method 16
Explosive Atmosphere	316			511	1st Part method 24
Acidic Atmosphere	319	60	4-03 / CN3	518	

4 The Reduction Process

The reduction process adopted by Expert Group 8 was based upon the criteria, set out in the two subsections below. This process was identified, as applicable, during the course of the assessments. The listed criteria have been identified to best discriminate between the various standards. Some overlap exists between the criteria and they are not necessarily mutually exclusive. Nevertheless the criteria generally express issues that arise when selecting and adopting standards for particular applications.

4.1 Criteria Used in Review of Test Procedures

The criteria set out below are the main discriminators between the various test procedures compared.

The weighting between the criteria will differ for different types of test procedure and materiel. Large sophisticated defence system operating in severe worldwide environmental condition will probably be biased towards the use of an up-to-date, technically innovative procedure which strongly aligns with the current defence procurement strategy. Conversely a small subsystem or component, supplied to a range of defence systems and possibly different industrial sectors, will be biased towards a standard which best allows interoperability and repeatability. Procedures for small components or subsystems may be set out in contractual requirements and need to be clear and explicit. Consideration of the criteria will also differ for the end user, the purchaser, the system integrator and subsystem supplier.

- i. **Technical Innovation.** Does the test procedure include technically innovative approaches? The implementation of technically innovative approaches generally results in a cost effective testing which is more able to replicate actual conditions. Many of the mechanical test procedures originated half a century ago when only limited test facilities were available. Today these may either poorly represent actual conditions or more cost effective approaches may now be possible. Technically innovative approaches may allow laboratory simulation of conditions and failure modes that could not previously be achieved. Such approaches also have significant benefit in ensuring equipment does not fail because of test un-representativeness rather than a real weakness.
- ii. **Up-to-Date Techniques.** Does the test procedure encompass the use of up-to-date & cost effective facilities, techniques and methodologies? The use of up-to-date facilities and techniques, such as encompassing the use of up-to-date computer control software, allows use of improved methods which would not otherwise be possible.
- iii. **Reproducibility.** Would the use of the specified test procedure generate repeatable results upon which the specifier of the test could rely? A primary goal of standards is to ensure tests which can be reliably repeated at different facilities over a long period of time. A good repeatable test procedure should allow the test to be taken at different test facility, or to be repeated over a long period of time, yet produce similar results.
- iv. **Strength of Reference.** Does the test procedure have sufficient strength and clarity to allow it to be used in contractual requirements? The test procedure needs to be presented in a firm, clear, well formatted manner with an unambiguous distinction between guidance information and the mandatory requirements of the test.
- v. **Interoperability.** Does the test procedure allow the use of COTS equipment without unnecessary re-testing for military use? Many components and subassemblies are no longer produced specifically for defence applications. In such cases the stated capabilities of the COTS items are likely to be against non-military standards. In practice most COTS equipment is tested using only a few essential procedures.
- vi. **Suitability for Purpose.** Does the procedure actually achieve the objectives it purports to accomplish? Some test procedure are used to replicates a wide range of in-

Service conditions, but in fact only have the ability to replicate a proportion of the potential failure modes.

vii. **Disadvantages to European Industry.** Does the test procedure disadvantage European industry and give advantage to offshore suppliers? Test procedures that are based upon procedures commonly used by offshore suppliers but not European industry can result in commercial disadvantage to Europe. For countries with a significant defence industrial base this can result in redesign and re-testing of MOTS and COTS equipment.

viii. **Alignment to European Defence Procurement Strategy.** Does the procedure fit into current procurement strategies? Procurement strategies differ from industry sector to industry sector and in the defence sector have changed in recent years. The equipment environmental assessment process forms part of that overarching strategy and the test procedures should be able to support that strategy.

ix. **Backward Compatibility.** Does the procedure prevent or limit the use of existing equipment? Defence equipment is frequently in-Service for periods in excess of ten years and possibly 20 to 30 years. During that period life extension and the purchase of spares, consumables and life limited items should be possible to original requirements. The consequences of the lack of backward compatibility could be removal from use or extensive re-testing.

x. **Equivalence of Standard.** Are the basic procedures, tolerances & approach identical, comparable or partly comparable with other standards? Broad consistency of procedure, tolerances & approach arising from technical similarity of procedures usually implies a broad range of product applicability and a wider availability of test house availability. Commercial viability requires that test facilities have the greatest range of potential application. Conversely a test specifier requires the availability of a number of test facilities.

4.2 Criteria Used in Review of Fallback Test Severities

The criteria set out below are the main discriminators between the various test severities compared.

i. **Suitability for Purpose / Applicability.** Does the severity represent the intended environmental conditions and/or does it adequately exercise the appropriate failure modes?

ii. **Strength of Reference.** Is the test severity clearly and fully defined? The test severity needs to be presented in a clear and unambiguous manner to ensure it can be applied without misinterpretation.

iii. **Reproducibility.** Would the use of the specified test severity ensure repeatable results? A primary goal of standards is to ensure tests which can be reliably repeated at different facilities over a long period of time. A good repeatable test severity should allow the test to be taken at different test facility, or to be repeated over a long period of time, yet produce similar results.

iv. **Up-to-Date Techniques.** Does the test severity encompass up-to-date environmental conditions? Test severities, in some standards, are based upon conditions that were common some time ago (50 years in at least one instance). In the interim the better designs or other improvements have produced conditions significantly better or worse than those encompassed by the test severity.

v. **Equivalence of Standard.** Are the severities comparable with other standards? Broad consistency of severity usually implies a broad range of product. Commercial viability require the largest market possible.

- vi. **Disadvantages to European Industry.** Does the test severity disadvantage European industry and give advantage to offshore suppliers? Test severities that are based upon those commonly used by offshore suppliers but not European industry can result in commercial disadvantage to Europe. For countries with a significant defence industrial base this can result in redesign and re-testing of MOTS and COTS equipment. Off-shore test severities may also be based upon conditions not experienced in Europe.
- vii. **Technical Innovation.** Is the test severity technically innovative? Technically innovative severities allow the use of facilities which are more able to replicate actual conditions or which are more cost effective. Many of the mechanical test severities originated half a century ago when only limited test facilities were available. Today these may either poorly represent actual conditions or more cost effective approaches may now be possible. Technically innovative severities may allow laboratory simulation of conditions and failure modes that could not previously be achieved. Such severities also have significant benefit in ensuring equipment does not fail because of test unrepresentativeness.
- viii. **Backward Compatibility.** Does the test severity prevent or limit the use of existing equipment? Defence equipment is frequently in-Service for periods in excess of ten years and possibly 20 to 30 years. During that period life extension and the purchase of spares, consumables and life limited items should be possible to original requirements. The consequences of the lack of backward compatibility could be removal from use or extensive re-testing.
- ix. **Alignment to European Defence Procurement Strategy.** Does the severity fit into current procurement strategies? Procurement strategies differ from industry sector to industry sector and in the defence sector have changed in recent years. The equipment environmental assessment process forms part of that overarching strategy and the test severity should comply with that strategy.
- x. **Interoperability.** Does the test severity allow the use of COTS equipment without unnecessary re-testing for military use? Many components and subassemblies are no longer produced specifically for defence applications. In such cases the stated capabilities of the COTS items are likely to be against non-military severities. In practice most COTS equipment is tested using only a few essential severities.

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5 Recommendations for Best Practice

The recommendations of Expert Group 8 fall into three groups; those associated with environmental management procedures, those associated with test procedures and those associated with environmental test severities. Recommendations for each, of these three areas, are addressed separately within this section. Set out in Annex A is the detailed rationale for the recommendations made by the Expert Group. That Annex addresses the comparisons with regard the environmental management procedures as well as for the review of test procedures. The rationale with regard the comparison of environmental test severities are summarised within the appropriate Table within this section.

5.1 Environmental Management Procedures

Since the early 1980's consideration of environmental susceptibility of defence equipment has been an integral part of the equipment design process. Since that time it has been usual for environmental factors to be related to those which the equipments are likely to experience during service use. These environmental factors are usually those to which the equipment are designed and proven. The manner in which environmental factors are defined in the procurement contract will depend upon the adopted procurement strategy. That strategy frequently varies for different groups of equipment and from country to country. The manner in which the environmental factors are specified influences the balance of risk and responsibility between the purchasing authority and the equipment supplier. Broadly, procurement against operational conditions, places almost all the risk and responsibility on the equipment supplier. Conversely, procurement against test severities, although much easier to specify in a contract, ultimately places a significant amount of risk and responsibility on the purchasing authority. Procurement against agreed environmental conditions may be considered as an intermediate situation.

The Expert Group considered Environmental Management in terms of four different aspects. The first was the process itself and how different standards require the equipment supplier to demonstrate the immunity of the equipment. The second aspect considered was the extent and scope of the environmental definitions (both climatic and mechanical) supplied in the various standards considered. These environmental definitions are frequently used as the starting requirements for contracts when procurement is against operational or environmental conditions. Although, new environmental definitions based upon actual measurements may still be required, considerable advantage can be achieved by use of pre-agreed conditions for aspects such as transportations, climatic conditions etc. The third aspect considered by the Expert Group was guidelines for the derivation of test severities from measured data. Such guidelines are required to ensure equipment suppliers define and demonstrate environmental immunity when the actual conditions were not known at the initiation of a procurement contract. In such cases the guidelines may need to be specified as a mandatory process in the procurement contract. The fourth and last issue considered by the Expert Group was the so called fallback test severities, which are used when purchasing against test requirements. In practice, particularly for munitions and equipment required to operate in severe environments, all the approaches set out above may be used in any specific procurement contract.

Annex A sets out the rationale for the recommendations made by the Expert Group with regard comparison of the environmental management procedures.

5.1.1 Environmental Management

When the Expert Group considered how different standards require the equipment suppliers to demonstrate the immunity of the equipment, it found considerable variation. The conclusions of the group were that no published standard could be recommended as having applicability to the European defence industry. Two processes currently exist, that set out in the UK Def Stan 00-35 and that set out in the French CIN-EG-1. Currently these two European national standards address the issues from different viewpoints. Although, not intrinsically using different methodologies, a user would find difficulty in merging the two. Whilst, the NATO STANAG

AECTP 100 provides no real coherent approach, it has a distinct bias towards a US approach. It was mostly for these reasons that Expert Group 8 found that no published standard had applicability to European wide defence procurement. Any recommendation concerning environmental management, would need to consider the generation of an approach which would have Europe wide acceptability as well as ensuring the equipment is safe and suitable for service. The generation of such an approach should, unlike the current NATO STANAG groups, involve the European defence industry, national procurement authorities and the European Defence Agency.

5.1.2 Definitions of Environmental Conditions

The extent and scope of the environmental definitions, contained within existing standards, separately addressed the climatic and mechanical aspects.

Mechanical Environments (acceleration, vibration, shock, drop etc). Consideration of the mechanical environments found that those set out in STANAG 4370 AECTP 200 were the most comprehensive. Nevertheless, these are not up to date and the range of European platform types encompassed is limited. Although the STANAG contains the most extensive compendium of mechanical platform environments, it is largely inadequate for European defence procurement purposes. The limited range of content could be a consequence of the lack of participation of defence industry from the generation of STANAG 4370. It is only with the inclusion of the European defence industry will the mechanical environmental conditions become sufficiently comprehensive for use within the European Defence Procurement Directive.

Climatic Environments (temperature, humidity, solar radiation & pressure). The Expert Group found that the main climatic definitions (temperature, humidity & solar radiation) were now common to three of the standards (STANAG 4370, Def Stan 00-35 and Mil Std 810). Moreover, the base data for these definitions originate from within Europe (the UK Def Stan 00-35). These data are traceable to highly detailed worldwide metrological data and have been linked to predictive models allowing planning for the effects of climate change to be embedded into European defence procurement. The definitions set out in Def Stan 00-35 and STANAG 4370 can all be used to specify the requirements for European defence procurement. Some advantage exists with the alignment with the US Mil Std 810, but this is a new requirement in that standard and it will time before it is widely used in the US.

Contaminates (rain, hail, snow, ice sand & dust etc). A considerable amount of commonality was found also to exist within the natural & man-made the contamination environments. The majority of the base data for these definitions exist within Europe. Individual recommendations for the contamination environments are tabulated hereinafter. The specification of the contamination requirements, for European defence procurement, may adopt specified environmental requirements although fallback test severities are frequently used.

5.1.3 Derivation Of Test Severities From Measured Data

When the Expert Group considered guidelines for the derivation of test severities from measured data, it found that currently published standards were generally poor, inconsistent and in some cases inaccurate. None of the published guidelines could be used, in a mandatory way, within a defence procurement contract. As a consequence no published standard could be recommended as having applicability to the European defence procurement. This deficiency has significant implications as control of the test derivation process is contractually essential if equipment suppliers have to establish tests from actual conditions only known after the procurement contract has been set out. Work is ongoing in this area, with revisions planned for three existing standards, NATO STANAG 4370, Def Stan 00-35, EN IEC 60721 and the two

French guideline documents (PR-NORM DEF 01-01 & ASTE-PR-01-02) which were recently made available.

5.1.4 Test Severities (When Purchasing Simple Equipment)

The last consideration, fall-back test severities, may be required when purchasing simple equipment. The Expert Group consider the fallback severities for each individual test type, and this is addressed later in this section. However, if only a single specification were to be recommended, then it was found that the majority of the individual recommendations originate from STANAG 4370 AECTPS 300 & 400. However, it should be noted that severities exist in all standards and some of those may be more applicable than those of STANAG 4370 for national applications. A warning also needs to be given the use of fallback severities can result in equipment which is unnecessarily costly and overweight.

Summary of Recommendations for Environmental Management & Severity Procedures					
	NATO STANAG	International EN / IEC	UK Def	US Mil Std's	France GAM & CIN
The Environmental Engineering Process	Currently, no published standard can be recommended as having applicability to the European Defence industry. The recommendation is a combination of the UK Def Stan and French GAM-EG approaches created with the involvement of the European Defence Industry				
	An untested derivative process created without input from industry	No equivalent Procedure	Recommended jointly with GAM EG 13	Part 1 process would put European Defence industry at a disadvantage	Recommended jointly with Def Stan 00-35
Environmental Conditions	Mechanical Environments				
	STANAG 4370 AECTP 200 recommended but is not up to date	EN IEC 600721 Part 3 Information is poor and out of date	Def Stan 00-35 Part 5 contains up to date platform specific information.	Mil Std 810 contains little information on environments.	
	Climatic Environments				
	STANAG 4370 AECTP 200 (and the earlier STANAG 2895) are based upon Def Stan 00-35 Part 4	EN IEC 60721 Pt 2 contains Natural Environmental information	Def Stan 00-35 Part 4 Recommended as it contains the base data used in STANAG 4370 AECTP 200	Mil Std 810 now reflects Def Stan 00-35 Part 4 data. Also contains climatic information from Mil Std 330	

Summary of Recommendations for Environmental Management & Severity Procedures					
	NATO STANAG	International EN / IEC	UK Def	US Mil Std's	France GAM & CIN
Guidelines For Deriving Test Profiles (Tailoring)	Currently, no published standard can be recommended as having applicability to the European Defence industry.				
	STANAG 4370 AECTP 200 falls well short on an acceptable standard	No procedures	Def Stan 00-35 Part 5 contains platform specific procedures	No procedures	PR-NORM DEF 01-01 & ASTE-PR-01-02 (not issued standard)
'Fall Back' Test Severities	Recommended Fall back test severities for individual environments are listed in separate Table				
	STANAG 4370 AECTP 300 & 400 is most commonly recommended	Fall back Severities exist in all standards some of these may be more applicable than those of STANAG 4370 for National applications			

5.2 Environmental Test Procedures

Expert Group 8 has considered a total of 45 different types of environmental test procedure, from within the five different standard groups, and had made a separate recommendation for each type of environmental test procedure. The rationale for each individual recommendation is set out in Annex A of this report. The table below summarises the recommendations for each of the 45 test types.

In this report test procedures are addressed separately from test severities. This is because test procedures are frequently used with user specified test severities. Most test procedures are written to allow the user specified severities to be adopted. In such cases alternative test severities may be specified by the equipment supplier, purchasing authority or another vertical standard. It is also possible to derive equipment and use specific severities from measured data. A few (mostly older) test procedures have severities embedded within them and this makes it difficult to adopt separate severities. In most cases recommending a test procedure does not necessarily imply recommendation of any attached severity. However, the test specifier needs to ensure no misunderstanding, in this regard can occur.

The vast majority of the 45 test types reviewed related to individual types of test procedure, usually related to the methodology or facilities used to under-take the test. These procedures usually have generic applicability allowing them be used to replicate a wide range of conditions. However, a few were found to relate to types of environment rather than actual test procedures. In most cases the inclusion of these, in standards, originates as a consequence of historical limitations of test equipment. In several cases these limitation no longer apply and the conditions may be simulated using one or more of the generic test procedures addressed under different headings.

It was not possible to make a recommendation in only 4 of the 45 test types reviewed. The separate reasons for not making a recommendation are set out below.

Gunfire. No recommendation has been made for the simulation of for gunfire because alternative and more generic test methods are available. This is an environment which can now be simulated using generic test methods. The consequential recommendation is to use time history replication (preferred) or shock response spectra methods.

Shock Response Spectra (SRS). None of the procedures reviewed can be recommended. Nevertheless, usable versions of the SRS shock test procedure exist in all standards. Significant differences exist between these existing procedures, mostly

concerning control and repeatability of a test method which inherently lacks repeatability. All existing test procedures require additional information or process to ensure adequate repeatability.

Matériel tie-down & Motion Platform. These procedure cannot be recommended in current form. Historically they have not been found necessary within Europe. A variety of much better commercial (CEN and ISO) standards exist but these are package type specific.

Summary of Recommendations (Procedures)					
	NATO STANAG 4370	International EN IEC 60068 & 60721	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
Vibration	Recommended Good for systems but lacks control over mandatory aspects	Firmly written and suitable for component testing	Good control over mandatory aspects, good for systems	Lacks control over mandatory aspects	Out of date but contains some information lacking in STANAG
Vibration (Incl. combined with temperature and/or humidity)					
Gunfire*	Could be recommended if brought up to date and made consistent with commercial control systems		No specific procedure rather recommends using THR methods	Recommend but only if no better alternative.	No specific procedure rather undertaken using existing methods
Recommendation is to use Time History Replication or Shock Response Spectra methods					
Time History Replication (THR)	Could be recommended if aligned to commercial control software	Procedure is usable but related to transients (earthquakes)	Recommend	Could be recommended if aligned to commercial control software	
Acoustic test Reverberant Chamber	Recommended	Test procedures very similar to STANAG			
Acoustic test Progressive Wave Tube	Recommended		Essentially same as STANAG		
Acoustic test Combined With Temperature & Vibration	Recommended		Essentially same as STANAG		
Buffet *			Recommended Uses conventional vibration test procedure		
<i>Recommendation is to use the basic random vibration test methods</i>					

CEN workshop 10
 Standardisation for Defence Procurement
 Expert Group 8 Environmental Engineering

Summary of Recommendations (Procedures)					
	NATO STANAG 4370	International EN IEC 60068 & 60721	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
Multi - Exciter Vibration	Acceptable procedure and could be recommended if brought up to date		Essentially the same as STANAG 4370	Recommended same as STANAG 4370 but with better guidance	
Classical waveform shock (using basic shock pulses)	Similar to European standards	Recommended Procedure for half sine, trapezoidal & trailing edge saw tooth pulses.	Recommended for decaying sinusoidal pulses otherwise Equivalent to EN IEC 6006	Significantly differs from other standards	Equivalent to EN IEC 60068
Drop	Concerns over differences with EN IEC 60068	Recommended	Equivalent to EN IEC 60068	Differs from other standards	Essentially equivalent to EN IEC 60068
Safety Drop Test for munitions or dangerous goods	STANAG 4375 Recommended	International Regulation set by UN for the "Transportation of Dangerous Goods" could also be required	Implements STANAG with additions		
Shock Response Spectra (SRS) shock	None of the procedures reviewed can be recommended. Versions of the SRS shock test procedure exist in all standards but with significant differences between procedures concerning control and repeatability of testing. STANAG would need to be improved before it could be recommended				
Pyrotechnic shock (shock originating from operation of small explosive devices)*	Recommended			Early version of STANAG	
	Recommendation is to use Shock Response Spectra methods				
Rail impact*	Recommended but question whether a European need exists	Various procedures and severities exist in all standards but with differences in severity, reflecting different wagons and rail systems. Conditions no longer exist in Europe and even in US "new" wagons significantly mitigate conditions.			
(UNDEX) test* Ship or Submarine shock de to nearby non-contact or underwater explosion	Recommended		Procedure similar to STANAG		Recommends use of SRS test procedure
	Recommendation is to use Time History Replication or Shock Response Spectra methods				
Ballistic shock*	Recommended but with reservation on disadvantage imposed on European industry	No specific test procedure		Same as STANAG procedure	
Catapult Launch / Arrested Landing*	No specific test but Time History Replication recommended		Recommended via Time History Replication	Comparable to Def Stan	

Summary of Recommendations (Procedures)					
	NATO STANAG 4370	International EN IEC 60068 & 60721	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
<i>Recommendation is to use Time History Replication or Shock Response Spectra methods</i>					
Bump (applicable to components only)		Recommended but question need for military use	Equivalent to EN IEC 60068		Equivalent to EN IEC 60068
Constant acceleration	Recommended but with reservations as to quality of procedure	Essentially equivalent to STANAG Test.			
Bounce / loose cargo	Recommended	Essentially equivalent to STANAG but note difference in motion between US and European based procedures.			
Materiel tie-down	Cannot be recommended in current form	Better commercial (CEN and ISO) standards exist			
Motion Platform	Cannot be recommended in current form	Better commercial (CEN and ISO) standards exist			
Large assembly transport (use of test tracks instead of laboratory tests)	Recommended but concern exists that this procedure reflects US facilities not necessarily available in Europe				
Materiel, lifting, stacking, bending and racking	Recommended		Equivalent to STANAG Test.		
High Temperature - Constant (for COTS equipment)		Recommended			Equivalent to STANAG Test
High Temperature – Diurnal or cyclic	Recommended		Cyclic test Equivalent to STANAG	Cyclic test Equivalent to STANAG	
Low Temperature - Constant (for COTS equipment)		Recommended	Equivalent to STANAG Test		Equivalent to STANAG Test
Low Temperature - Diurnal or cyclic	Recommended		Cyclic test Equivalent to STANAG	Cyclic test Equivalent to STANAG	
Solar Radiation (encompassing thermal and actinic degradation)	Recommended	Similar to STANAG	Similar to STANAG	Similar to STANAG & good guidance	Similar to STANAG

CEN workshop 10
Standardisation for Defence Procurement
Expert Group 8 Environmental Engineering

Summary of Recommendations (Procedures)					
	NATO STANAG 4370	International EN IEC 60068 & 60721	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
Thermal Shock	Incomplete	Useful for COTS equipment	Recommended		
Humidity – constant cyclic and aggravated	Recommended	Acceptable for COTS equipment	Equivalent to STANAG	Equivalent to STANAG	Equivalent to STANAG
Pressure (at altitude as well as normal, extreme and abnormal pressure change during air transport/ carriage)	Recommended	Suitable for COTS equipment	Essentially equivalent to STANAG but includes a greater range of application specific procedures	Essentially equivalent to STANAG	Essentially equivalent to STANAG
Combined Temperature, Humidity Altitude (usually associated air carriage)	Recommended as general procedure	Recommended for specific applications related to aircraft & space equipment			Essentially equivalent to STANAG
Icing (not including impact of ice on aircraft and missiles in flight)	Recommended as general procedure	Better commercial standards exist for specific aircraft icing conditions	Cyclic test Equivalent to STANAG	Cyclic test Equivalent to STANAG	
Freeze / Thaw	Recommended enhanced from Def Stan & GAM versions		Older version of STANAG		Older version of STANAG
Immersion (including accidental immersion and vehicle fording)	Recommended for Fording aspects	Jointly Recommended for Immersion aspects		Technically similar to STANAG for Immersion	Technically similar to STANAG
Mould growth	Recommended compatible with three national defence standards	The most recent procedure addressing availability of species and health and safety issues	Requirements encompassed within STANAG but they are not necessarily compatible with each other.		
Salt fog	Not compatible with commercial standards.	Commonly used for COTS equipment and contains aspects not in STANAG.	Recommended contains a better cycle and durations over STANAG	Similar to STANAG	
Rain and water tightness	Recommended. Encompasses national standards but needs to be made compatible with EN IEC 60529 (IP protection	EN IEC 60529 (IP protection codes) commonly used for equipment rather than EN IEC 60068			

Summary of Recommendations (Procedures)					
	NATO STANAG 4370	International EN IEC 60068 & 60721	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
	codes)				
Condensation and Dripproofness.	So weakly written that compatible with other standards cannot be guaranteed.	EN IEC 60529 (IP Protection codes) commonly used for equipment rather than EN IEC 60068	Recommended Needs to be made compatible with EN IEC 60529 (IP Protection codes)	Not entirely consistent with other standards	
Sand and dust	Recommended. Encompasses national standards but needs to be made compatible with EN IEC 60529 (IP protection codes)	EN IEC 60529 (IP Protection codes) commonly used for equipment rather than EN IEC 60068	Compatible with STANAG		
Contamination by fluids	Recommended	Technically similar to STANAG			
Explosive atmosphere (Safety regulations may require a specific (IP) rating rather than this test)	Recommended but needs to be made compatible with EN IEC 60529	EN IEC 60529 may be more applicable to many items		Technically Similar to STANAG	
Acidic atmosphere	Recommended		Technically Similar to STANAG		Technically Similar to STANAG

* Categories marked refer to types of environment rather than an actual test procedure. In most cases the inclusion of these originates for historical considerations when testing for these environments required specific procedures. In most cases this limitation no longer applies and the conditions can be simulated using one or more of the generic test procedures addressed under different headings. In such cases the applicable procedure is indicated.

5.3 Environmental Test (Fallback) Severities

Expert Group 8 considered the fallback test severities for each of the 45 different test types, from the five different standard groups, and had made a separate recommendation for each. These recommendations are set out in the table below. That table also contains a summary of the rationale for each individual recommendation. However, some aspects are also addressed in Annex A of this report.

Fallback test severities should be used with considerable care. They frequently represent quite severe conditions which may unrealistically influence the cost and design of equipment. Conversely, some fallback severities may be inadequate for some in-service conditions. For some test types the use of fallback test severities is quite common, generally, these are in the climatic and contamination test groups. However, the use of fallback severities are usually avoided for some test types, generally but not exclusively, these are in the mechanical test groups.

As already observed test procedures have been addressed separately from test severities. This is because test procedures are frequently used with different severities. Alternative test

severities may be specified by the equipment supplier, purchasing authority or another vertical standard. Also test severities may need to be derived from measured data. In the table below some recommendations align with those for the test procedure. However, this is not necessarily the case and both sets of recommendations should be considered.

In the table below the test severities of CEN IEC 60068 are listed. However, severities are also listed in CEN IEC 60721 Part 4, which reconciles the environmental severities of CEN IEC 60721 Part 3 with the individual severities listed in CEN IEC 60068. Whenever, viable the reconciliation severities should also considered.

In a few cases no recommendation has been made as to appropriate fallback test severity. In most such instances this is because a fallback severity is not appropriate for that specific test type. This is usually because, for that test type, a severity is almost always based upon measured data or test severity data which is highly application specific. Usually, this arises when the test type is quite specialised and used when accurate representations of actual in-service severity conditions need to be adopted. The test types for which no severity recommendation are made, for these reasons, include; gunfire, time history replication, multi-exciter vibration, pyro-shock, undex (or underwater shock) and ballistic shock. No generic recommendation for test severity has been made for large assembly transport (which uses vehicle test tracks rather than undertakes laboratory tests) because the severities relate to US tracks and surfaces of European test tracks are different. Recommendation for test severity have also not been made for thermal shock or immersion as, in both cases, the most severe severities are highly application specific. This is also partly the case for contamination by fluids, were users need to consider the specific fluid contamination an equipment may experience No fallback severity recommendations have been made for tracked vehicle equipment, because, no existing test severity has generic applicability to all European tracked vehicles.

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
Vibration (see separate Table)	401	6 57 59 64 80	2-01 / M1	514 528	1st Part methods 41, 42	<i>See Separate Table for platform specific recommendations</i>
Vibration (Incl. combined with temperature and/or humidity)		53		520		
Gunfire	405		2-19 / M19	519	Included in general vibration procedures	<i>No fallback severities with general applicability can be recommended. STANAG 4370 AECTP 405 gives guidance on the derivation of severities but is related to US guns / ammunition</i>
Time History Replication		57		525		
Acoustic Tests (Incl. combined with temperature & vibration)	<i>Recommend 402 but only for low performance aircraft 413</i>	65	2-08 / M8 2-09 / M9 2-10 / M10	515 523	1st Part method 48	<i>STANAG 4370 AECTP 401 reflects the fallback severities of Def Stan 0-35, Mil-Std-810, GAM EG 13 and CEN 60068. However, these severities are only applicable for low performance aircraft.</i>
Aircraft Buffet Vibration	<i>Recommend but not generally applicable. 420</i>		<i>Encompassed in general vibration procedures</i>			<i>STANAG 4370 AECTP 420 contains similar severities to UK Def Stan 00-35 and Mil Std 810. However, severities should not be assumed to encompass all conditions likely to be experienced.</i>

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
Multi - Exciter Vibration	421		2-02 / M2	527		<i>No fall back severities are quoted.</i>
Classical Waveform Shock	403	<i>Recommend for COTS equipment 27</i>	<i>Recommend for MOTS & Defence equipment (2-03 / M3)</i>	516	Method 43	<i>STANAG 4370 AECTP 403 severities reflect Mil Std 810 and in part the Def Stan 00-35 severities. The STANAG / Mil Std severities are simplistic, incomplete and prone to misuse. EN IEC 600068 & DEF Stan 00-35 contain better severities.</i>
Handling And Drop	414	31 32	<i>Recommend 2-04 / M4 2-05 / M5</i>	516 Proc II,III,IV & VI	Method 43 Proc 3, 4 & 5	<i>STANAG 4370 AECTP 414 severities are not as comprehensive as Def Stan 00-35. Document EMB1 is used in France but not reflected in STANAG.</i>
Safety Drop Test	<i>Recommend STANAG 4375</i>	UN Transportation requirements for Dangerous cargo. ST/SG/AC.10/R ev.12	5-03 / FX3 BR8541			<i>Although STANAG 4375 is used widely as a safety test, it only reflects a minimum drop height and a number of European countries require greater than this. The UN International regulation may additionally be required.</i>
Shock Response Spectra	417	57 81	2-06 / M6	516	Method 43	<i>No severities quoted except as alternative to classic waveform test. Consequently see classic waveform test for recommendation.</i>
Pyroshock	415			517	Method 43 Proc 7	<i>No severities quoted.</i>

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
Rail Impact	<i>Recommend but with reservation on applicability in Europe</i> 416	(within 27)	(within 2-03 /M3)	516 Proc VII	Method 43 Proc 6	STANAG 4370 AECTP 415 contains severities for both US & Europe (the difference reflecting spring and hydraulic buffers). Nevertheless, <i>the so called European values are rarely applicable as shunting is rarely performed on loaded wagons.</i>
Undex Test	419		2-07 / M7			<i>No severities quoted.</i>
Ballistic Shock	422			522		STANAG 4370 AECTP 422 quotes guidance on severities but are highly application specific. <i>No European fallback severities can be recommended.</i>
Catapult Launch / Arrested Landing			2-19 / M19 (Severity in Part 5)	<i>Recommend</i> 516 Proc VIII	Method 43 Proc 8	Mil Std 810 procedure 516 Proc VIII is relatively old but still seems to be used. GAM EG 13 Method 43 Proc 8 may be alternative European variant but is also old.
Bump		<i>Recommend</i> 29	2-12 / M12		Method 43 Proc 9	Severities of EN IEC 60068 used by other standards
Constant Acceleration	<i>Recommend but with reservation</i> 404	7	2-13 / M13	513	1st Part method 45	STANAG 4370 AECTP 404 severities are high and may exceed design load cases for some of the platforms listed.
Bounce / Loose Cargo	406	<i>Recommend for COTS equipment</i> 55	<i>Recommend for MOTS & Defence equipment</i> 2-11 / M11	514 Procedure II	1st Part method 42 - procedure 5	Amplitude severity set by design of test facility only duration can be altered. STANAG 4370 AECTP 406 does not quote any durations. EN IEC 60068 & Def Stan 00-35 do quote durations

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
Materiel Tiedown	<i>Recommend</i> 407					<i>No European severities in use.</i>
Motion Platform	<i>Recommend</i> 418					<i>No European severities in use.</i>
Large Assembly Transport	408		2-14 / M14	514 Procedure III	1st Part method 42 - procedure 4	STANAG 4370 AECTP 408 reflects Mil Std 810 and relates entirely to US test tracks. These cannot be related to European test track surfaces. <i>No European fallback severities can be recommended..</i>
Materiel Lifting	<i>Recommend</i> 409		2-15 / M15			STANAG 4370 AECTP 409 reflects Def Stan 00-35 which complies with UK code of practices.
Materiel Stacking	<i>Recommend</i> 410	UN Transportation requirements for Dangerous cargo. ST/SG/AC.10/R ev.12	2-16 / M16			STANAG 4370 AECTP 410 reflects Def Stan 00-35. However, UN international regulation may take precedence for dangerous goods.
Materiel Bending	<i>Recommend</i> 411		2-17 / M17			STANAG 4370 AECTP 411 reflects Def Stan 00-35.
Materiel Racking	<i>Recommend</i> 412		2-18 / M18			STANAG 4370 AECTP 412 reflects Def Stan 00-35.
High Temperature Cyclic test	302	2 14	<i>Recommend</i> Part 4 Chapter 1-01 & 1-02	501	Part 1 Method 02 hot	As original source Def Stan 00-35 is recommended but STANAG 4370, STANAG 2895 and Mil Std 810 are now all equivalent.

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
Low Temperature Cyclic test	303	1 14	<i>Recommend</i> Part 4 Chapter 1-01 & 1-02	502	Part 1 Method 01 Cold	As original source Def Stan 00-35 is recommended but STANAG 4370, STANAG 2895 and Mil Std 810 are now all equivalent.
Thermal Shock	304	14	3-14 / CL14	503	Part 1 Method 7 Thermal Shock	The test is application specific, consequently adopting fallback severities is inappropriate. <i>No severities are recommended.</i>
Solar Radiation	305	5 Test Sa 9 Guidance	<i>Recommend</i> Part 4 Chapter 1-01 & 1-02	505	Part 1 Method 9 Solar Radiation	As original source Def Stan 00-35 is recommended but STANAG 4370, STANAG 2895 and Mil Std 810 are now all equivalent.
Humidity Cyclic test	306	30 38	<i>Recommend</i> Part 4 Chapter 1-01 & 1-02	507	Part 1 Method 03 Humid Heat	As original source Def Stan 00-35 is recommended but STANAG 4370, STANAG 2895 and Mil Std 810 are now all equivalent.
Pressure	<i>Recommend</i> 312	13	3-21 / CL21 3-20 / CL 20 3-09 / CL 09	500		STANAG 4370 AECTP 312 reflects key low pressure severities of all other standards. However, Def Stan 00-35 has a number of other high and low pressure conditions.
Temperature, Humidity Altitude	317	39 40 41	<i>Recommend</i> Part 4 Chapter 1-01 & 1-02	520	05 10 11	As original source Def Stan 00-35 is recommended but STANAG 4370, STANAG 2895 and Mil Std 810 are now all equivalent.
Icing	<i>Recommend</i> 311		3-10 / CL 10	521	14	STANAG 4370 AECTP 311 quotes a limited range of severities which are

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
						<i>broadly consistent with other standards..</i>
Freeze Thaw	<i>Recommend</i> 315		3-24 / CL 24		22	<i>The severities are embedded into the process. As such the recommendation of process (STANAG 4370 AECTP 315) gives severities also.</i>
Immersion	307	17 18	3-29 / CL29 4-05 / CN5	512	1st Part method 15	<i>The test severity is equipment specific, consequently the use of fallback severities is inappropriate. STANAG 4370 AECTP 308 does not quote severities, but other standards give better advice.</i>
Mould Growth	<i>Recommend</i> 308	10	4-01 / CN1	508	1st Part method 13	<i>The severities are an inherent part of the process. As such the recommendation of process (STANAG 4370 AECTP 308) gives severities also.</i>
Salt Fog	309	11 52	<i>Recommend</i> 4-02 / CN2	509	1st Part method 04	<i>The severities of STANAG 4370 AECTP 310 are weakly written and purpose is not clear. The severities in the Def Stan are more clearly specified and are applicable to corrosion.</i>
Rain and Water Tightness	310	18	<i>Recommend</i> 3-27 / CL27 3-28 / CL28	506	1st Part methods 12, 20	<i>The severities of STANAG 4370 AECTP 310 are weakly written and a specific condition cannot be guaranteed. The severities in the Def Stan are more clearly specified.</i>
Condensation and Dripproofness	310 Procedure III	18 Test R & Ra Method 2	<i>Recommend</i> 3-28 / CL28	506 Procedure III		<i>The severities of STANAG 4370 AECTP 310 are weakly written and a specific condition cannot be guaranteed. The severities in the Def Stan are more clearly</i>

Matrix of Environmental Test Severities						
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)	Additional Comments
						<i>specified.</i>
Sand And dust	<i>Recommend</i> 313	68	3-25 / CL25	510	1st Part method 18	<i>The fallback severity of STANAG 4370 AECTP 313 work and have consistency with other standards. However, the STANAG is not compatible with EN IEC 60529 (applicable to IP codes) mostly relating to severity.</i>
Contamination By Fluids	314	74	4-04 / CN4	504	1st Part method 16	<i>The fluids to be considered require an analysis of equipment usage. The list given in STANAG 4370 AECTP 314 is not exhaustive or applicable to all European countries, nor does it encompass NBC decontaminates or NBC materials As such no recommendation of severity is justified.</i>
Explosive Atmosphere	<i>Recommend</i> 316			511	1st Part method 24	<i>The severities are a part of the process. As such the recommendation of process (STANAG 4370 AECTP 316) gives severities also.</i>
Acidic Atmosphere	<i>Recommend</i> 319	60	4-03 / CN3	518		<i>The severities are a part of the process. As such the recommendation of process (STANAG 4370 AECTP 319) gives severities also.</i>

Vibration Standards Containing Severities Considered Most Appropriate for Each Application		
	Recommendation	Comments
Transportation in Wheeled Truck	STANAG 4370 AECTP 401 but use vertical axis severity only.	STANAG 4370 AECTP 401 is the same as Def Stan 00-35 in vertical axis but not Mil Std 810. In other axes AECTP 410 same as Mil Std but spectra differ from Def Stan 00-35. Test durations for distance travelled differ significantly. IEC 60068/60721 differs from others but difference not that great in vertical axis.
Transportation in Jet Aircraft	STANAG 4370 AECTP 401 but cruise conditions only.	STANAG 4370 AECTP 401 clarifies conditions in Mil Std 810 but overestimates conditions for take-off / landing by significant margin.
Transportation in Propeller Aircraft	STANAG 4370 AECTP 401.	STANAG 4370 AECTP 401 does not encompass all variants of propeller aircraft. Over-severe for modern aircraft but nevertheless as representative as any other standard.
Transportation in Helicopter	STANAG 4370 AECTP 401.	STANAG 4370 AECTP 401 does not encompass all variants of rotary wing aircraft. Nevertheless as representative as any other standard.
Transportation by Surface Ship	Mil Std 810	Levels generally very low and sometimes difficult to achieve. Modern standards require a random test but STANAG 4370 AECTP 401 uses sine test of Def Stan 00-35. Mil Std 810 uses a random test.
Transportation by Railroad	STANAG 4370 AECTP 401.	Levels generally very low. STANAG 4370 AECTP 401 as representative as any other standard.
Deployment in Tactical Wheeled Vehicle	Def Stan 00-35	STANAG 4370 AECTP 401 are same as Mil Std 810 and are US vehicle specific. Test difficult to achieve, represents old vehicle designs and not representative of modern suspension systems.
Deployment in Trailer Vehicle	Def Stan 00-35	STANAG 4370 AECTP 401 are same as Mil Std 810 and US vehicle specific. Test difficult to achieve, represents old vehicle designs and not representative of modern suspension systems. US Mil Std and STANAG based upon 2 wheel trailers, mostly 4 wheeled trailers are used in Europe.

Vibration Standards Containing Severities Considered Most Appropriate for Each Application		
	Recommendation	Comments
Deployment in Tracked Vehicle	No severity can be recommended.	STANAG 4370 AECTP 401 and all other standards adopt out of date severity which can give rise to failures during test which do not occur in service.
Deployment in Propeller Aircraft	STANAG 4370 AECTP 401.	STANAG 4370 AECTP 401 does not encompass all variants of propeller aircraft. Over severe for modern aircraft but nevertheless as representative as any other standard.
Deployment in Helicopter	STANAG 4370 AECTP 401.	STANAG 4370 AECTP 401 does not encompass all variants of rotary wing aircraft. Nevertheless as representative as any other standard.
Stores on Jet Aircraft	STANAG 4370 AECTP 401 but only applicable to low performance aircraft	STANAG 4370 AECTP 401 reflects original Mil Std spectra which represents basic spectra for detached flow. Only valid for low performance aircraft. Other mechanisms predominate for high performance aircraft.
Stores on Propeller Aircraft	STANAG 4370 AECTP 401.	STANAG 4370 AECTP 401 does not encompass all variants of propeller aircraft. Over severe for modern aircraft but nevertheless as representative as any other standard.
Stores on Helicopters	STANAG 4370 AECTP 401.	STANAG 4370 AECTP 401 does not encompass all variants of rotary wing aircraft. Nevertheless as representative as any other standard.
Tactical Missiles	STANAG 4370 AECTP 401 but only applicable to low performance aircraft	STANAG 4370 AECTP 401 reflects original Mil Std spectra which represents basic spectra for detached flow. Only valid for low performance aircraft. Other mechanisms predominate for high performance aircraft.

6 Recommendations For Standardisation Process

The manner in which environmental factors are defined in a procurement requirement will depend upon the adopted equipment procurement process. Currently, the manner in which environmental factors are defined in the procurement requirement frequently varies from country to country and for different types of defence equipment. Nevertheless, the manner in which the environmental factors are specified influences the balance of risk and responsibility between the purchasing authority and the equipment supplier.

Broadly, procurement against operational conditions, places almost all the risk and responsibility on the equipment supplier. Procurement against operational conditions may well necessitate the supplier establishing the actual environmental conditions equipment will experience. That in turn will require an agreed strategy for deriving verification test severities. Alternatively the use of existing environmental conditions may be adopted in the procurement requirement, still allowing some flexibility by the equipment supplier. Conversely, procurement requirements setting fallback test severities, although much easier to specify in a requirement, ultimately places a significant amount of risk and responsibility on the purchasing authority. The approach may also result in overdesigned and overweight equipment.

The Expert Group considered the different aspects of Environmental verification:

The first consideration was the Environmental Management process itself and how different standards require the equipment supplier to demonstrate the capability of the equipment. The overall approach is, today, usually integrated into the equipment design verification process. However, the detailed approach used does have significant implications and also varies considerably, frequently from country to country, and for different equipment types. The need for such variations is essential as high value equipment experiencing severe environmental conditions need to be treated differently to low value more robust equipment. Equipment, such as munitions, will degrade due to imposed environmental conditions and establishing a safe working life is a major issue in planning verification strategies.

The second consideration of the group was the extent and scope of the environmental definitions (both climatic and mechanical) supplied in the various standards considered. These environmental definitions are frequently used as the starting requirements for contracts when procurement is against operational or environmental conditions. Although, new environmental definitions based upon actual measurements may still be required, considerable advantage can be achieved by use of pre-agreed conditions for aspects such as transportations, climatic conditions etc. The use of environmental definitions for world-wide climatic conditions is extremely common.

The third consideration of the group was the process for the derivation of test severities from measured data. Such processes are required to ensure equipment suppliers define and demonstrate environmental capability when the actual conditions were not known at the initiation of a procurement contract. In such cases the guidelines may need to be specified as a mandatory process in the procurement contract.

The fourth consideration of the group was the environmental test procedures themselves. Some 45 different test types were address which represent the most commonly used procedures for defence equipment. However, even though the range of test types considered was extensive they do not encompass the Environmental Management process every eventuality. Test procedures have being addressed separately from test severities, as test procedures are frequently used with different severities. Most test procedures are written to allow the user specified severities to be adopted.

The fifth and last consideration by the Expert Group was the so called fallback test severities, which are used when purchasing against test requirements. This approach is usually used for simple equipment not subject to severe conditions.

6.1 Environmental Management Process

When the Expert Group considered how different standards require the equipment supplier to demonstrate the capability of the equipment, it found considerable variation. The conclusions of the group were that no published standard could be recommended as having applicability to the European defence industry. Two processes currently exist, that set out in the UK Def Stan 00-35 and that set out in the French CIN-EG-1. Currently these two European national standards address the issues from different viewpoints. Although, not intrinsically using different methodologies, a user would find difficulty in merging the two. Whilst, the NATO STANAG AECTP 100 provides no real coherent approach, it has a distinct bias towards a US approach. It was mostly for these reasons that Expert Group 8 found that no published standard had applicability to European defence procurement. Any recommendation concerning environmental management, would need to consider the generation of an approach which would have Europe wide acceptability as well as ensuring the equipment is safe and suitable for service. The generation of such an approach should, unlike the NATO STANAG groups, involve the European defence industry, national procurement authorities and the European Defence Agency. The CEN workshop concept could be a good initial platform for the initial stages of this work, although ultimately a formal standard would be required.

6.2 Environmental Definitions

6.2.1 Climatic Environments.

The Expert Group found that the main climatic definitions, temperature, humidity & solar radiation, were now common to three of the standards (STANAG 4370, Def Stan 00-35 and Mil Std 810). Moreover, the base data for these definitions originate from within Europe (the UK Def Stan 00-35). These data are traceable to highly detailed worldwide metrological data and have been linked to predictive models allowing planning for the effects of climate change to be embedded into European defence procurement. The definitions set out in Def Stan 00-35 and STANAG 4370 can all be used to specify the requirements for European defence procurement. A considerable amount of commonality was found also to exist within the other climatic environments as well as the contamination environment. The majority of the base data for these definitions also exist within Europe.

6.2.2 Mechanical Environments.

Consideration of the mechanical environments found that those set out in STANAG 4370 AECTP 200 were the most comprehensive. Nevertheless, these are not up to date and the range of European platform types encompassed is limited. Although the STANAG contains the most extensive compendium of mechanical platform environments, it is largely inadequate for European defence procurement purposes. The limited range of content could be a consequence of the lack of participation of defence industry from the generation of STANAG 4370. It is only with the inclusion of the European defence industry will the mechanical environmental conditions become sufficiently comprehensive for use within the European Defence Procurement Directive. Establishing a European specific database of environmental descriptions is an ideal application for the CEN Workshop concept were it could benefit from full involvement of the European defence industry. This database would form a compendium from which contractual requirements could be specified.

6.3 Derivation of Test Severities From Measured Data

When the Expert Group considered guidelines for the derivation of test severities from measured data, it found that currently published standards were generally poor, inconsistent and in some cases inaccurate. None of the published guidelines could be used, in a mandatory way, within a defence procurement contract. As a consequence no published standard could be recommended as having applicability to the European defence procurement. This deficiency has significant implications as control of the test derivation process may need to be contractually specified, if equipment suppliers have to establish tests from actual conditions only known after

the procurement requirements have been set. Work is ongoing in this area, with revisions planned for three existing standards, NATO STANAG 4370, Def Stan 00-35 and EN IEC 60721 and the two French guideline documents, PR-NORM DEF 01-01 & ASTE-PR-01-02, which were recently made available. As a consequence some potential exists for ensuring the co-ordinated views of the European defence industry are taken into account.

6.4 Environmental Test Procedures

A significant proportion of the effort of the expert group was spent on technically reviewing several hundred available test procedures within 45 different test types. The effort was expended because these procedures, at some point, in an equipment verification process, form a mandatory and contractual requirement. The comparison undertaken by the expert group encompassed both military, at international and national level, and civilian standards. In most cases the comparison indicated that the EN IEC standards, as set out in 60068, have limited applicability to sophisticated defence system. However, they are frequently applicable for COTS equipments and subsystems and generally are the most firmly written and repeatable procedures. Although the expert group has made individual recommendations with regard the 45 different test groups, NATO STANAG 4370 produces the greatest number of recommendations with regard test procedures. Caveats were made to a number of test procedures recommended and It was not possible to make a recommendation in only 4 of the 45 test types reviewed. The separate reasons for this various, but in virtually every case these aspects are correctable by the appropriate standards agency.

6.5 Fallback Test Severities

The last consideration, fall-back test severities, may be required when purchasing simple equipment. The expert group consider the fallback severities for each of the 45 different test types, from the five different standard groups, and had made a separate recommendation for each. However, if only a single specification were to be recommended, then it was found that the majority if the individual recommendations originate from STANAG 4370 AECTPs 300 & 400. However, it should be noted that severities exist in all standards and some of those may be more applicable than those of STANAG 4370 for national applications. Actual environmental severities may be platform specific and no guarantee exists that fallback severities will not be exceeded. Conversely they may result in over designed equipment which may have significant implications on equipment, such as munitions, which have a relatively high degradation rate.

Fallback test severities should be used with considerable care. They frequently represent quite severe conditions which may unrealistically influence the cost and design of equipment. Conversely, some fallback severities may be inadequate for some in-service conditions. For some test types the use of fallback test severities is quite common, generally, these are in the climatic and contamination test groups. However, the use of fallback severities are usually avoided for some test types, generally but not exclusively, these are in the mechanical test groups.

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7 Conclusions

Expert Group 8 considered a total of 45 different types of environmental test, and approximately 250 individual test procedures. The Expert Group made a separate recommendation for each of the 45 different types of environmental test type addressed. These recommendations are made separately for both the necessary procedure to undertake the test type and the severities that could be used. These 45 different types of environmental test encompass the majority that may be employed to verify defence systems and individual equipment. The rationale for each individual recommendation is set out in this report.

The manner in which different types of environmental test are employed will depend upon how the environmental rationale mandated by the equipment procurement process. Currently no single environmental rationale, or environmental management process, is employed by all European countries. Indeed the environmental management process varies significantly from country to country and for different types of defence equipment. Nevertheless, the manner in which the environmental management process is employed influences the balance of risk and responsibility between the purchasing authority and the equipment supplier.

Broadly, procurement against operational conditions, places almost all the risk and responsibility on the equipment supplier. Procurement against operational conditions may well necessitate the supplier establishing the actual environmental conditions equipment will experience. That in turn will require an agreed strategy for deriving verification test severities. Alternatively the use of existing environmental conditions may be adopted in the procurement requirement, still allowing some flexibility by the equipment supplier. Conversely, procurement requirements setting fallback test severities, although much easier to specify in a requirement, ultimately places a significant amount of risk and responsibility on the purchasing authority. The approach may also result in overdesigned and overweight equipment.

For these reasons the Expert Group considered Environmental Management process and how different standards require the equipment supplier to demonstrate the immunity of the equipment.

The Expert Group also considered the extent and scope of the environmental definitions (both climatic and mechanical) supplied in the various standards considered. These environmental definitions are frequently used as the starting requirements for contracts when procurement is against operational or environmental conditions. Although, new environmental definitions based upon actual measurements may still be required, considerable advantage can be achieved by use of pre-agreed conditions for aspects such as transportations, climatic conditions etc.

The Expert Group additionally considered guidelines for the derivation of test severities from measured data. Such guidelines are required to ensure equipment suppliers define and demonstrate environmental immunity when the actual conditions were not known at the initiation of a procurement contract. In such cases the guidelines may need to be specified as a mandatory process in the procurement contract.

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ANNEX A
Detailed Comparative Review Between
Standards

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A.1 Review and Comparison of Environmental Management Standards

A.1.1 Standards Under Consideration

The standards reviewed and compared with regard Environmental Management are set out in the following table.

Matrix of Environmental Management Process					
	NATO STANAG's	International EN IEC	UK Def Stan	France GAM & CIN	US Mil Std's
The Environmental Engineering Process	STANAG 4370 AECTP 100	Not Addressed	Def-Stan 00-35 Part 1	CIN-EG 01	Mil-Std 810 Part 1
Environmental Conditions (either linked to the life cycle of the materiel or otherwise)	STANAG 4370 AECTP 200 (STANAGs 2895, 2914, 4242 are now merged in AECTP 200)	EN IEC 60721-2 (Natural only) EN IEC 60721-3	Def-Stan 00-35 Part 4, 5 & 6	GAM EG 13 Annex for environmental data ASTE-PR-01-02 <i>(not published as standard)</i>	Mil-Std 810 Part 1 & 2 Mil-Hdbk 310 (climatic)
Guidelines For Deriving Test Profiles (Tailoring)	STANAG 4370 AECTP 200	Not addressed	Def Stan 00-35 Part 4, 5 & 6	Mechanical; PR-NORM DEF 01-01 climatic: ASTE-PR-01-02 <i>(not published as standard)</i>	Mil Std 810 (some elements)
Default or 'Fall Back' Test Severities	STANAG 4370 AECTP 300 & AECTP 400	EN IEC 60721-4	Def-Stan 00-35 Part 3	Guidance documents for specific applications (GAM EG 13 A, B, C, D and E)	Mil-Std 810 Part 2

A.1.2 Technical Comparison

A.1.2.1 The Environmental Engineering Process.

Until relatively recently few standards included information on how to conduct the environmental engineering process, within an overall design and procurement programme for defence systems. The inclusion of such information originates from the growing trend of passing responsibility and risk to the system supplier of ensuring the equipment works in-service.

Although the Environmental Engineering process is designated as Part 1 of UK Def Stan 00-35, it was included several years after many of the test procedures and environmental severities had been published. The current environmental engineering process in Def Stan 00-35 was written in the early 1990's and is intended to align with the defence material design process used in the UK. The process sets out to demonstrate the equivalence in terms of documents and processes between the environmental engineering requirement and the design process. Def Stan 00-35 Part 1 sets out an overall idealised process which can be used under almost any procurement approach. It then indicates how this can be tailored into four different procurement strategies. These four strategies encompass the core approaches used for the vast majority of defence equipment procurement. Advice on the risks and responsibilities associated with each of these four strategies is set out. Although the standard explains the process by means of documentation, it concedes the titles of these documents may change from procurement to procurement and also environmental documentation may be incorporated into general design process documentation. Although Part 1 of Def Stan 00-35 sets out the management process it does not supply technical advice on how to implement strategies and programmes. That aspect

is intended to be incorporated into Def Stan 00-35 Part 2, but that part of the document is currently only partly complete.

The French military standard CIN EG01 sets out guidelines for accounting for the environment in military programmes. This document was issued in 1999 but based on earlier work which set out the technical aspects of how to implement strategies and programmes. The content includes; a description of the environmental engineering tasks at each phase of a development programme. It also addresses the validation process, the variability of the product resistance to the environment as well as considering uncertainty and the test factors. The document does not contain a great deal of information on overall management strategy. On the technical aspects CIN EG01 is far more extensive than the UK Def Stan 00-35. In this regard the CIN EG01 and the Def Stan appear to be aimed at different people. Intrinsicly the two processes are not actually that different, they are both based upon ensuring the defence system is able to operate in the service environment and go through the same stages of establishing a requirement, formulating a strategy, defining the tasks and work programme, undertake the task and demonstrate compliance. The French military standard CIN EG01 implements a single process but does not explain how this can be used for different procurement strategies. However, the CIN EG 1 has some unique content not seen in other standards reviewed.

The US Mil Std 810 sets out an environmental management process that developed over two decades from earlier version of the standard. The process is comprehensive but does not align with either the UK or French approaches. Moreover, it does not seem to be the unique process adopted within the US for defence equipment procurement. This seems to be because the Mil Std process is very much related to how US Department of Defence agencies undertake pre-service environmental testing and assurance rather than the suppliers. The Mil Std environmental management process is very much built around documentation which does not appear to be particularly flexible. Indeed experience would suggest it is often not adopted by US defence equipment suppliers.

The environmental management process of NATO STANAG 4370 AECTP 100 is intended as hybrid of US and European approaches. However, it effectively sets up yet another process which complies with none in national European use. It also does not appear to be particularly flexible and has not stood the test of any real usage.

Neither the process of US Mil Std 810 or NATO STANAG 4370 AECTP 100 appear to align with the procurement strategies that are adopted by many European countries. No do those processes appear to align with that proposed within the European Defence Procurement Directive. The adoption of the US standards for European procurement would put the European defence industry at a disadvantage. An identical argument could be made for the NATO standard which has also not stood the test of extensive usage. Neither the UK Def Stan 00-35 Part 1 nor the French CIN EG 1 have these shortfalls, together, they are better than the NATO STANAG 4370 AECTP 100 process. Amalgamation of the French and UK environmental management processes into a form which would properly support the European Defence Procurement Directive is viable as they cover similar ground but are aimed at different groups of users.

A.1.2.2 Environmental Conditions

Since the early 1980's it has become the norm to use environmental test severities based upon in-service conditions. When this approach was first initiated it necessitated the initiation of many expensive data collection exercises. However, since then it has become common to include environmental conditions in environmental testing standards.

Environmental severities differ from test severities in several ways. Environmental severities are a measure of the actual conditions an item could experience without the addition of factors. Environmental severities should represent all the conditions equipment may experience. This should be regardless of historically identified failure modes. The environmental conditions should be primarily capable of been used in the design process.

Environmental conditions can be broadly divided into two groups, those which describe the natural environment and those which describe the conditions self induced by defence equipment. Descriptions of the world-wide natural environment should have a degree of commonality to all countries and equipment. Conversely, the induced environments are likely to be unique to a particular platform and consequently country and equipment specific. The split between natural environments and the self induced conditions is historical and frequently related to climatic and mechanical conditions. However, this split cannot always be clearly established and defined. This notwithstanding, the definition of environmental conditions for the natural environment are can be relatively easily achieved as they are not extensively platform dependant as is the case the mechanical conditions.

Natural climatic conditions are described in a number of standards. These are generally reference documents indicating the extent and likelihood of world-wide natural climatic conditions. The most commonly referenced values relate to the temperature, humidity, solar radiation, precipitation (rain and snow) and wind conditions occurring world-wide. These are all available from national and international metrological measurement databases some of which comprise a significant historical base. Of lesser quality, but from similar sources is information on sand & dust, salt atmosphere, ice, hail etc.

The UK Def Stan 00-35 Part 4 presents an extensive description of natural conditions based upon UK Meteorological Office records. Part 4 of Def Stan 00-35 is extensively based upon information the earlier Def Stan 07-55 and its use has a significant historical base in the UK. Generally, each section in Part 4 addresses a separate natural environment. Currently, each section comprises two chapters the first presenting data from the Meteorological Office records and the second offering advice on how this can be used in defence equipment design. The temperature and humidity distribution maps included in Part 4 have recently been updated by professional meteorological staff. Unlike some standards they are based upon the forecasting database which includes significantly more measurements at a far great number of locations than is used in databases of historical records (such as used in EN IEC 60721 Part 2 and Mil Std 310).

The UK Def Stan 00-35 Part 4 presents climatic categories appropriate for the design and assessment of defence equipment against temperature, humidity and solar radiation conditions. The climatic categories described in Chapter 1-02 are equivalent to those set out in STANAG 4370 AECTP 200 Leaflet 2311 and Mil Std 810. Each climatic category has "meteorological" and "storage & transport" values.

The "meteorological" values, are extracted from information gathered for meteorological purposes. Specifically the temperatures are shade air temperatures measured under strict conditions such as in a Stevenson's Screen. Solar radiation and humidity are measured separately but each under strictly controlled conditions. Meteorological conditions apply to materials that are exposed directly to the natural climatic environment. Current climatic zone definitions specify daily temperature variations for a range of worldwide climatic zones. As the meteorological climatic categories relate to shade air temperatures the appropriate thermal effects of solar radiation need to be summed with the shade air temperature to broadly represent the actual temperatures that may be experience by materiel.

The meteorological values for shade air temperatures and solar radiation are based upon a substantial and verified database of measurements acquired over long term periods in the respective climatic zone. The shade air temperatures and solar radiation values were measured separately and relate to conditions which can independently be exceeded for 1% of the most severe month of the year. Although information are supplied to allow conditions for other probabilities to be derived.

The "storage & transport" values are from data sets collected from with selected storage and transport facilities. The storage and transport temperatures represent the conditions inside poor quality storage facilities and transport vehicles as a result of combined effects of air temperature

and solar radiation impinging on the outside of the storage facility or transport vehicle. The database of measurements used to set the Storage and Transport temperatures is small and acquired through targeted experiment rather than statistical analysis.

The highest storage and transport temperatures should not be assumed to relate to the sum of the highest meteorological shade air temperature and highest level of solar radiation occurring within a vehicle or storage facility. The storage and transport temperature measurements have been acquired entirely independently of the meteorological temperature conditions. Historically the storage and transport conditions have been taken to represent air temperatures inside poor storage and transport structures, typified by the stationary wooden rail car, subject to full solar radiation. Again the storage and transport temperatures can be considered as those that will be exceeded for 1% of the worst month of the year. Although information are supplied to allow conditions for other probabilities to be derived.

Although the storage and transport temperatures are generally considered to represent the highest temperatures a materiel may experience, this is not necessarily the case. For equipment subject to extended periods of direct solar radiation the potential exists to reach much higher temperatures than experienced due to even very poor quality storage and transport.

STANAG 4370 AECTP 200 presents the same meteorological data as in UK Def Stan 00-35 Part 4. STANAG 4370 AECTP 200 replaces NATO STANAG 2895 which presents an earlier version of the UK Def Stan 00-35 meteorological data. NATO STANAG 2895 has proven difficult to obtain in the past but now appears to be available from the NATO website. Although containing the same information as the UK Def Stan 00-35 Part 4 the NATO STANAG 4370 is generally acknowledged as much easier to use and understand (hence the revision of the Def Stan 00-35).

The French GAM EG 13 "Environmental Data and Models" also contains natural climatic information which is grouped in a similar manner. The data appears to be based upon French meteorological data, as a consequence, some differences are apparent but they are generally not that great. As was the case in the previous two cases, the extreme temperature and temperature/ humidity conditions are presented in map form. Unlike a lot of GAM EG 13, the climatic conditions are only available in the French language and this has limited NATO adoption.

The US Mil Std 310 (previously 210) contains US natural climatic information. Again this is laid out in a similar manner to the other standards. In this case the data presented are mostly extreme conditions and do not appear to be based upon the same level of detailed information as the NATO STANAG, the UK Def Stan or French GAM EG 13 documents. This appears to be because the maps are based upon historical databases which originate at far fewer locations than forecasting databases. This is reflected in the much coarser maps contained in Mil Std 310. The latest US Mil Std 810 now supersedes the content of Mil Std 310. The US Mil Std 810 now contains the same information as the UK Def Stan 00-35 Part 4 and the NATO STANAG 4370. However, it retains backward compatibility with US Mil Std 310. The latest US Mil Std 810 does contain some useful guidance information but is not particularly helpful in assisting the user select the appropriate severities from the metrological data.

The international civil standard EN IEC 60721 Part 2 presents information on the natural environment. However, the information is notably less extensive than that presented in the defence standards. Whilst, the extreme temperature and temperature/ humidity conditions are presented in map form, the criteria used to create these are unclear. The maps are very different to those of any other reviewed and appear to be based upon considerably coarser information (probably from a historical database). The information in EN IEC 60721 Part 2 was last reviewed over 15 years ago although currently a programme of revision is underway. That revision only has access to public domain databases and operates without a budget or professional meteorological expertise. As consequence, it seems highly unlikely that the current revision will produce a result anything like as good as the defence standards.

Of the information on the natural climatic environment, that contained in NATO STANAG 4370 AECTP 200 appears to be the most widely adopted both in NATO and Europe. It is based upon high resolution UK Meteorological information for world-wide conditions. The UK has updated Def Stan 00-35 document and hence the STANAG using funded meteorological expertise. It seems unlikely that any other defence or civil standard will approach the quality of the Def Stan 00-35 / STANAG 4370 for some time to come.

Information on induced environmental conditions is contained within a number of national and international standards. A large majority of this information on induced environmental conditions relates to mechanical conditions which in turn relates to the particular platforms and methods of operation in use in individual countries. As a consequence commonality of induced environmental conditions is unlikely to be achieved by standards except at a generic level. Even when it is the case that the same platform and method of operation is used in several countries, the resultant description and derived test severity may vary. This is because different countries may adopt different methods and factors in the derivation of environmental descriptions and test severities. Induced environmental severities can be greatly influenced by the method used to transform measurements into appropriate environmental and test severities. As a consequence direct comparison of induced severities is not viable. Moreover, recommendation on induced environmental conditions would have little general benefit to the user. Nevertheless the following paragraphs are offered for general information.

Currently, EN IEC 60721 Part 2 contains no information on induced environmental conditions. EN IEC 60721 Part 3 contains quantitative information on environmental conditions for a variety of conditions, no descriptive information is supplied. Moreover, the categories for which the quantitative information is supplied are broad, only vaguely defined and frequently considered out of date. The quantitative information itself is very coarsely specified and set out in the form of test severities rather than environmental descriptions. Overall EN IEC 60721 Part 3 contains the sort of information that was common in the 1960's and 70's but which has not been used for anything but minor defence procurement since the 1980's. Most vertical civil standards which use EN IEC 60068 test procedures specify their own severities rather than adopt those of EN IEC 60721 Part 3.

The US national standard Mil Std 810 Part 2 contains more information on induced environmental conditions than did the earlier versions. However, most of the information is by way of illustration rather than a deliberate intent to specify environmental conditions. Mostly, Mil Std 810 Part 2 contains fall back test severities which may be based upon actual in-service data. Not only is the method of transformation not generally specified, but different approaches are used for different environments. Some of the in-service environments are unique to US platforms and a few worst of the cases represent platforms no longer in-service use.

The French national standard GAM EG 13 contains an annex for induced environmental data. This annex contains sample information for a good range of platforms in common use by the French military for a range of in-service conditions. Similarly the UK Def Stan 00-35 Parts 5 and 6 contains information on induced environmental for mechanical and climatic conditions respectively. Again the standard contains a range of sample information for a good range of platforms in common use by the UK military for a range of in-service conditions. The UK Def Stan 00-35 also contains a compendium of information describes the mechanisms causing the induced environments and the sensitivity of the severities to different usage conditions. As the French GAM EG 13 is no longer been updated, the environmental information is becoming progressively out dated. This is not the case for the UK Def Stan 00-35 which is been regularly updated to contain more relevant an applicable environmental information.

The NATO STANAG 4370 AECTP 200 contains information on induced environments. The base for the induced environments seems to be mostly older versions of Part 5 of UK Def Stan 00-35. However, contributions from the French GAM EG 13 and the US Mil Std can be identified. Overall AECTP 200 is strongly biased towards European information. Moreover, the AECTP 200 document appears to contain both the most recent and extensive information on environmental

conditions. Any such information database is unlikely to be comprehensive and in this case has a notable absence of data from a number of major European countries who manufacture defence equipment.

A.1.2.3 Guidelines for Deriving Test Profiles (Tailoring).

The strategy of deriving test severities from in-service has led to the need to supply guidance information on methods for the deriving test severities from measured In-service data. This information is mostly by way of guidelines as no single set of procedures has been found to be applicable in all circumstances and to all countries. As no consensus exists as to appropriate methods it is unlikely that any real recommendation is possible. The following indicates the information available.

The French CIN EG 1 gives information on how to tailor different the type of environment, but without presenting any details regarding specific type of environment. Two more recent guidelines present respectively guidelines for mechanical environmental tailoring process and guidelines for climatic environmental tailoring process. These guidelines present a methodology for developing the life profile and present detailed examples:

Guidelines for Mechanical Environmental Tailoring Process. (PR-NORM DEF 01-01)
This guidance document presents information on the characterization of the mechanical environmental factors from measured data.

Guidelines for Climatic Environmental Tailoring Process. (ASTE-PR-01-02) This climatic guidance document presents information on the characterization of the climatic environment.

The UK Def Stan 00-35 presents extensive information on the conditions and mechanisms causing many induced environments. Understanding the conditions causing the environments is considered an essential precursor to the use of any test derivation process. The current issue of Def Stan 00-35 includes some guidelines on the derivation of test severities but are these are not comprehensive, modern nor particularly innovative. However, the next issue of Def Stan 00-35 will contain significant additional content specifically related to the generation of test severities from measured data for a variety of platform types. This includes one method based upon a STANAG 4370 AECTP 2410 approach, an extension of that method to other platforms and one method based upon the GAM EG 13 approach.

Mil Std 810 contains relatively few guidelines on the derivation of test severities and mostly these relate to specific test types. It does make reference to a fair number of reports. The guidelines that are contained in the Mil Std 810 are mostly derived from those reports although the information is not always well or consistently extracted.

NATO STANAG 4370 AECTP 200 contains limited guidelines on the derivation of mechanical vibration test severities. This is essentially a summary of several processes; some used to create severities for the US Mil Std, but not published in that standard. It also addresses a method originally contained in the French GAM EG 13. For a partial overview of potential mechanical methods the NATO STANAG is quite useful, but is incomplete and not the best available. Some of the approaches are quite old using assumptions long ago considered of questionable validity. None of the methods are presented in a particularly user friendly way and contain few checks and balances to ensure bounds of validity are not inadvertently exceeded. Two strong complaints have been raised against the guidelines on the derivation of mechanical vibration test severities in the latest issue of AECTP 2410. The first is that the primary method presented is not generically applicable to all platform types, and has doubtful applicability to several of the platform types generating the most significant vibration conditions. The second European complaint, against AECTP 2410, is that it presents a US interpretation of method, used in some European countries. Unfortunately this interpretation is both limited and incorrectly. This is somewhat surprising when the AECTP 2410 could have been based upon the original in the French GAM EG 13.

Currently, no published standard can be recommended as having applicability to the European Defence industry. It is acknowledged that work is still ongoing in this area, nevertheless, it is clear that no single approach has general acceptability and that the US written STANAG presents European originated methods in a poor and inaccurate manner, to the benefit of a US originated approach which has only limited capability and based upon a methodology which has significant limits of validity. Even within the limited methods formally presented within existing standards almost none could be used in a mandatory fashion which could be essential in a European Defence Procurement when no platform specific information are available.

A.1.2.4 'Fall Back' Test Severities.

Historically all environmental test procedures contained related test severities. However, over the past few decades these have been replaced by a strategy of deriving tests based upon intended in-service use. As a consequence the severities remaining attached to the test severities are intended only for use when no information is available or when the item may be used in many platforms (typically COTS and MOTS items). Mostly use of these fallback severities is intended to be limited to small items, subsystems or components. Many of the remaining test severities are relatively rudimentary and are frequently intended for use on the most basic test equipment.

The test procedures of UK Def Stan 00-35 Part 3 mostly have fallback test severities appended. Some procedures also contain guidance on these severities. The severities are mostly historical and have a long track record. With that said they have all been reviewed for applicability at reasonable intervals. The severities indicate backward compatibility has been considered. Whilst, the fallback severities have a degree of commonality with other specifications, overall they are not precisely equivalent with other standards.

The French GAM EG 13 Part 2 also addresses the fall back levels. These fallback levels were established under the responsibility of each service, except ground equipment which are multi services. They are split in to five documents, for army, air force, navy, missiles and for ground equipments.

The above fall back levels have not been updated from the original issue and are now superseded by NATO STANAG 4370 AECTP200 except for air force (not including aero transport) where DO160 is recommended. When NATO STANAG 4370 AECTP200 does not encompass user need, GAM EG 13 A, C and D are still applicable. For aero transport, GAM EG 13 B remains applicable when AECTP200 is not covering.

Most of the test procedures within the French GAM EG 13 also have fallback test severities appended. Again the severities are mostly historical and have a long track record. The severities indicate backward compatibility but are no longer updated. Whilst, the fallback severities have a degree of commonality with other specifications, overall they are not precisely equivalent with any other standard.

The test procedures of the US Mil Std 810 again contain have test severities. Although a few of these have a long track record, others have changed markedly as the various revisions of Mil Std 810. Backward compatibility does not seem to have been a consideration in those that have changed. Whilst, the fallback severities have a degree of commonality with other specifications, overall they are not precisely equivalent with other standards.

A significant proportion of the test procedures of NATO STANAG 4370, specifically the AECTP 300 and 400 series, relates to fallback severities. Indeed the amount of information frequently swamps that the procedure itself. This does result in a marked loss of firmness of statement. Generally, the fallback severities are based upon the UK Def Stand 00-35, the French GAM EG 13 and the US Mil Std 810. In some cases a single fallback severity recommendation results. However, in a lot of others a compromise approach of presenting several options is adopted. Although it is intended that the NATO STANAG 4370 fallback severities will be broadly implemented, at the moment, it is difficult to identify which severities are used in different

countries. It has been argued that in combining the various national requirements, a test schedule more extensive can result than is required by a national defence procurement authority. In this regard the STANAG 4370 fallback severities may be resulting in more expensive programmes than is necessary. If the NATO STANAG 4370 fallback severities are adopted for European defence procurement some of the gold plating may need to be rubbed off.

As already indicated EN IEC 60721 Part 3 contains quantitative information on environmental conditions for a variety of conditions. However, a review around 8 years ago indicated a significant number of discrepancies between this document and the test severities set out in the various test procedures of EN IEC 60068. To resolve these inconsistencies, EN IEC 60721 Part 4 was generated to recommend a resolution for each Part 3 category. EN IEC 60721 Part 4 is set out as a series of test schedules for some notional electro-mechanical equipment. As was the case for Part 3 the environmental categories for which test severities are supplied, the categories used are very broad and frequently considered out of line with current commercial (and military) practice. The actual test severities are; very rudimentary, out of date and appear to make undefined sweeping assumptions about life cycle (in-service) usage. EN IEC 60721 Part 4 is based very much on the test definitions of the type common in the 1960's and 70's, an approach which is no longer used for defence procurement for two decades. Vertical civil standards which use EN IEC 60068 test procedures mostly specify their own severities rather than adopt those of EN IEC 60721 Part 3 or 4.

Overall the fallback test severities embedded in the NATO STANAG 4370 test procedures of AECTP 300 & 400 contain the most comprehensive array of fallback severities. In the near future these are likely to be embedded into the remaining European national procedures. As a consequence the STANAG fallback severities are likely to become a European standard without any recommendations from this Expert Group. Nevertheless a consequence of combining the various national requirements is test schedules more extensive and costly than really necessary. If NATO STANAG 4370 fallback severities are adopted for European defence procurement then a strategy for limiting the test schedules may result in cost savings. It is also the case that the use of fallback test severities for all European Defence Procurements may result in expensive and overweight equipment especially for challenging environments such as air carried weapons and tracked vehicle equipment.

A.1.3 Conclusions of Review of Environmental Management Standards

A summary of the recommendations is shown in the table below which is expanded in the following paragraphs.

Summary of Recommendations for Environmental Management & Severity Procedures					
	NATO STANAG	International EN / IEC	UK Def	US Mil Std's	France GAM & CIN
The Environmental Engineering Process	Currently, no published standard can be recommended as having applicability to the European Defence industry. The recommendation is a combination of the UK Def Stan and French GAM-EG approaches created with the involvement of the European Defence Industry				
	An untested derivative process created without input from industry	No equivalent Procedure	Recommended jointly with GAM EG 13	Process set out in Part 1 but would put European Defence industry at a disadvantage	Recommended jointly with Def Stan 00-35
Environmental Conditions	Mechanical Environments				
	STANAG 4370 AECTP 200 recommended but is not extensive or up	EN IEC 600721 Part 3 Information is poor and out of date	Def Stan 00-35 Part 5 contains platform specific information which is kept	Mil Std 810 contains little information on environments.	

Summary of Recommendations for Environmental Management & Severity Procedures					
	NATO STANAG	International EN / IEC	UK Def	US Mil Std's	France GAM & CIN
	to date		reasonably up to date		
	Climatic Environments				
	STANAG 4370 AECTP 200 (and the earlier STANAG 2895) are based upon Def Stan 00-35 Part 4	EN IEC 60721 Pt 2 contains Natural Environmental information	Def Stan 00-35 Part 4 Recommended as it contains the base data used in STANAG 4370 AECTP 200	Mil Std 810 now reflects Def Stan 00-35 Part 4 data. Also contains climatic information from Mil Std 330	
Guidelines For Deriving Test Profiles (Tailoring)	Currently, no published standard can be recommended as having applicability to the European Defence industry.				
	STANAG 4370 AECTP 200 falls well short on an acceptable standard	No procedures	Def Stan 00-35 Part 5 contains platform specific procedures	No procedures	PR-NORM DEF 01-01 & ASTE-PR-01-02 (not in English)
'Fall Back' Test Severities	Recommended Fall back test severities for individual environments are listed in separate Table				
	STANAG 4370 AECTP 300 & 400 is Recommended	Fall back Severities exist in all standards some of these may be more applicable than those of STANAG 4370 for National applications			

A.1.3.1 The Environmental Engineering Process.

The Environmental Engineering process essentially sets out the approach that should be used to establish the environmental conditions equipment may experience in-service. The Environmental Engineering process also sets out the required demonstrations and validations that are required to verify that the equipment, is able to survive and operate in the a required environments. The Environmental Engineering process is an important methodology that needs to be established by any European Defence Procurement.

Neither the US Mil Std 810 or the NATO STANAG 4370 AECTP 100 processes align with the procurement process that are adopted by many European countries. Nor does it necessarily align with that of the European Defence Procurement Directive. The adoption of the US standard for European procurement would put the European defence industry at a disadvantage. A similar argument can be made for the NATO standard which is a derivative approach, has had little input from the European defence industry and has not withstood the test of real usage. Although both the UK and French standards have some shortfalls, together, they are far better than the STANAG 4370 AECTP 100 process. Amalgamation of the French and UK environmental management processes is entirely viable as they cover similar ground but are aimed at different people. Amalgamation of the two processes would also allow integration with the European Defence procurement process and with the involvement of the European defence industry should not put it at a disadvantage.

A.1.3.2 Environmental Conditions.

A European procurement has several options for setting environmental requirements, it can use an existing database of environmental conditions, require the supplier to measure the actual conditions or specify fallback test severities. In practice all three options are likely to be required. The availability of existing databases of environmental conditions is addressed below.

Information on the natural climatic environment is presented in national defence standards from the UK, France and the US as well as the civil standard EN IEC 60721 Part 2. Information contained in NATO STANAG 4370 AECTP 200 (and the earlier STANAG 2895) are based upon that in UK Def Stan 00-35. The earlier STANAG has existed for some time and appears to be widely adopted both in NATO and Europe. It is based upon high resolution UK Meteorological information for world-wide conditions. The UK has updated Def Stan 00-35 using funded meteorological expertise and the NATO STANAG has utilised this update. The information in the defence standards is the source data and standard. It is markedly different from that in EN IEC 60721 Part 2 which is based upon a much courser climatic database with no identifiable documented underlying criteria. The latest issue of the US Mil Std 810 now reflects the conditions in NATO STANAG 4370 AECTP 200 and consequently is based upon the data within the UK Def Stan 00-35 Part 4.

It seems unlikely that any other defence or civil standard will approach the quality of Def Stan 00-35 climatic environmental information for some time to come. As a consequence UK Def Stan 00-35 Part 4 is recommended as the base source for information on the natural environment. NATO STANAG 4370, STANAG 2895 and Mil Std 810 are acceptable alternatives as they contain the same data as the UK Def Stan 00-35 Part 4. To allow ongoing use the UK Meteorological office has taken the existing climatic conditions and zones and undertaken change predictions for the next 50 years. These, currently unpublished, predictions should allow European defence equipment to be designed for future climate change.

Currently the NATO STANAG 4370 AECTP 200 contains the largest compendium of information on induced mechanical environments and includes information measured on platforms from a number of countries. Mostly based upon the US, UK and French national standards, it contains European platforms, although those included are not up to date. For these reasons this document is recommended. Nevertheless, this document does not constitute a comprehensive compilation of induced environmental conditions applicable to the European Defence industry and European platforms.

A.1.3.3 Guidelines for Deriving Test Profiles (Tailoring).

European procurement has several options for setting environmental requirements, when no platform specific information is available it may be necessary to require the supplier to measure the actual conditions. The processes for converting measured data into environmental test severities have been reviewed as part of the work of Expert Group 8. Unfortunately, currently no published standard can be recommended as having applicability to the European defence industry. It is also clear that no single approach has general acceptability. Even within the limited methods formally presented within existing standards none could be used in a mandatory fashion which could be essential in a European Defence Procurement when no platform specific information are available.

Work is ongoing in this area, with revisions planned for three existing standards, NATO STANAG 4370, Def Stan 00-35, EN IEC 60721 and the two French guideline documents (PR-NORM DEF 01-01 & ASTE-PR-01-02) which were recently made available. As a consequence some potential exists for ensuring the co-ordinated views of the European defence industry are taken into account.

A.1.3.4 'Fall Back' Test Severities.

Fallback test severities can be used in European defence procurement although such an approach has been historically found to have significant problems. For over 25 years this approach has been used only for robust equipment which is not used in severe environments. Nevertheless, as part of its review of standards Expert Group 8 has reviewed available fallback severities.

The fallback test severities, used when no other more appropriate data or severities are available, that are embedded into the NATO STANAG 4370 test procedures of AECTP 300 &

400 contain the most comprehensive array of such severities. These have been created by combining the individual national fallback severities. In the near future these are likely to be embedded into the remaining European national procedures. A consequence of combining the various national requirements is that the test schedules are more extensive than necessary or required by any single nation.

Although NATO STANAG 4370 contains the most comprehensive array of fallback severities, they are not individually the most appropriate. For that Expert Group 8 has further reviewed the severities separately. The individual recommendations are set out in the conclusions of this report. Mostly these originate from the NATO STANAG 4370 but not exclusively.

The historic issue with adopting fallback severities is that they almost always over-test the materiel and sometimes excessively so. This can raise the cost of defence materiel and prevent the adoption of otherwise adequate commercial equipment. It is for this reason that the concept of the use of test severities tailored to the actual environment was widely introduced in the early 1980s. If fallback severities are adopted for European defence procurement then a strategy for limiting the test schedules is likely to be needed to prevent excessive over-design and cost.

A.2 Review and Comparison of Vibration Test Methods

A.2.1 Standards Under Consideration.

The standards reviewed and compared with regard vibration inducing test methods are set out in the following table.

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Vibration	401	6 57 59 64 80	2-01 / M1	514 528	1st Part methods 41, 42
Vibration (Incl. combined with temperature and/or humidity)		53		520	
Gunfire	405		2-19 / M19	519	Included in general vibration procedures
Time History Replication		57		525	
Acoustic Tests (Incl. combined with temperature & vibration)	402 413	65	2-08 / M8 2-09 / M9 2-10 / M10	515 523	1st Part method 48
Aircraft Buffet Vibration	420		Encompassed in general vibration procedures		
Multi - Exciter Vibration & Shock	421		2-02 / M2	527	

A.2.2 Technical Comparison

A.2.2.1 Vibration Test Procedures

The general vibration test in UK national defence standard Def Stan 00-35, the two tests in the French national defence standard GAM EG 13 and two basic vibration tests (Sinusoidal and Random) in the commercial standard EN IEC 60068 display a distinct common base. However, the point of commonality appears to originate from some time in the early 1970's. The divergence appears to have occurred when the original tests were augmented for military use in the late 1970's and amended to allow the use of digital control equipment.

In the late 1980s the UK national defence standard Def Stan 00-35 combined sine sweep vibration testing and random vibration testing. Further additions were made to allow its use for military applications. Those modifications added new test procedures that had become available and formalised the method to allow controlled response testing which had become commonly adopted. The modifications also tightened the test tolerances to improve repeatability. However, even with these extensive changes the procedure made a declared effort to ensure backward compatibility with EN IEC 60068. Essentially a limited portion of the procedure viz. for basic sine and random tests using single point controlled input, the procedure was entirely compatible with

EN IEC 60068. The UK Def Stan was forced to adopt an approach for more complicated tests simply because they were not adequately encompassed by the EN IEC 60068 tests.

The French GAM EG 13 follows a similar development history to the UK Def Stan excepting that the original vibration tests and the original IEC 60068 tests were developed in parallel with significant overlap and interaction between the two. As a consequence the two groups of test procedures originally had considerable commonality. Although over the years the GAM EG 13 test procedures have been augmented for military use and to accommodate commercial advances in test control capabilities. The French GAM still includes separate test procedures for sine and random but the pressure to advance the procedures for military use are apparent and seem identical to those in the UK. The French GAM EG 13 tests are now considered to have been superseded by the tests in NATO STANAG 4370. The French GAM EG 13 standard is no longer supported. For general vibration testing the French MoD has adopted the NATO 4370 AECTP 400 method 401 as a system of reference with the mechanical guidelines of CIN EG 01 considered as an alternative to fall back test levels, and as a support to derive tailored severities from measured data before the test itself.

In the early 1970's the commercial standard EN IEC 60068 included vibration test procedures that were as good as any available. However, since then they have continually lagged behind advances in test control technology. The random test switched to a procedure for digital control systems almost a decade after the UK, French and US military standards. EN IEC 60068 recently included a vibration test procedure for "mixed mode" testing (sine on random, narrow band on random etc). However, similar procedures have available in the UK Def Stan, US Mil Std 810 and AECTP 400 for almost two decades. The EN IEC 60068 procedures are largely controlled input tests for smaller items of. Vibration testing of larger defence systems would not be viable using only the procedures in EN IEC 60068. This notwithstanding, the procedure of EN IEC 60068 is adequate for small component and sub-assembly tests. For COTS equipment the test procedure of EN IEC 60068, or more commonly derivatives called in product (vertical) standards, are often adopted. The firmness of definition of the basic EN IEC 60068 vibration tests implies that the test specifier can be confident in the manner the test is conducted. The precision and homogeneity of the EN IEC publications is particularly notable. The commercial standard EN IEC 60068-2-6 for sinusoidal vibration and EN IEC 60068-2-64 for broadband random vibration globally align with the national UK and US standards and with NATO 4370, and no real deficiency is apparent and as military standards they recommend to use real measurements to derive test severity. Nevertheless, these commercial standards are not sufficient to encompass the global requirement and specificity of military test activity at system level; for these reasons IEC standards can't be used alone for military applications without an important resort to existing international or national military standards.

Unlike the tests so far reviewed the US vibration test procedure of Mil Std 810 has no apparent commonality with any international standard. Every re-issue of Mil Std 810 appears to make changes to the vibration test procedures this has generally accommodated commercial advances in test control capabilities. Some of these advances are not always backwardly compatible with earlier versions or indeed compatible with any other standard. Additionally in recent times the text of the Mil Std 810 procedures have become less firmly written and consequently they are no longer particularly good at ensuring repeatability of testing. The procedure has no clear distinction in layout and terminology between mandatory and advisory (guidance) information. Traditionally the Mil Std has been used as a guidance document and in the US deviations from it are commonly noted. In circumstances where tight controls over test procedures are required, such as contractual and manufacturing requirements, the Mil Std use is very frequently re-written in a more firm style and issued as product specific procedure. General more firmly written versions of the Mil Std procedures include TOPs (Test Operating Procedures) and ITOPs (International Test Operating Procedures). Care needs to be taken with these alternatives as they currently relate to out of date versions of the Mil Std. The latest version of Mil Std 810 includes significant commonality with NATO STANAG 4370.

The latest version of the vibration test procedure in the NATO STANAG 4370 contains identifiable contributions from the latest US Mil Std, UK Defence Standard and the French national defence standard. The vast majority of the vibration standard relates to severities for different types of application. The portion related to the actual test procedure is relatively small and the distinction between mandatory and advisory (guidance) is not always unclear (although is getting better). In this regard it seems to adopt much of the guidance style of Mil Std 810 rather than the firm style of EN IEC 60068, Def Stan 00-35 and GAM EG 13. Those test procedures also have a clear distinction in their layout and terminology between mandatory and advisory (guidance) information. The NATO STANAG 4370 procedure has sufficient similarity with Def Stan 00-35, GAM EG 13 and Mil Std 810 to allow the more sophisticated vibration testing to be undertaken in an almost identical manner. Although whether it does so with an acceptable degree of repeatability is questionable. For simple controlled input tests used for small components and COTS equipment, the STANAG fails to achieve the clear definition and repeatability of EN IEC 60068. Overall the STANAG appears to have centred on ensuring commonality with the more sophisticated portions of Mil Std 810 and Def Stan 00-35 rather than ensuring it meets the basic requirements necessary of a test procedure.

So far this review has centred on the general vibration testing of equipment; however, several of the military standards also include specific test procedures related to testing of complete stores and missiles. Those tests mostly originate from test facility limitations of the 1970's and 80's. Whilst, testing of stores and missiles can still present some difficulties, mostly problems with vibration only testing have been overcome. In this regard the STANAG, Def Stan and Mil Std procedures all resolve the problems with sufficient commonality for none to have any real advantage over the others. In recent times the store & missile vibration test has developed into a combined acoustic / vibration / temperature test and multi-vibrator tests which are addressed separately.

The majority of the Defence standards allow vibration testing to be undertaken along with temperature and / or humidity. However, two standards, EN IEC 60068 and Mil Std 810, have a specific procedure for combined vibration and climatic conditions. The combined vibration, temperature and humidity procedure of EN IEC 60068 procedure appears to exist for historical reasons. The combined vibration, temperature, humidity and altitude test of Mil Std 810 appears to primarily exist to assist in users in undertaking combined temperature, humidity and altitude tests. Such tests are notoriously difficult to undertake accurately. The vibration aspects do not appear to be the primary subject of the procedure.

None of the vibration test standards addressed in this section deal comprehensively with the testing of packaged equipment. Whilst, most can accommodate the testing of some packages none can be said to allow all forms of package to be tested reliably. In this regard both very stiff and very soft packages will be difficult to adequately control under test with the current procedures. Also large and palletised equipment can only be tested with difficulty with existing procedures and then neither consistently or repeatably.

In selecting a vibration test procedure as a recommended standard for military equipment it is necessary to consider two apparently conflicting criteria. The test procedure needs to encompass commercial advances in test control capabilities in a manner to allow testing of large sophisticated defence systems in a cost effective manner. However, it also needs to be able to allow simple tests on the large number of smaller less sensitive equipment in a consistent repeatable manner. Such consistency is required for contractual reasons and to ensure consistency in testing of components and COTS items. To achieve consistency and repeatability in such cases a clear distinction in layout and terminology between mandatory and advisory (guidance) information is essential.

The NATO STANAG 4370 encompasses the key portions of the national military standards with regard testing of sophisticated equipment and when using the more complicated vibration test procedures, with the exception of time history testing (addressed separately hereinafter). In this regard the STANAG is as good as the national contributing standards. However, the manner in

which this information is included is poor. Specifically the format, consistency in terminology and weak underlying strategy are a concern. The procedure does not, at its core, include a firm and clear mandatory process which a test specifier can contractually rely upon as a basis for purchasing components, sub-systems and COTS equipment. In this regard the two European standards, Def Stan 00-35 and the now unsupported GAM EG 13, combines both tests for sophisticated equipment and a well defined mandatory process which a test specifier can contractually rely upon. Whilst, the commercial standard EN IEC 60068 contains several very well defined vibration test procedures, they have little technical innovation and marked limitations. Indeed the vibration testing of a large proportion of defence systems would prove practically impossible using only the procedures in EN IEC 60068.

A.2.2.2 Gunfire and Time History Test Procedures

The gunfire vibration / shock test included in several of the military standards are mostly intended to simulate the effects of aircraft gunfire on aircraft equipment and missiles / stores. Although the procedures could be used for other gunfire conditions, not all the procedures contain guidance or information on severities for those. None of the procedures are intended to simulate the effects of gunfire blast directly but rather the secondary vibration / transient effects on equipment. Over the years many reports, papers and specific procedures have been generated addressing the effects of gunfire. These have postulated a considerable number of approaches for specific conditions and only a few have also been developed into full blown generic test procedures. Although, procedures exist to undertake gunfire simulation on commercially available vibration test controllers, some require specialist equipment.

Since the mid 1970's various issues of the US Mil Std 810 have contained procedures to establish gunfire vibration severities for aircraft equipment. This original US Mil Std 810 process was relatively easy to implement as a test as it comprised narrow band random vibration superimposed upon a broad random background. Although frequently subject to technical criticism the severity derivation processes were used for several decades to establish equipment gunfire vibration severities for many aircraft and their equipment. As the derived test severity could be applied with the general vibration test procedures, a common strategy in Europe was to use the US severities with their own general vibration test procedure. Hence, the UK and French military standards consider they include gunfire even though no specifically named test procedure exists.

The main criticism of the historic US Mil Std 810 process was that it was really only applicable for aircraft equipment located some way from the excitation source (in this case the gun muzzle). In those cases the multiple transmission paths and intervening aircraft structure meant that the effect at the equipment was dominated by structural responses not blast pressure pulses. The US Mil Std 810 process usually produced severities that were severe when sophisticated muzzle breaks were utilised. Conversely the use of such devices usually means that the narrow band random vibration superimposed upon a broad random test type was valid for equipment located even closer to the muzzle.

For equipment close to the muzzle and for items subject to blast pressure pulses (frequently including missiles and stores), then the waveform experienced is usually dominated by the repeated shock pulses. Several ways of testing for these conditions have been postulated over the years and included in latter editions of Mil Std 810. However, not all of these were realistically practical and the test procedures were commonly poorly defined. This situation has improved with the current issue of Mil Std 810 which allows the use of several alternative methods. The historic narrow band random vibration superimposed upon a broad random test is still permitted although is only recommended for design purposes. The procedure also allows the use of stochastically generated input / responses based upon measured waveforms. This portion of the procedure is better presented than previously but still requires considerable user interpretation. The consequence of this is poor test repeatability and difficulties when used for contractual purposes.

A new procedure allowed is the time history replication method. This is not specifically limited to gunfire simulation and can, with some implementations, be used to simulate complex vibration waveforms. The time history replication test control software is mostly originally intended for automotive applications and used to establish durability. The time history replication procedures can be adapted to allow simulation of the repeated gunfire shock pulses. Those pulses could be established either analytically or from measured data. The main difficulty with the time history replication procedures is the difficulty of setting of tolerances on the resultant waveform. As time history replication is in current use for the automotive industry, test controller software is commercially available from several suppliers. Nevertheless, marked differences do exist between the software packages available.

Two time history replication procedures have recently appeared and one, with a limited capability, has existed for some time. The new Def Stan 00-35 procedure was initiated specifically to allow gunfire testing but was written in a form to allow general applicability to complicated vibrations. The procedure suggests several tolerance strategies but leaves the final selection to the user. It also gives advice on the use of the procedure for gunfire. The new Mil Std 810 procedure gives significant guidance on the setting of test severities including assistance on setting tolerances. With that said the actual procedure does not align well with existing test controller software. The procedure in EN IEC 60068 has existed for some time to allow the simulation of earthquakes. It is essentially a transient test and the last change, some years ago, adapted it to include Shock Response Spectra as a tolerance strategy. As it currently written the EN IEC 60068 has limited applicability compared to the Def Stan 00-35 and the Mil Std 810 procedures. The EN IEC 60068 could not be practically adopted for the replication of repeated gunfire.

The new US Mil Std 810 contains three alternative approaches for directly simulating the gunfire shock pulses. This includes the option of using time history replication. The NATO STANAG 4370 procedure is close to a direct copy of the test procedure in the previous issue of Mil Std 810. That procedure was not as well specified as the recent procedure and consequently commercial concern exist that the test procedures are not defined adequately for contractual purposes. The NATO STANAG 4370 procedure allows time history replication but does not contain an adequate procedure or one that aligns with commercial test control software. The recent UK Def Stan 00-35 time history replication procedure has been written to have general applicability with existing test control software.

In summary the NATO STANAG 4370 gunfire test procedure has been superseded by the new Mil Std 810 procedure. That newer procedure allows the use of historic methods, recently used methods and recently introduced methods. The procedure is better defined than previously, although it unlikely to be considered to be written in a sufficiently firm manner if used in contractual requirements. The new Mil Std 810 has the most up to date guidance and would be recommended if no alternative exists. The NATO STANAG 4370 gunfire test procedure would be acceptable in many applications. However, the use of Time History Replication or the Shock Response Spectra method is recommended for gunfire testing.

The new Mil Std 810 procedure allows the use of Time History Replication and includes a new specific procedure which can be used for a variety of purposes. Although the NATO STANAG 4370 also allows the use of Time History Replication it is a basic process only applicable to gunfire. The new Def Stan 00-35 Time History Replication procedure was specifically generated to allow gunfire testing but was written in a form to allow general applicability. It can be used with existing commercially available test control software. As a consequence this is the recommended procedure for Time History Replication as well as for gunfire testing.

A.2.2.3 Acoustic Test Procedures

Acoustic test procedures are usually used to replicate either a high intensity acoustic field or the effects of fluid flow such as the aerodynamic flow effects on aircraft skins and external equipment. The intent may be to simulate the acoustic field itself or more commonly the

vibrations that are induced. Testing of equipment using acoustic methods requires large and costly facilities. In consequence such methods are only used for high cost equipment when no other methods are suitable. Acoustic testing of commercial equipment has included items such as satellites, nuclear reactor interior equipment and civil aircraft external surface equipment.

Historically two main types of facility have been available; progressive wave tubes and reverberant chambers. The former originated as simple ducts able to raise high acoustic power levels with modest powered transducers. They are frequently used to establish fatigue damage of panels (typically mounted in one wall of the duct) such as those used on aircraft skins. A reverberant chamber is generally a much larger facility using room reverberations to both to hold the complete equipment and generate the characteristics of the acoustic field.

A generic acoustic test procedure for commercial equipment exists in EN IEC 60068. However, that is a relatively recent procedure written 10 to 15 years ago. Although this commercial standard claims to include procedures for several different types of acoustic test facility, in fact, it is predominantly only for reverberant chambers and offers little information on progressive wave tubes. The standard sets criteria which are attempts at ensuring the acoustic pressure field has specific reproducible characteristics notably an uncorrected random pressure field with a similar spectra occurring over the entire equipment.

The main use of acoustic test methods in military applications is to simulate the effects of aerodynamic flow on say high performance aircraft equipment, missiles and externally carried stores. Whilst, the acoustic characteristics set out in commercial procedure could achieve the required simulations for these applications, it was found many years ago that better simulations could be achieved by the deliberate contravention some of the criteria of earlier standards. Additionally it was found even better simulations could be achieved by including enhancements to the procedure such as adding mechanical vibrations at low frequency.

The French national defence standard GAM EG 13, two of the three UK Def Stan 00-35 procedures and earlier versions of the US Mil Std 810 all contain acoustic test procedures based around commercial acoustic test procedures. However, they do contain refinements specifically for use in the military testing of externally carried missiles and stores. All these military procedures contain a significant amount of additional guidance on the derivation of acoustic tests for military applications. The French and UK standards have specific procedures for both reverberant chambers and progressive wave tubes. The third UK procedure and the latest US Mil Std standard incorporate even further refinements for combined acoustic, vibration and temperature testing. The latest version of the NATO STANAG 4370 contains significant identifiable contributions from the latest US Mil Std 810, UK Def Stan 00-35 and some inputs from the French national defence standard GAM EG 13.

The military use of acoustic testing has developed considerably from the equivalent commercial tests. Indeed the level of evolution of the military test has become so great that the military and commercial tests are now arguably entirely different animals. Indeed acoustic test facilities able to undertake the latest and most effective military tests would not be permissible within the commercial standards. Conversely, it would be impracticable to use the commercial standards for military applications. The latest version of NATO STANAG 4370 not only combines the majority of the national standards but also adds additional enhancements.

A.2.2.4 Buffet Vibration Test Procedures

The so called buffet vibration tests are specifically intended to simulate the transitory aerodynamic conditions that occur when a high performance aircraft adopts flight attitudes which give rise to shedding of large scale vortices. The creation of these vortices gives rise to vibration at the location they are generated. However, the vibration (and loading) induced is far greater when the vortices impinge, downstream, on aircraft or weapon structure. Aircraft shed large scale vortices in only a small range of flight conditions which are only maintained for short periods (a few seconds at most). Moreover, the worst case conditions occur over only a very narrow range of flight conditions, are very location specific and vary considerably from aircraft to

aircraft. Vortices normally excite a single response mode of the aircraft structure, wing or external weapon, related to the size of the vortex.

An early 1980's version of the US standard Mil Std 810 included buffet in the vibration test procedures. It is understood this inclusion arose from experience and problems with one specific US aircraft. Moreover, the severities were based upon very limited data. Nevertheless, the severity proposed for that aircraft remains to this day. The test severity comprised a crude Power Spectral Density envelope of a single response mode. This was applied separately to the normal flight vibration test severity as its total duration was typically a few hundred seconds. However, it adopted the normal random vibration test procedure. The US Mil Std 810, UK Def Stan 00-35 and French GAM EG 13 national military standards all utilised the general random vibration test procedure to apply buffet vibrations.

The above notwithstanding NATO STANAG 4370 includes a specific chapter for buffet. However, the real content is essentially only guidance on test severities. Although this guidance is better than anything else available, it still utilises the general vibration test. The guidance does not justify a separate test procedure which could easily be encompassed within the general vibration test procedure.

A.2.2.5 Multi - Exciter Vibration

NATO STANAG 4370 includes a specific chapter relating to multi-exciter test methods. Although multi-exciter testing has been undertaken for some time in both the military and automotive fields, they were adopted as solutions to only a very small range of military problems. The STANAG chapter is an attempt to impose a generic military procedure.

Frequently a test item's weight, physical dimensions, complex dynamic response, or specific in-service environment require the use of multi-exciter methods for laboratory simulation of a dynamic environment. A common multi-exciter application is testing of long slender materiel with a high length to diameter ratio, such as a missile system. Multi-exciter test methods can permit a better distribution of vibratory energy on the structure than could be achieved with a single exciter. Two or more exciters may also be coupled in phase, or inverted phase, to a horizontal slip table for testing. multi-exciter testing can be used to establish a degree of confidence that the materiel can structurally and functionally withstand a specified dynamic environment that is defined by motions in more than a single-degree-of-freedom (SDOF) i.e., in multiple-degree-of-freedom (MDOF) motion. Specification of the environment may be through a detailed summary of measured field data related to the test materiel that entails more than one degree-of-freedom, or analytical generation of an environment that has been properly characterized in MDOF. In general specification of the environment will include several degrees of freedom in a materiel measurement point configuration, and testing of the materiel in the laboratory in a SDOF mode is considered inadequate to properly distribute vibration energy in the materiel in order to satisfy the specification.

The US national military standard Mil Std 810 issue G introduced a method 527 called Multi-Exciter testing. This test method is largely based upon the STANAG methodology with the inclusion of additional guidance.

DEF STAND 00-35 Part 3 Issue 4 includes a new method Test M2 in the chapter 2-02. This part is the same as the NATO STANAG 4370. No equivalent procedure exists in EN / IEC 60068. The NATO STANAG 4370 is replicated in UK Def Stan 00-35 and is very similar to the procedure included in the recent issue of US Mil Std 810 which includes some very useful guidance on the implementation of multi-exciter and multi-axis testing. No equivalent procedure exists in EN IEC 60068.

A.2.3 Conclusions of Review of Vibration Test Methods

A summary of the recommendations is shown in the table below which is expanded in the following paragraphs.

Summary of Recommendations for Vibration Tests					
	NATO STANAG 4370 AECTP	International EN IEC 60068	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
Vibration	Recommended Good for systems but lacks control over mandatory aspects	Firmly written and suitable for component testing	Good control over mandatory aspects, good for systems	Lacks control over mandatory aspects	Out of date but contains some information lacking in STANAG
Vibration (Incl. combined with temperature and/or humidity)					
Gunfire	Could be recommended when brought up to date and made consistent with commercial control systems		No specific procedure rather recommends using THR methods	Recommend but only if no better alternative.	No specific procedure rather undertaken using existing methods
Time History Replication (THR)	Could be recommended if aligned to commercial control software	Procedure is usable but related to transients (earthquakes)	Recommend	Could be recommended if aligned to commercial control software	
Acoustic test Reverberant Chamber	Recommended	Test procedures very similar to STANAG			
Acoustic test Progressive Wave Tube	Recommended		Same as STANAG		
Acoustic test Combined With Temperature & Vibration	Recommended		Same as STANAG		
Buffet	Specific test but essentially guidance		Recommended Uses conventional vibration test procedure	Uses conventional vibration test	Uses conventional vibration test
Multi - Exciter Vibration	Acceptable procedure and could be recommended if brought up to date		Essentially the same as STANAG 4370	Recommended same as STANAG 4370 but with better guidance	

A.2.3.1 Vibration Test Procedures

In selecting a vibration test procedure as a recommended standard for military equipment it is necessary to consider two apparently conflicting criteria. The test procedure needs to encompass commercial advances in test control capabilities in a manner to allow testing of large sophisticated defence systems in a cost effective manner. However, it also needs to be able to allow simple tests on the large number of smaller less sensitive equipment in a consistent repeatable manner. Such consistency may be required for contractual reasons and to ensure consistency in testing of components and COTS items. To achieve consistency and repeatability in such cases the procedure needs to be firmly written with a clear distinction in layout and terminology between mandatory and advisory (guidance) information.

Currently the NATO STANAG 4370 encompasses the key portions of the Def Stan 00-35, GAM EG 13 and Mil Std 810 with regard testing of sophisticated equipment and the more complicated vibration test procedures. In this regard the STANAG is as good as the three contributing standards. However, the manner in which this information is included is poor. Specifically the poor format, consistency in terminology and weak underlying strategy are a concern. The procedure does not, at its core, include a clear mandatory process that a test specifier can contractually rely upon for purchasing components, sub-systems and COTS equipment. This is also the case for the US Mil Std 810 procedure. Conversely, the UK Def Stan 00-35 test procedure, combine tests for sophisticated equipment and well as a defined mandatory process which a test specifier can contractually rely upon. Whilst, the commercial standard EN IEC 60068 contains several very well defined vibration test procedures, they have little technical innovation, they are limited to controlled input testing, are not as up to date as the military standards and largely unsuitable for military use on large systems.

The main review undertaken here related to the general vibration testing of equipment. However, several of the military standards also include specific test procedures related to testing of complete stores and missiles. Whilst, testing of stores and missiles can still present some difficulties, mostly problems with vibration testing have been overcome. In this regard the STANAG, Def Stan and Mil Std procedures all resolve the problems and have sufficient commonality for one to have any real advantage over the others. In recent times the store & missile vibration test has developed into a combined acoustic / vibration / temperature test.

None of the vibration test standards addressed in this section can be considered to adequately deal with the testing of packaged equipment. Whilst, some can accommodate the testing of some packages none can be said to allow any form of package to be tested reliably. In this regard both very stiff and very soft packages will be difficult to adequately control under test with the current procedures. Also large and palletised equipment can only be tested with difficulty with existing procedures and then neither consistently or repeatable.

In summary the NATO STANAG 4370 is technically innovative, up to date and encompasses key components of the three contributory national standards Def Stan 00-35, GAM EG 13 and Mil Std 810. The NATO STANAG 4370 procedure is the most useful for the testing of complex systems. However, the STANAG lacks firmness of statement and does not include a clear mandatory process such that a test specifier could not contractually rely upon it. As such the NATO STANAG 4370 is frequently found to be inadequate for the procurement of sub-systems and components. The procedure in Def Stan 00-35 demonstrates technical innovation and firmness of statement in a practical manner. The procedures in EN IEC 60068 are by comparison to the military standards limited in scope. However, they are firmly written and frequently used as the basis for indicating the capability of COTS equipment. Nevertheless, these civil procedures could not be easily adopted a range of defence systems. For these reasons the recommendation is the international NATO STANAG 4370 but with additional contributions was from other national military standards were necessary on poorly addressed issues.

A.2.3.2 Gunfire and Time History Test Procedures

Since the Mid 1970's the various issues of the US Mil Std 810 has contained a variety of procedures to establish gunfire vibration severities for aircraft equipment. This historic US Mil Std 810 process was relatively easy to implement as it comprised narrow band random vibration superimposed upon a broad random background. Although frequently subject to some technical criticism the severity derivation processes were used for several decades to establish equipment gunfire vibration severities for many aircraft.

As the derived test severity could be applied perfectly well with the general vibration test procedures, a common strategy in Europe was to use the US severities but with their own general vibration test procedure. Hence, the UK and French military standards consider they include gunfire even though no specifically named test procedure exists. The UK Def Stan 00-35

and French GAM EG 13 military standards would consider their tests procedures are more suitable in a contractual situation.

The main criticism of the historic US Mil Std 810 process was that it was only applicable for aircraft equipment located some way from the excitation source (in this case the gun muzzle). For equipment close to the muzzle and for items subject to blast pressure pulses (frequently including missiles and stores), then the waveform experienced is usually dominated by the repeated shock pulses. Several ways of testing for these conditions have been postulated over the years and some included in standards such as latter editions of Mil Std 810. However, not all of these were realistically practical and the test procedures were frequently poorly defined. Although this situation has improved, the alternatives are still quite complicated and considerable user interpretation is still required.

This situation has improved with the current issue of Mil Std 810 which allows the use of three alternative methods. The historic narrow band random vibration superimposed upon a broad random test is still permitted although is only recommended for design purposes. The procedure also allows the use of stochastically generated input / responses based upon measured waveforms. This portion of the procedure is better presented than previously but still requires considerable user interpretation. The consequence of this is poor test repeatability and difficulties when used for contractual purposes. The third procedure allowed is the new time history replication method.

In recent years a practical alternative test methods has become available. Those methods allow the user to apply a specific and lengthy time history to the equipment. These time history replication procedures have been adopted from the automotive industry where they are used to establish durability. The time history replication procedures can be adapted to allow simulation of the repeated gunfire shock pulses. Those pulses could be established either analytically or from measured data. The time history replication procedures have a broader applicability than just gunfire and they can be used to replicate most complicated waveforms including combined shock and vibration conditions. The main difficulty with the time history replication procedures is the difficulty of setting of tolerances on the resultant waveform. As time history replication is in current use for the automotive industry, test controller software is commercially available from several suppliers. Nevertheless, marked differences do exist between the software packages available.

Two time history replication procedures have recently appeared and one, with a limited capability, has existed for some time. The latest Def Stan 00-35 procedure was initiated specifically to allow gunfire testing but was written in a form to allow general applicability. The procedure suggests several tolerance strategies but leaves the final selection to the user. It also gives advice on the use of the procedure for gunfire. The new Mil Std 810 procedure gives significant guidance on the setting of test severities including assistance on setting tolerances. With that said the actual procedure does not align well with existing test controller software, which is not the case for the Def Stan 00-35 procedure. The procedure in EN IEC 60068 has existed for some time to allow the simulation of earthquakes.

In summary the NATO STANAG 4370 gunfire test procedure has been superseded by the new Mil Std 810 procedure. That newer procedure allows the use of historic methods, recently used methods and recently introduced methods. The procedure is better defined than previously, although it unlikely to be considered to be written in a sufficiently firm manner if used in contractual requirements. The new Mil Std 810 has the most up to date guidance and would be recommended if no alternative exists. The NATO STANAG 4370 gunfire test procedure would be acceptable in many applications. However, the use of Time History Replication or the Shock Response Spectra method is recommended for gunfire testing.

The new Mil Std 810 procedure allows the use of Time History Replication and includes a new specific procedure which can be used for a variety of purposes. Although the NATO STANAG 4370 also allows the use of Time History Replication it is a basic process only applicable to

gunfire. The new Def Stan 00-35 Time History Replication procedure was specifically generated to allow gunfire testing but was written in a form to allow general applicability. It can be used with existing commercially available test control software. As a consequence this is the recommended procedure for Time History Replication as well as for gunfire testing.

A.2.3.3 Acoustic Test Procedures

The Acoustic test procedures are usually used to replicate either a high intensity acoustic field or the effects of fluid flow such as the aerodynamic flow. The main use of acoustic test methods in military applications is to simulate the effects of aerodynamic flow on say high performance aircraft equipment, missiles and externally carried stores. Acoustic test methods have developed considerably in the military field from their use in testing commercial items. Indeed the level of evolution of the military test has become so great that the military and commercial tests are now arguably entirely different. To illustrate this, acoustic test facilities that are able to undertake the latest and most effective military tests, would not be acceptable using the commercial standards. Conversely, it would be impracticable to use the commercial standards for military applications. The latest version of the NATO STANAG 4370 not only combines the majority of the national standards but also adds additional enhancements.

In summary, the primary reason for using acoustic testing in military applications differs from that of commercial applications. With that said, the actual test procedures for military and commercial applications should be interchangeable. However, the commercial standards are markedly less advanced than the military standards and lack technical innovation. Of the military standards NATO STANAG 4370 are the most sophisticated and recommended.

A.2.3.4 Buffet Vibration

The US Mil Std 810, UK Def Stan 00-35 and French GAM EG 13 national military standards all utilised the general random vibration test procedure to apply the so called buffet vibrations. Whilst, NATO STANAG 4370 includes a specific chapter for buffet, the real content is essentially only guidance on test severities. As guidance the content is better than anything else currently available. With that said, it does not use a test procedure different from the general vibration test and the guidance does not justify a separate chapter. Moreover, the existing general random vibration test of the UK Def Stan 00-35 standard comprise far better test procedures than that of NATO STANAG 4370. As such that procedure is recommended here.

A.2.3.5 Multi - Exciter Vibration

NATO STANAG 4370 contains a multi-exciter vibration test procedure. The NATO STANAG 4370 is replicated in UK Def Stan 00-35 and a very similar the procedure is included in the recent issue of US Mil Std 810. No equivalent procedure exists in EN IEC 60068. Although the STANAG 4370 procedure is recommended here, The US Mil Std 810 is the most complete method developed with four guidance sections describing information about the transducer placement, the system identification for linear time invariant multi-degree of freedom system, the procedure for time waveform replication and the procedure for spectral density matrix generation.

A.3 REVIEW AND COMPARISON OF SHOCK TEST METHODS

A.3.1 Standards Under Consideration

The standards reviewed and compared with regard mechanical shock conditions are set out in the following table.

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Classical Waveform Shock	403	27	2-03 / M3	516	Method 43
Handling And Drop	414	31 32	2-04 / M4 2-05 / M5	516 Proc II,III,IV & VI	Method 43 Proc 3, 4 & 5
Safety Drop Test	STANAG 4375	UN "Orange" BOOK (ST/SG/AC.10/ Rev.12)	5-03 / FX3 BR8541		
Shock Response Spectra	417	57 81	2-06 / M6	516	Method 43
Pyroshock	415			517	Method 43 Proc 7
Rail Impact	416	(within 27)	(within 2-03 /M3)	516 Proc VII	Method 43 Proc 6
Undex Test	419		2-07 / M7		
Ballistic Shock	422			522	
Catapult			(Severity only in Part 5)	516 Proc VIII	Method 43 Proc 8
Bump		29	2-12 / M12		Method 43 Proc 9

A.3.2 Technical Comparison

A.3.2.1 Classic Waveform or Basic Shock Test

The classic waveform or basic shock test procedure is one of the oldest shock test procedures available. In all cases the procedures encompass three basic shock pulses viz. a half sine pulse, a trapezoidal pulse and a trailing edge saw tooth. All of the procedures allow a range of test equipment to be used provided the requirements are met. This is because from the very early days a wide range of different test facilities were in use to generate this type of shock.

The latest UK National defence standard Def Stan 00-35 introduces a new type of basic shock, the damped sinusoidal waveforms. The decaying sinusoid waveform replicates the effect of the linear response of materiel to shock loading. This is in contrast to the previous three waveforms, which represent the excitation shock.

This test procedure has been used historically by suppliers of COTS components and sub-system (both military and commercial) to demonstrate their equipment has a degree of hardness against shock conditions. It is important therefore that the test procedure is common to both commercial and military equipment.

By design the UK and French national defence standards have historically adopted the same basic procedure of the International standard that is now EN IEC 60068. Indeed two way interactions occurred in the generation of the International standard that is now EN IEC 60068 and the French defence standard. The type of pulse permitted the tolerances on the pulses and the general confirmation tolerances are all identical in all three standards.

Consistency between standards is not the case for the US Mil Std 810 procedure (although it also appears in other US standards such as Mil Std 331) which only intrinsically includes trailing edge saw tooth and trapezoidal pulses. The tolerance on the pulses and the general confirmatory approach are also markedly different to those of the EN IEC 60068 (albeit the tolerances on the pulses are tighter). Additionally the latest US Mil Std sets out a Shock Response Spectra definition as a permitted “alternative” to the use of basic pulses. This “alternative” is intrinsically inconsistent with the basic pulse and differs in both potential damage and tolerances (more lax than EN IEC 60068). The latest version of the NATO STANAG appears to be broadly based upon the EN IEC 60068. However, for no clear reason, the trapezoidal pulse is defined differently and has different tolerances. The defined trapezoidal pulse seems to have no commonality with other standards and is more difficult to achieve than that used in European standards.

As this test is used by suppliers of COTS equipment commonality between commercial and military procedures is highly desirable. Both the UK and French military standards align with the procedure of EN / IEC 60068. In two out of three cases this is also the case for NATO STANAG 4370. However, the procedure of US Mil Std 810F differs from all others to a significant extent. Moreover, the US Mil Std permits an “alternative” process which can result in yet greater variations. It has to be observed that the use of the Mil Std is disadvantageous to European industry.

A.3.2.2 Handling Drops and Impacts

This group of tests simulates both drops and impacts that occur during packaged and unpackaged handling. They differ from the classic shock tests in that rather than reproduce the effects of the shock they reproduce the causal conditions. In order to reproduce the correct effects of the causal conditions the equipment has to comprise a complete assembly with (if applicable) the equipment in its normal packaging. As a consequence it is not usually possible for this test to be used by suppliers of COTS equipment or OEM suppliers.

A group of tests are actually encompassed viz. vertical drop, topple & roll, horizontal impact and bench drop. The test severities are essentially hardness criteria based only approximately on maximum credible conditions. The equipment (packaged or bare) would be expected to remain “safe & serviceable” following exposure to these tests. For equipment with safety implications (such as those containing dangerous items and particularly energetic material) a significantly more severe “safety impact test” would be adopted. However, in those cases the equipment would be expected to remain “safe only”.

By design the two UK Def Stan 00-35 tests align with the two EN IEC 60068 tests, albeit with some slight amendments. The UK Def Stan 00-35 tests and to some extent the two EN IEC 60068 tests are not prescriptive on severities allowing a degree of flexibility to be adopted. Whilst, the Def Stan & EN IEC tests both include Drop & Topple neither include Bench Handling tests. The vertical impact tests include drops onto each face, corner and edge.

The US Mil Std 810 procedure does not reflect the two EN IEC 60068 tests to any real extent. Moreover, the vertical impact severities are prescriptive and based upon mass of the item. The French GAM EG 13 test procedures are somewhat similar to the US Mil Std but do include a greater contribution from the two EN IEC 60068 tests. The vertical impact severities adopt mass related prescriptive severities but are slightly lower than the US procedure. The US and French tests include bench handling tests although the GAM EG 13 severity appears to be 10 times that of the US test. The horizontal impact test velocities are identical.

NATO STANAG 4370 includes three procedures vertical impact, horizontal impact and bench handling. The horizontal impact and bench handling impacts are essentially those of US Mil Std 810 and GAM EG 13 standards but with the US severity for bench handling. The vertical impact severity is prescriptive and based upon mass of the item (from the US standard).

In practice NATO STANAG 4370 is the US Mil Std with apparently only modest acknowledgment to other specifications. In particular the procedures differs from the two EN IEC 60068 tests arguably without apparent good cause. Moreover, the use of prescriptive “hardening” severities for the vertical impact test could be seen as limiting the use of commercial equipment and packaging in circumstances where full military hardening criteria are not necessary. Superficially this would suggest an implication on European industry, however, the various procedures have become so intertwined over the years that the effect is likely to be relatively modest. Moreover, this is not usually adopted for COTS equipment.

A.3.2.3 Safety Drop Test

For systems containing dangerous items and particularly energetic materials a separate set of handling tests are commonly mandated either by national or international requirements. These can be grouped as “safety impact test” in which the equipment would be expected to remain “safe only”. In fact several criteria may be adopted dependent upon purpose and whether the equipment or package is under consideration.

The current UK Def Stan 00-35 Test 5-03 (or FX3) was specifically intended for munitions and implement the requirements of STANAG 4375 issue 1 as well as the requirements of an earlier UK Def Stan and the safety drop test of UK specification BR8541 (Explosive Safety Requirements for Armament Stores for Naval Use). The UK Def Stan test requirements are significantly greater than those of NATO STANAG 4375 because of the need for a potentially greater drop height and drops onto spigots. NATO STANAG 4375 issue 1 requires drops of not less than 12 m onto face and edges of the packaged and / or unpackaged weapon. Following such drops the munitions are required to be safe for disposal only. The impact surface was 75 mm of steel on a substantial concrete or gravel base. As this was a more robust impact surface than had been specified previously a concession to use existing surfaces was included. NATO STANAG 4375 issue 1 include a test to verify the munitions are ‘safe to use if no visible damage’. The drop height for this was up to 3 m. This aspect of the test has been deleted from the latest NATO STANAG 4375 issue 2. Generally the UK Def Stan includes considerably more information than the STANAG test.

The UN “Orange” Book (or more formally Recommendations on the Transport of Dangerous Goods ST/SG/AC.10/Rev.12) contains a drop test which is intended as an international requirements for demonstrating the adequacy of packages when transporting dangerous goods. Dangerous goods in this instance are categorised as a range of materials one of which is explosives. UN certification against nationally implemented versions of this standard is required before dangerous goods can be transported using most commercial means. This is especially the case for international transportation. Although the test procedure of the UN test is relatively similar to all those so far addressed, the severity and criteria differ. The drop height required for explosives in the drop test set out in the UN standard is significantly less than the heights required in the specifically military tests already addressed. However, the criteria required to be achieved are more demanding. These differences will not normally allow the military safety drop tests to encompass the requirements of the UN test or vice versa.

NATO STANAG 4375 is frequently listed along with a number of other safety tests (fire, bullet impact etc). These are frequently used to demonstrate ‘insensitive munitions’ (IM) criteria. However, the safety drop test is always included as an IM test in every country

A.3.2.4 Shock Response Spectra Based Procedures

The Shock Response Spectra (SRS) test method is a relatively new shock procedure made possible by improvements in test equipments over the last 20 years. The procedure allows

simulations of the effects of shocks to be achieved rather than attempting to replicate the source of the shock. In many cases this is potentially more realistic than permitted by the basic shock tests. Additionally, the SRS test method is undertaken on vibration test equipment. As such if vibration testing is also been undertaken, (as is usually the case; additional special test equipment and rigs are not required, reducing both test time and costs. A deficiency of the SRS test method is that an SRS severity is not a unique definition and consequently, unless the procedure is specific, can result in lack of repeatability of testing. The problem is such that it can be difficult for a test specifier to be certain as to the test actually undertaken and whether the assumed damage modes have correctly exercised. The generation of adequate acceptance criteria especially the verification of tolerances can also be problematic. This problem of repeatability is made worse by the range of methods and assumptions used in the various commercial software packages used to undertake this test.

The UK Def Stan 00-35 test is probably the oldest of the procedures and was intended primarily to replicate compound decaying sinusoidal type profiles. The problem of ensuring repeatability was circumvented by requiring the components of the shock time history to be defined. The International EN IEC 60068-2-57 test procedure was originally intended to simulate the effects of earthquakes but was significantly modified to allow the use of SRS severity definitions. Again the method was based largely around decaying sinusoidal type profiles. The latter International EN IEC 60068-2-81 test procedure is quite recent and is significantly different to its predecessor as it is centred on the more modern wavelet approach. However, it has limitations in terms of ensuring repeatability relying mostly on extensive guidance as a means of ensuring repeatability.

The original US Mil Std 810 adoption of the SRS test methods lacked any real test procedure and seemed to be a way of allowing a more flexible tolerance strategy than of the classic waveform shock. The French GAM EG 13 method seems to be a reasonable working compromise between the EN IEC 60068-2-57 test procedure and the Mil Std. The most recent version of the US Mil Std 810 includes more information than earlier versions, but still does not really address the main testing issues.

The latest NATO STANAG 4370 method is extensively revised from earlier versions. It appears to encompass issues from the UK Def Stan, the French GAM EG 13 method and the Mil Std 810 . In addition it contains a lot of background information on the derivation of SRS severities from measurements. However, it does not seem to address issues related to repeatability and is entirely different to the recent EN IEC 60068-2-81 test procedure.

The latest NATO STANAG 4370 method and the recent the EN IEC 60068-2-81 test procedure undoubtedly comprise the most up to date SRS methods available. However, they are entirely different from each other and so far both are unproven in the real world testing of equipment. Both give considerable flexibility to the test house in the conduct of the test and the waveform actually applied. However, this is a disadvantage to the test specifier who cannot necessarily be certain the assumed damage modes have correctly exercised. In contrast the UK Def Stan 00-35 and the French GAM EG 13 method have been shown to work and address the problems of associated with ensuring repeatability. However, they do not necessarily allow use of the latest techniques included in commercial control software packages. For these reasons no test procedure can be recommended.

A.3.2.5 Pyroshock

This procedure is intended to simulate the effects of high frequency shocks such as those induced by the operation of explosively operated cutters, bolts, line cutting charges etc. It could also be used to simulate other high frequency shocks particularly those arising from high velocity impact. For the most part this type of shock is unique to military equipment; the main exception to this is the separation shocks arising in commercial satellites / boosters. Consequently, it is not surprising that this test method is not contained in any general commercial standards (although it is both an ESA and NASA requirement).

Historically a separate pyroshock test was included in military specifications as it required entirely different test equipment and a different approach to that used for other types of shock. At that time simulating high frequency shocks either required very specialist simulation equipment (gas guns etc) or the reproduction of the event itself (by firing the pyrotechnic device). Since then the simulation of the effects of the using SRS methods has become possible albeit for a limited range of conditions.

The latest US Mil Std 810 procedure supplies advice the test specifier on appropriate strategies for simulating or reproducing shock responses. The US procedure also supplies considerable information on how to measure and quantify the shock environment as well as how to verify that the shock has been adequately reproduced. However, it has to be said that the source of this information (an IEST working practices document originally commissioned by the US DOD) is far more comprehensive. As a considerable range of test equipment may be adopted then the procedure is able to give only basic information in this regard. The Mil Std 810 procedure has been enhanced significantly over the years as better simulation and verification methods became more readily available. The French GAM EG13 procedure is slightly older than the latest US Mil Std 810 procedure (or more accurately has not been updated quite as recently) and consequently does not encompass the latest information and methods. However, it is essentially equivalent to the preceding version of the Mil Std 810.

The latest NATO STANAG 4370 method was revised from earlier versions as well as the latest version of the US Mil Std 810 procedure. It appears to be based largely on the Mil Std with additional information but would seem to adequately encompass the relevant aspects of the French GAM EG 13 procedure. As such the NATO STANAG 4370 would seem to be the best document available. Although firmness of the standard could be an issue with the NATO STANAG, in practice documentation for this type of test is mostly treated as guidance because of the range of methods that can be adopted. Nevertheless if repeatability were essential the user would need to re-write the document.

A.3.2.6 Rail Impact

The rail impact test procedure is essentially intended to simulate the effects of rail shunting shocks on packaged goods. Two different strategies are observed to be adopted by the different standards reviewed. The strategy adopted by one group of standards is simulate the actual rail shunting / impact conditions by forcing rail wagons into one another at defined velocities. The other strategy is to simulate the effects of the impact using procedures such as the classic waveform test procedure with appropriate test severities.

Earlier versions of the US Mil Std 810 test appear to have been based upon a US Federal Test in which rail cars are subject to impact of various velocities. Historically the US Federal Test was utilised for large commercial equipment viz. by US and European car manufacturers. The latest version of the Mil Std has substantially modified the original procedure but it is still US rail system specific and needs to be done with rail wagons. The French standard GAM EG 13 also contains a rail impact test. Whilst, this procedure also requires complete rail wagons, very little definitive information is contained in GAM EG 13.

EN IEC 60068 does not contain a specific rail procedure, although EN IEC 60721 (the associated environmental severities) does encompass rail shock by means of classic waveform test procedure. A similar strategy is adopted in the UK Def Stan 00-35 for reasons set out below.

NATO STANAG 4370 contains three procedures; two of these impact loaded rail wagons to produce the shock, the third allows laboratory simulation using either the classic waveform test or the SRS procedures. Of the two procedures that impact loaded rail wagons, one is stated as mandatory for the US rail system (although why it should be mandatory is not clear) the other is indicated as a requirement for the European rail system (again why it should be a requirement is not clear). The required amplitude severities for the latter are quoted, are modest and can be sensibly achieved on laboratory equipment.

In recent times rail shock severities on the European rail systems have decreased substantially. This is because European rail vehicles now use better buffing equipment (hydraulic buffers produce much lower shocks than spring) and more significantly the operating procedures have changed. The change of operating procedures has eliminated shunting impacts for all but low value item (such as mineral transports). This is because rail train sets are rarely broken into individual vehicles (especially when loaded). Today the need for a specific procedure to reproduce rail impact appears to originate almost entirely from consideration of the US rail system. For European defence equipment laboratory simulation is the only cost effective and practical approach that is if a test is needed at all.

The NATO STANAG 4370 appears to contain the most options for undertaking the test. However, the European need for such a test is doubtful and the severities (significantly exceed) the European need and commercial standards such as EN IEC 60721.

A.3.2.7 Underwater Shock (or Undex) Test

The simulation, of the shock effects from non-contact explosions adjacent to warships, has historically used a range of specialist facilities. Generally each of the various facilities had accompanying specific test procedures. Consequently, the test was not usually included in more general military procedures. A move towards the use of a broader range of test facilities has necessitated the inclusion of appropriate test procedures in military procedures. As the type of test is entirely military, no commercial equivalents are available. Of the procedures reviewed the UK Def Stan 00-35 includes a very basic procedure aimed at setting up the test but does not include information on tolerances or severities. The NATO STANAG 4370 contains a specific and recent procedure. The procedure contains extensive guidance and allows the use of both general and specific equipment. It also includes information on tolerance strategy.

A.3.2.8 Ballistic Shock

The Ballistic shock test method simulates a high-level transient shock that generally results from the impact of projectiles or ordnance on armoured combat vehicles, hardened targets, or other structures. Such impact may produce a very high rate of momentum exchange at a point, over a small finite area or over a large area. The high rate of momentum exchange may be caused by collision of two elastic bodies or a pressure wave applied over a surface. Ballistic shock can be considered as a specific application of transient or pyrotechnic shock.

Historically a separate ballistic shock test was included in military specifications as it required entirely different test equipment and a different approach to that used for other types of shock.

The latest NATO STANAG 4370 method is effectively identical to the latest US Mil Std 810 procedure. Whilst, the STANAG is somewhat more readable than Mil Std 810, the severity defined as a Shock Response Spectra is not included in STANAG 4370 making it essentially inoperable. The test does not appear in French military specification GAM EG 13 or the UK Def Stan 00-35. Arguably the ballistic shock requirement is included in those standards within the generic shock test procedures. As it is entirely a military requirement the test method does not exist in IEC or EN commercial standards.

Both the latest NATO STANAG 4370 and the Mil Std 810 methods includes several sub-procedures:

- i. Ballistic Hull & Turret.
- ii. Large Scale Ballistic Shock Simulator.
- iii. Light Weight Shock Machine.
- iv. Medium Weight Shock Machine.
- vi. Drop Table.

The first of these sub-procedures uses actual conditions and hence is not strictly a laboratory test. The last sub-procedure uses a commonly available basic drop test facility but the sub-procedure is only permitted for items below 40 Kg. The remaining three sub-procedures relate to US specific facilities which would be expensive to reproduce in Europe. Moreover, alternative

methods of simulating ballistic shock, gas guns etc, are not addressed. It has to be concluded that the adoption of the NATO STANAG 4370 ballistic shock test could put European industry at a disadvantage. This could be easily resolved if the procedure is written in terms of the real requirement rather than as a procedure relating to specific types of equipment.

A.3.2.9 Catapult Launch /Arrested Landing

Since the earliest version the US Mil Std has included, a virtually identical, catapult launch / arrested landing shock test procedure. The test has limited application for naval aircraft equipment and weapons. It is a relatively simple decaying sinusoidal waveform of modest amplitude (about 2 g). In most cases the severities are likely to significantly encompass by other environments. Today the test can readily be undertaken on various shock test equipment.

The UK national defence standard Def Stan 00-35 introduces Time History Replication Test (THR) as the way to replicate the effects of catapult launch and arrested landing in order to demonstrate the adequacy of materiel to resist to this kind of shocks without unacceptable degradation of its functional and/or structural performance. Indeed, it can be necessary to reproduce specific in-service time history because the waveforms are more complex than those accommodated by test procedures that only use SRS control strategy. Moreover THR method has also the advantage of allowing a combination of shock and vibration conditions within a single test signal.

The US national defence standard Mil Std 810G is comparable to the UK Def Stan 00-35 procedure because THR tests (with a combination of shocks and vibrations) are also recommended when measured data are available. The US Mil Std 810G proposes a control strategy when measured data are not available. In such cases, the US standard recommends Applying a short transient sine wave for several cycles.

The French GAM EG 13 references a severity for the environment but has no specific procedure rather uses existing shock test procedures. The latest NATO STANAG 4370 method does not include a specific test procedure but the SRS procedure could easily be adapted. EN IEC 60068 does not include a specific procedure but EN IEC 60068-2-57 time history test procedure could replicate this. That procedure is essentially the SRS procedure for low frequency applications (earthquakes). However, procedures that essentially use SRS control strategies may not necessarily be representative in term of generated time history. Indeed the waveform generated during test may be quite different to the in-service.

The Time History Replication Test defined in UK Def Stan 00-35 is considered to be the most representative way to test a materiel to catapult launch and arrested landing shocks. However, the UK Def Stan 00-35 procedure does not recommend a procedure when no measured data are available.

A.3.2.10 Bump

The bump test has similar providence to the classic waveform or basic shock test procedure. It is quite an old test using relatively simple mechanical test equipment and allowed the application of repetitive shocks of reasonable amplitude at a time when vibration test equipment was expensive and not widely available. A test using this procedure typically utilises several a half sine pulse, repetitively applied, with a few seconds interval between each pulse. None of the procedures specify a particular item of test equipment, but test equipment specifically for this procedure is relatively cheap and widely available.

The test is generally not considered to replicate a particular environmental condition but rather to demonstrate equipment has a degree of hardness against shock and vibration conditions. It has been used historically by many COTS component and sub-system suppliers (both military and commercial) to indicate the capability of their equipment. Although used to a lesser extent today it is still common to see the test listed in technical specifications for smaller electrical and mechanical components. It is important therefore that the test procedure is common to both commercial and military equipment.

As was also the case for the classic waveform or basic shock test procedure, the UK Def Stan 00-35 and French GAM EG 13 standards have, by design, historically adopted the same basic procedure of the International standard that is now EN IEC 60068. The test set up, the tolerances on the pulses and the general confirmation tolerances are all identical. The test procedure does not appear in the US standard nor is it addressed in the NATO STANAG 4370. The argument for the latter is that it does not replicate a particular environmental condition.

Although, the original rationale for this test has long been superseded, it is still used by suppliers of COTS and OEM equipment to demonstrate the ruggedness of components and subsystems. For this reason, commonality between commercial and military procedures is highly desirable. Both the UK and French military standards align with the procedure of EN IEC 60068. The test does not appear in NATO STANAG 4370 largely because it does not replicate a particular environmental condition.

A.3.3 Conclusions of Review of Shock Test Methods

A summary of the recommendations is shown in the table below which is expanded in the following paragraphs.

Summary of Recommendations for Shock Test Procedures					
	NATO STANAG 4370 AECTP	International EN IEC 60068	UK Def Stan 00-35	US Mil Std 810F	France GAM EG 13
Classical waveform shock (using basic shock pulses)	Similar to European standards	Recommended Procedure for half sine, trapezoidal & trailing edge saw tooth pulses.	Equivalent to EN IEC 6006 Recommended for decaying sinusoidal pulses	Significantly differs from other standards	Equivalent to EN IEC 60068
Handling & Drop	Concerns over differences with EN IEC 60068	Recommended	Equivalent to EN IEC 60068	Differs from other standards	Essentially equivalent to EN IEC 60068
Safety Drop Test for munitions or dangerous goods	STANAG 4375 Recommended	International Regulation set by UN for the "Transportation of Dangerous Goods" could also be required	Implements STANAG with additions		
Shock Response Spectra (SRS) shock	None of the procedures reviewed can be recommended. Versions of the SRS shock test procedure exist in all standards but with significant differences mostly concerns exist on repeatability of all procedures.				
Pyrotechnic shock (shock originating from operation of small explosive devices)	Recommended			Early version of STANAG	
Rail impact	Recommended but question whether a European need	Various procedures and severities exist in all standards but with differences in severity, reflecting different wagons and rail systems. Conditions no longer exist in Europe and even in US "new" wagons			

Summary of Recommendations for Shock Test Procedures					
	NATO STANAG 4370 AECTP	International EN IEC 60068	UK Def Stan 00-35	US Mil Std 810F	France GAM EG 13
	exists	significantly mitigate conditions.			
(UNDEX) test <i>Ship or Submarine shock due to nearby non-contact or underwater explosion</i>	Recommended		Procedure similar to STANAG		Recommends use of SRS test procedure
Ballistic shock	Recommended but with reservation on disadvantage imposed on European industry	No specific test procedure		Same as STANAG procedure	
Catapult Launch / Arrested Landing	No specific test but Time History Replication recommended		Recommended via Time History Replication	Comparable to Def Stan	
Bump (applicable to components only)		Recommended but question need for military use	Equivalent to EN IEC 60068		Equivalent to EN IEC 60068

A.3.4.1 Classic Waveform or Basic Shock Test

The Classic Waveform or Basic Shock Test is used by suppliers of COTS equipment commonality between commercial and military procedures are highly desirable. Both the UK and French military standards align with the procedure of EN IEC 60068. Mostly that is also the case for NATO STANAG 4370, although the form and tolerances on one pulse type differ for no apparently good reason. The procedure of US Mil Std 810 differs from all the other standards to a significant extent. Moreover, the US Mil Std permits an “alternative” process which can result in yet greater variations.

In summary, insignificant exist between the UK Def Stan 00-35, the French GAM EG 13 military standards as well as the EN IEC 60068 for classical waveform, as such any of these could be adopted. The UK Def Stan 00-35 has defined a new damped sinusoidal waveform which is more representative of many transients actually experienced particularly on road vehicles. The NATO STANAG 4370 military standard could replace the European military standard and commercial procedures but for the lack of total commonality in several key areas. As the classic waveform shock test is commonly used for COTS equipment, the lack of commonality has significant implications. Further work is needed to align the technical details of the STANAG test to those of European and commercial standards. For this reason the procedure of EN IEC 60068 is recommended but either of the UK and French military standards are acceptable equivalents. The UK national defence standard is recommended if a damped sinusoidal waveform is required.

A.3.4.2 Handling Shock Test

The Handling Test comprises several procedures. NATO STANAG 4370 includes three procedures vertical impact, horizontal impact and bench handling. The horizontal impact and bench handling impacts are essentially those of the US Mil Std 810 and GAM EG 13 standards but with the US severity for bench handling. The vertical impact severity is prescriptive and based upon mass of the item (from the US standard). In practice NATO STANAG 430 is the US Mil Std 810 with apparently only modest acknowledgment to other specifications. In particular the procedures differ from the two EN IEC 60068 tests arguably without apparent good cause. Moreover, the use of prescriptive "hardening" severities for the vertical impact test could be seen as limiting the use of commercial equipment and packaging in circumstances where full military hardening criteria are not necessary.

The NATO STANAG 4370 military standards currently cannot be considered a replacement for European military standard or commercial procedures. The handling shock test is frequently used for COTS equipment and lack of commonality with commercial standards has significant implications. For this reason the procedure of EN IEC 60068 is recommended although the UK Def Stan 00-35 and French GAM EG 3 military standards are acceptable alternatives.

A.3.4.3 Safety Drop Test

For systems containing dangerous items and particularly energetic materials a separate set of handling tests are commonly mandated either by national or international requirements. These can be grouped as "safety impact test" in which the equipment would be expected to remain "safe only" or "safe only for disposal".

The main test procedure is NATO STANAG 4375 requires drops of not less than 12 m onto face and edges of the packaged and / or unpackaged weapon. The impact surface is enhanced from previous definitions but the procedure is backwardly with existing surfaces. The current UK Def Stan 00-35 Test sets requirements above and beyond the NATO STANAG 4375 because of specific UK need for a potentially greater drop heights and drops onto spigots (although this latter requirement is only infrequently requested). The procedure appears to be based upon the previous issue of NATO STANAG 4375 (safety drop test). STANAG 4375 is frequently listed along with a number of other safety tests (fire, bullet impact etc). A subset of these are used to demonstrate 'insensitive munitions' (IM) criteria. In most countries the safety drop test is not a mandatory IM test, although, it is in some and is mandatory in others for different reasons.

The UN Recommendations On The Transport Of Dangerous Goods ST/SG/AC.10/Rev.12 (sometimes known as the orange book) contains a drop test which is intended as an International Regulation for certifying the adequacy of packages when transporting dangerous goods. The drop height required for explosives in the drop test set out in the UN standard is significantly less than the heights required in the specifically military tests already addressed. However, the acceptance criteria that must be met differ and are more demanding. These differences will not normally allow the military safety drop tests to encompass the requirements of the UN test or vice versa.

The NATO STANAG 4375 encompasses other national military requirements and is consequently recommended. However, this test is not compatible with the International Regulation set by the UN for the Transport of Dangerous Goods. For munitions, in particular, both tests are likely to be necessary.

A.3.4.4 Shock Response Spectra Test

The Shock Response Spectra Test included in the latest NATO STANAG 4370 method is extensively revised from earlier versions. It appears to encompass issues from the UK Def Stan, the French GAM EG 13 method and Mil Std 810. The latest NATO STANAG 4370 method and the recent the EN IEC 60068-2-81 test procedure undoubtedly comprise the most up to date SRS methods available. However, they are entirely different from each other and so far both are unproven in the real world testing of equipment. Both give considerable flexibility to the test house in the conduct of the test and the waveform actually applied. However, this is a

disadvantage to the test specifier who cannot necessarily be certain the assumed damage modes have correctly exercised. In contrast the UK Def Stan00-35 and the French GAM EG 13 methods have been shown to work and address the problems of associated with ensuring repeatability. However, they do not necessarily allow use of the latest techniques included in commercial control software packages.

The primary reason for shock testing in military applications differs from that of commercial applications. Nevertheless, ideally, the actual test procedures for military and commercial applications should be interchangeable. Of the military standards NATO STANAG 4370 is recent but the approach is not well proven in real world applications. None of the methods fully address the main weakness of the SRS method that is repeatability. If repeatability is an issue a test specifier may find the UK Def Stan 00-35 and the French GAM EG 13 method as more useful. Nevertheless, concerns regarding the inability of any of the procedures to ensure repeatability are sufficiently strong that no test procedure can be currently recommended.

A.3.4.5 Pyrotechnic Shock Test

The Pyrotechnic test procedure is intended to simulate the effects of high frequency shocks such as those induced by the operation of pyrotechnic operated cutters, bolts, line cutting charges etc. Mostly this type of shock is unique to military equipment; the main exception is the separation shocks arising separation systems in commercial satellites / boosters. Consequently, it is not surprising that this test method is not contained in general commercial standards, excepting specialist ESA or NASA requirements. The latest NATO STANAG 4370 method is updated from earlier versions as well as the latest version of the US Mil Std procedure. It appears largely based largely on the Mil Std 810 with additional information but would seem to adequately encompass the relevant aspects of the French GAM EG 13 procedure.

In summary, the NATO STANAG 4370 procedure appears to encompass existing tests and is consequently recommended.

A.3.4.6 Rail Impact Test

The rail impact test procedure is essentially intended to simulate the effects of rail shunting shocks on packaged goods. Two different strategies are observed; one to replicate the actual rail shunting / impact conditions by forcing rail wagons into one another at defined velocities, the other strategy is to simulate the effects of the impact using procedures such as the classic waveform test procedure with appropriate test severities.

The latest version of the Mil Std has substantially modified earlier (Federal) procedures but it is still US rail system specific and needs to be done with rail wagons. The French standard GAM EG 13 also contains a rail impact test. Whilst, this procedure also requires complete rail wagons, very little definitive information is contained in GAM EG 13. The EN IEC 60068 test does not contain a specific rail procedure, although EN IEC 60721 (the associated environmental severities) does encompass rail shock by means of classic waveform test procedure. A similar strategy is adopted in the UK Def Stan 00-35. NATO STANAG 4370 contains three procedures; two of these impact loaded rail wagons to produce the shock, the third allows laboratory simulation using either the classic waveform test or the SRS procedures. Of the two procedures that impact loaded rail wagons, one is stated as mandatory for the US rail system (although the justification for the mandatory statement is questionable) the other is indicated as a requirement for the European rail system (the justification is questionable).

In recent times rail shock severities on the European rail systems have decreased substantially. This is because European rail vehicles now use better buffing equipment (hydraulic buffers produce much lower shocks than spring) and more significantly as operating procedures have changed. Changed operating procedures have essentially eliminated shunting impacts because rail train sets are rarely broken into individual vehicles (especially when loaded). Today the need for a specific procedure to reproduce rail impact appears to originate almost entirely from

consideration of the US rail system. For European defence equipment laboratory simulation are the only cost effective and practical approach, if a test is needed at all.

In summary, the NATO STANAG 4370 appears to contain the most options but contains implied requirements for testing and the severities which do not align with commercial standards such as EN IEC 60721. Concern exists that the STANAG may be over specifying requirement to meet US criteria which do not exist in Europe. Nevertheless as a procedure that of NATO STANAG 4370 is recommended.

A.3.4.7 Underwater Shock (or Undex) Test

The Undex Test simulates the shock effects from non-contact explosions adjacent to warships. The test has historically used a range of specialist facilities. Generally each of the various facilities had accompanying specific test procedures. Consequently, the test was not usually included in more general military procedures. A move towards the use of a broader range of test facilities has necessitated the inclusion of appropriate test procedures in military procedures. As the type of test is entirely military, no commercial equivalents are available. Of the procedures reviewed the UK Def Stan 00-35 includes a very basic procedure aimed at setting up the test but does not include information on tolerances or severities. The NATO STANAG 4370 contains a specific and recent procedure. The procedure contains extensive guidance and allows the use of both general and specific equipment. It also includes information on tolerance strategy.

In summary, the NATO STANAG 4370 test is really the only coherent procedure and as such is recommended.

A.3.4.8 Ballistic Shock Test

The Ballistic Shock Test method simulates a high-level transient shock that generally results from the impact of projectiles or ordnance on armoured combat vehicles, hardened targets, or other structures. The latest NATO STANAG 4370 method is effectively identical to the latest US Mil Std procedure, although without severity information. The test does not specifically appear in French military specification GAM EG 13 or the UK Def Stan 00-35 although it could be argued that it is included within the generic shock procedure. As it is entirely a military requirement the test method also does not exist in IEC or CEN commercial standards. The main issue with both the US Mil Std 810 and NATO STANAG 4370 procedures is that three of the five sub-procedures utilise US test facilities. Moreover, the only sub-procedure that uses facilities that are commonly available in Europe has limited applicability to equipment with a mass of 40 Kg.

In summary, although the NATO STANAG 4370 procedure is recommended, it is with significant reservations as to the disadvantages it imposes on European industry. Also the absence of severities in the STANAG makes the procedure of doubtful practical value. These issues could be resolved with further work to define requirements as is the norm in Europe rather than cook book procedures to use specific test equipment which seems to be the norm in the US.

A.3.4.9 Catapult Launch /Arrested Landing Test

The Catapult Launch / Arrested Landing Test has appeared in the US Mil Std 810 since almost the earliest version. The test was intended for naval aircraft equipment and weapons. The French GAM EG 13, the UK Def Stan 00-35 and the NATO STANAG 4370 refer to a severity but use more general procedures. In recent times this has commonly used the Shock Response Spectra test procedure. However, procedures that use the SRS approach may not be representative in term of generated time history. Indeed the waveform generated during test may be different to that occurring during in-service life. The Time History Replication (THR) test procedure define in UK Def Stan 00-35 is considered to be a more representative way to test a materiel to catapult launch and arrested landing shocks. However, the UK Def Stan 00-35 procedure needs to indicate a process in case measured data are not available.

A.3.4.10 Bump Test

The Bump Test uses relatively simple test equipment and allowed the application of repetitive shocks of reasonable amplitude at a time when vibration test equipment was not widely available. A test using this procedure typically utilises several a half sine pulse, repetitively applied, with a few seconds interval between each pulse. Although, the original rationale for this test has long been superseded, it is still used by suppliers of COTS and OEM equipment to demonstrate the ruggedness of components and subsystems. For this reason, commonality between commercial and military procedures is highly desirable. Both the UK Def Stan 00-35 and French GAM EG 13 military standards align with the procedure of EN IEC 60068. The test does not appear in NATO STANAG 4370 largely because it does not replicate a particular environmental condition.

In summary, the procedure of EN IEC 60068 is reflected in other standards which still contain this test. As a procedure to test both assemblies and sub-assemblies, it is undoubtedly inappropriate; it may still have value for components, but only to a limited extent.

A.4 REVIEW AND COMPARISON OF MISCELLANEOUS MECHANICAL TEST METHODS

A.4.1 Standards Under Consideration

The standards reviewed and compared with regard miscellaneous mechanical conditions are set out in the following table.

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Constant Acceleration	404	7	2-13 / M13	513	1st Part method 45
Bounce / Loose Cargo	406	55	2-11 / M11	514 Procedure II	1st Part method 42 - procedure 5
Materiel Tiedown	407				
Motion Platform	418				
Large Assembly Transport	408		2-14 / M14	514 Procedure III	1st Part method 42 - procedure 4
Materiel Lifting	409		2-15 / M15		
Materiel Stacking	410	UN "Orange" Book ST/SG/AC.10/R ev.12	2-16 / M16		
Materiel Bending	411		2-17 / M17		
Materiel Racking	412		2-18 / M18		

A.4.2 Technical Comparison

A.4.2.1 Constant Acceleration

The constant acceleration procedure is one of the oldest mechanical tests and appears in many compendiums of standards for most types of equipment especially for aerospace components. It is also one the simplest mechanical test procedures with variations mostly centred on guidance and severities. It is frequently the case that this test procedure experiences very few changes most related to guidance and severity. The most common type of test equipment for undertaking this test is a centrifuge although in certain cases sled tracks can also be used. Although the latter are sometimes used for commercial equipment they are more frequently employed on military equipment requiring higher levels of acceleration.

In the majority of cases the use of the constant acceleration tests is likely to be limited to sub-assemblies rather than complete systems (the capabilities of which are likely to establish by computation). As these sub-assemblies may be COTS equipment it is important that commercial and military test procedures align.

The commercial procedure EN IEC 60068 and the UK Def Stan 00-35 procedure are specifically written for use with a centrifuge, although, both could be adapted for use with sled tracks. The French GAM EG 13 standard and the US Mil Std 810 both address centrifuge and sled tracks. The latest NATO STANAG has a degree of commonality with the UK, French and US national standards. However, the latest version contains considerable amount of guidance mixed within

the procedural requirements. This is to such an extent that the actual requirements are difficult to ascertain and firmness of content could be considered to have been compromised.

A.4.2.2 Bounce / Loose Cargo

This is again a very old test procedure originally written around particular piece mechanical test equipment. The test equipment causes a platform able to move in two dimensions onto which sits the packaged equipment under test. When the platform is stimulated at a fixed frequency by cams the packaged equipment moves as a loose item and is able to “bounce” on the platform. The original intent was to crudely simulate the most severe motions of a wheeled transport vehicle and consequently the impacts that an item of loose cargo may experience. The particular piece of mechanical test equipment utilised originates from around the 1950’s and can only be utilised for this specific purpose.

The test amplitudes are set intrinsically by the mechanical construction of the particular piece of test equipment utilised and the only real variable is test duration. The machine uses two cams to produce platform motion each running at a fixed speed but at slightly different speeds from each other. The two cams produce two dimensional motion of the platform via linkages.

The test was originally derived for packaged items transported by wheeled vehicles. The test severities were originally developed for commercial applications. However, they are generally no longer considered applicable for that use. This is mostly because vehicles and road surfaces have improved. As a consequence the test was frequently found to induce damage not generated in practice. As the test amplitudes cannot be readily adjusted the use of the test has significantly decreased for commercial applications. The severities were found to be more realistic for military items carried either off-road or on degraded roads. Although, originally intended for packaged equipment, for military applications it is often utilised for unpackaged equipment in its tactical configuration. For military applications the test may be called to simulate transport in tracked vehicles, however, the particular piece of mechanical test equipment used for “bounce” testing has no real technical basis for use in simulating those conditions.

The commercial procedure EN IEC 60068, the UK Def Stan procedure, the French GAM EG 13 standards and the US Mil Std 810 are essentially written around the use of the original 1950’s mechanical test equipment. A slight difference exists in the way the cams transmit motions to the platform in the US test procedure from that set out in all the other procedures listed. This is a subtle difference as it seems likely to generate a smaller difference in equipment response than the differences between different manufacturers test equipment. The latest NATO STANAG is also written around the use of the original 1950’s mechanical test equipment. However, it does resolve the subtly differences in motion between the US and European national procedures.

Some alternatives to the 1950’s mechanical test equipment do exist but none are universally accepted. The UK Def Stan and to some extent the NATO STANAG allow the use of alternative equipment but only provide they generate similar motions to the 1950’s mechanical test equipment. Such alternative equipment is usually a two dimensional platform excited by (usually) four hydraulic rams. The (quite old) US Mil Std 331 permits the loose cargo testing of packaged fuzes on a single axis electro-mechanical vibrator. The loose cargo testing of commercial packages is frequently achieved on single dimensional electro-hydraulic or electro-dynamic vibrators as part of a vibration test. Similar methods have been utilised for some specific military ordnance items in several countries. These alternative commercial methods are already enshrined in some product specific international commercial standards. Moreover, generic CEN and ISO standards encompassing such procedures are likely to be issued shortly.

The NATO STANAG has a slight advantage over the EN IEC 60068 and the various national military standards. This advantage arises simply because it resolves the subtly differences in motion between the US and European national procedures. This notwithstanding, the specific 1950’s mechanical test equipment all these methods resolve around is not particularly flexible or repeatable. The use of modern and more flexible test equipment is permitted by some product

specific commercial procedures and generic CEN and ISO standards are likely to be available shortly.

A.4.2.3 Materiel Tie Down

NATO STANAG 4370 includes a test method used demonstrate the adequacy of a package or container to resist, during tie down, the applied loads without unacceptable degradation of its structural and/or its functional performance. It is particularly applicable to materiel having integral attachments such handles, eye bolts and shackles. None of the European national military standards include a similar test nor does EN IEC 60068. However, various CEN and ISO package standards do include similar basic requirements.

The NATO STANAG 4370 test is a basic static loading test of container handling features which does not necessarily encompass CEN, ISO or European legislative requirements. Military use may require loadings in excess of those specified (in CEN & ISO standards) by commercial use. However, the specified lowest loadings should be the commercial standards and European legislative requirements.

A.4.2.4 Motion Platform

NATO STANAG 4370 contains a test to replicate the motion that may be induced on platforms such as a large ship during a rough sea state. The test is intended is intended to replicate rigid body motion in terms of linear and rotational motions. The need for an equipment to operate at different angular positions is requirement of many platforms. Compliance with these requirements is normally verified by a range of methods. These methods are not normally included as environmental tests. Nevertheless ship board equipment may be COTS intended for fixed installation; consequently a standard method of verifying adequacy is useful. Although no equivalent test exists in EN IEC 60068, a Ship platform specific (vertical) IEC standard does exist and the NATO STANAG 4370 should adopt that procedure.

A.4.2.5 Large Assembly Transport Test

This test procedure was intended to be an alternative to laboratory simulation when items were very large or massive. The procedure may be used for large / heavy packaged items, large packs of artillery rocket, large command & communications shelters or large NBC monitoring systems. Essentially the procedure permits mounting of the equipment on appropriate vehicles which then transits appropriate surfaces (usually test tracks), at appropriate speeds for appropriate durations.

The UK Def Stan 00-35 includes a specific test procedure for large assembly transport testing. It does not specify specific surfaces, speeds or durations. Rather it suggests these should be derived from knowledge of intended usage. An alternative option for large equipment is also permitted in the French GAM EG 13 standard and the US Mil Std. The latest NATO STANAG includes a specific large assembly transport test procedure as an alternative to laboratory simulation. This reflects all the components of the national standards. Again the basic procedure does not contain specify requirements for surfaces, speeds or durations. Whilst, it does include some guidance, that resolves entirely around US test track surfaces and test operating procedure. No equivalent exists in the commercial procedure EN IEC 60068.

A.4.2.6 Materiel Lifting, Stacking, Bending and Racking Tests

The four test procedures materiel lifting, stacking, bending and racking tests all originate from packaging test standards. They were originally intended to verify the adequacy of packages but can also be used to verify that the conditions do not degrade the equipment within the package.

The original UK Def Stan 00-35 tests are effectively identical to those of Def Stan 81-41 Part 3. The NATO STANAG 4370 tests reflect the UK Def Stan procedures. The Def Stan 81-41 part 3 test procedures are also those of NATOSTANAG 4340 AEPP-3. No equivalent exists in the commercial procedure EN IEC 60068. However, various CEN and ISO package standards do

include similar basic requirements. Given that they encompass a larger range of package type is difficult to understand why the STANAG does not encompass such commercial procedures.

The UN "Orange" Book (or more formally Recommendations on The Transport of Dangerous Goods ST/SG/AC.10/Rev.12) contains a stacking test which is intended as an international requirements for demonstrating the adequacy of packages when transporting dangerous goods. Dangerous goods in this instance are categorised as a range of materials one of which is explosives. UN certification against nationally implemented versions of this standard is required before dangerous goods can be transported using most commercial means. This is especially the case for international transportation. Although the test procedure of the UN test is the same as that in the Def Stan 00-35 & NATO STANAG ££&) tests, the severity and criteria differ. Although these differences would currently dictate separate they are not so great as to be insurmountable.

A.4.3 Conclusions of Review of Miscellaneous Mechanical Test Methods

A summary of the recommendations is shown in the table below which is expanded in the following paragraphs.

Summary of Recommendations for Miscellaneous Mechanical Tests					
	NATO STANAG 4370 AECTP	International EN IEC 60068	UK Def Stan 00-35	US Mil Std 810	France GAM EG 13
Constant acceleration	Recommended but with reservations as to quality of procedure	Essentially equivalent to STANAG Test.			
Bounce / loose cargo	Recommended	Essentially equivalent to STANAG procedure but note differences in motion between US/ITOP procedures and European procedures.			
Materiel tie-down	Cannot be recommended in current form	Better commercial (CEN and ISO) standards exist			
Motion Platform	Cannot be recommended in current form	Better commercial (CEN and ISO) standards exist			
Large assembly transport (use of test tracks instead of laboratory tests)	Recommended but reflects US facilities not necessarily available in Europe				
Materiel, lifting, stacking, bending and racking	Recommended		Equivalent to STANAG Test.		

A.4.3.1 Constant Acceleration

The Constant Acceleration test procedure is usually limited to sub-assemblies rather than complete systems (the capabilities of which are likely to established by computation). As the sub-assemblies may be COTS equipment it is important that commercial and military test procedures align. The procedure in EN IEC 60068 and the UK Def Stan 00-35 were specifically written for use with a centrifuge, although, both could be used with sled tracks. The French GAM EG 13 and the US Mil Std 810 both address both centrifuge and sled tracks. The latest NATO STANAG 4370 has a degree of commonality with the UK, French and US national standards. It

also addresses centrifuge and sled tracks. However, the latest version contains considerable amount of guidance mixed within the procedural requirements. This guidance exists to such an extent that the actual requirements are difficult to ascertain and firmness of content could be considered to be compromised.

In summary, the difference between the various tests is not particularly significant and any of those reviewed could be adopted. The NATO STANAG 4370 has the greatest degree of commonality to the other military standards; however, it is compromised by the lack of firmness of content. As this test is frequently used for COTS equipment this has significant implications. For the same reason greater effort is also required to align the NATO STANAG 4370 to commercial standards. If it were not for this it would be the most applicable single standard and recommended.

A.4.3.2 Bounce / Loose Cargo

The Bounce / Loose Cargo test procedure is quite old and written around a particular item of mechanical test equipment. The test amplitudes are set by the mechanical construction of the test equipment and the only real variable is test duration. The commercial procedure EN IEC 60068, the UK Def Stan 00-35 procedure, the French GAM EG 13 standards and the US Mil Std 810 are essentially written around the use of the original 1950's mechanical test equipment. The NATO STANAG 4370 procedure has a slight advantage over the EN IEC 60068 the various national military standards. This is because it resolves the subtle differences in motion between the US and European national procedures. This notwithstanding, the specific 1950's mechanical test equipment all these methods resolve around is not particularly flexible or repeatable. The use of modern and more flexible test equipment is permitted by some product specific commercial procedures and generic CEN and ISO standards are likely to be available shortly.

In summary, the NATO STANAG 4370 addresses the slight differences between the US and European approaches, something the EN IEC 60068 test fails to do. As NATO STANAG 4370 has greatest degree of commonality to both civil and other military standards it is recommended here. However, all the procedures utilise very old equipment and badly require a degree of technical innovation to update this approach.

A.4.3.3 Material Tie Down.

The NATO STANAG test is a basic static loading test of container handling features which does not necessarily encompass CEN, ISO or European legislative requirements. None of the European national military standards include a similar test nor does EN IEC 60068. However, various CEN and ISO package standards do include similar basic requirements. Military use may require loadings in excess of those specified (in CEN & ISO standards) by commercial use. The specified lowest loadings should be the commercial standards and European legislative requirements. As such the NATO STANAG 4370 test cannot be recommended in its current form.

A.4.3.4 Motion Platform.

NATO STANAG 4370 contains a test to replicate the motion that may be induced on platforms such as a large ship during a rough sea state. The test is intended to replicate rigid body motion in terms of linear and rotational motions. The need for an equipment to operate at different angular positions is requirement of many platforms. Compliance with these requirements is normally verified by a range of methods. These methods are not normally included as environmental tests. Nevertheless ship board equipment may be COTS intended for fixed installation; consequently a standard method of verifying adequacy is useful. Although no equivalent test exists in EN IEC 60068, a Ship platform specific (vertical) IEC standard does exist and the NATO STANAG 4370 should move towards adopting that procedure. As such the STANAG 4370 test cannot be recommended in its current form.

A.4.3.5 Large Assembly Transport

The Large Assembly Transport test procedure was intended to be an alternative to laboratory simulation when items were very large or massive. The UK Def Stan 00-35 includes a specific test procedure for large assembly transport testing. An alternative option for large equipment is also permitted in the French GAM EG 13 and the US Mil Std standards. The latest NATO STANAG includes a specific large assembly transport test procedure as an alternative to laboratory simulation. This reflects all the components of the national standards. However, the basic procedure does not contain specify requirements for surfaces, speeds or durations. It does include some guidance on this but that resolves around US test track surfaces and test operating procedure. No equivalent exists in the commercial procedure EN IEC 60068. In summary this test reflects the large nature of certain military equipment and the need to use other than laboratory test facilities. The NATO STANAG 4370 reflects other military standards and is hence recommended.

A.4.3.5. The Four Materiel Lifting, Stacking, Bending and Racking Tests

The Four Materiel Lifting, Stacking, Bending And Racking test procedures all originate from packaging test standards but can also be used to verify that the conditions do not degrade the equipment within the package. The original UK Def Stan 00-35 tests are effectively identical to those of Def Stan 81-41 Part 3. The NATO STANAG 4370 tests reflect the UK Def Stan procedures. The Def Stan 81-41 part 3 test procedures are also those of STANAG 4340 AEPP-3. No equivalent exists in the commercial procedure EN IEC 60068.

In summary the NATO STANAG 4370 reflects other military standards and is hence recommended. However, the STANAG stacking test does not encompass the UN Transport of Dangerous Goods stacking test which may additionally be required

A.5 Review and Comparison of Temperature, Humidity and Pressure Test Methods

A.5.1 Standards Under Consideration

The standards reviewed and compared with regard temperature, humidity and pressure test methods are set out in the following table.

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
High Temperature	302	2 Test B Dry Heat 14 Change of Temperature	3-01 / CL1 3-02 / CL2 3-11 / CL11	501	Part 1 Method 02 Hot
Low Temperature	303	1 Test A Cold 14 Change of Temperature	3-04 / CL4 3-05 / CL5	502	Part 1 Method 01 Cold
Thermal Shock	304	14 Change of Temperature	3-14 / CL14	503	Part 1 Method 7 Thermal Shock
Solar Radiation	305	5 Test Sa 9 Guidance	3-03 / CL3	505	Part 1 Method 9 Solar Radiation
Humidity	306	30 Damp Heat Cycle 38 Temperature Humidity Cycle	4-07 / CL7 4-06 / CL6	507	Part 1 Method 03 Humid Heat
Pressure	312	13	3-21 / CL21 3-20 / CL 20 3-09 / CL 09	500	
Temperature, Humidity Altitude	317	39 40 41	3-11 / CL 11 3-12 / CL 12 3-13 / CL13	520	05 10 11
Icing	311		3-10 / CL 10	521	14
Freeze Thaw	315		3-24 / CL 24		22

A.5.2 Technical Comparison

A.5.2.1 High and Low Temperature Test Procedures

Constant temperature testing, either hot or cold, is undertaken to demonstrate equipment functions correctly at elevated or reduced temperature. Constant amplitude temperature tests are frequently used, by suppliers of COTS equipment, to demonstrate a high and low temperature operational capability. In this form, the test procedures are relatively old and exist in both civil and national military standards. When the procedures are used for COTS equipment, commonality between civil and defence specifications is important. For demonstrating operational capability, the specifications should also be firmly written such that the test actually undertaken is well understood.

All the standards reviewed have separate constant temperature hot and cold procedures. However, for practical purposes the comparison arguments are essentially identical regardless

of whether hot or cold procedures are considered. To avoid repetition the two types of test are addressed together here.

Although, the constant temperature hot and cold test procedures are similar, they differ from the thermal cycling test procedures. Progressively the thermal cycling test procedures are being used to simulate ageing and taking over from the constant temperature tests for complete systems. This is because a demonstration that equipment is able to operate and survive in a thermal cycling test has shown to be more beneficial. Test procedures to allow realistic thermal cycling appear differently in the various standards. In some standards, they appear as separate procedures, in others as different options within the hot and cold procedures. They are also sometimes combined with humidity or solar radiation testing. For these reasons direct comparison is consequently difficult.

The civil standard IEC EN 60068-2-1 Cold and EN IEC 60068-2-2 Dry heat are both firmly written constant temperature tests. These tests appear to be the base for both the original UK Def Stan 00-35 tests and the French GAM EG 13 test procedures. The EN IEC 60068 tests are also commonly used for COTS equipment. A separate procedure exists EN IEC 60068-2-14 Test N Change of Temperature, which permits a coarse cyclic test. This latter test is not particularly sophisticated and does not permit user defined temperature cycles. One of the cycle types set out in this procedure which was, historically, commonly used for defence applications. However, it was found to generate unrepresentative failures and consequently the cycle has been superseded in most military standards, which now allowing the tailoring of the cycle profile to replicate either actual daily cycles or user defined cycles.

The UK national military standard Def Stan 00-35 contains two constant temperature test procedures. Test CL1 Constant High Temperature - Low Humidity Test is essentially identical to EN IEC 60068-2-2 Test B Dry heat test procedure. Test CL4 Constant Low Temperature Test is technically similar to EN IEC 60068-2-1 Part 2 Tests A Cold. Test CL5. However, Def Stan 00-35 does not recommend either of these test procedures. Rather it recommends the two procedures, which permit diurnal temperature cycling. Test CL2 High Temperature, Low Humidity and Solar Heating Diurnal Cycle Test is technically comparable to test procedures of Method 302 (AECTP 300). The diurnal cycle test allows the use of a standardised but representative 24 hour thermal cycle. The solar heating portion of the Def Stan test is achieved by modifying the temperature cycle rather than by simulating direct solar radiation (with lights). The second temperature cycling test procedure is Low Temperature Diurnal Cycle Test, which is technically comparable to test procedures of Method 303 (AECTP 300). The various diurnal temperature (and humidity) cycles included in Def Stan 00-35 are now reproduced in the NATO STANAG 4370 and in the latest issue of the US national standard Mil Std 810.

The French national defence standard GAM EG 13 Cold and Dry Heat test methods are comparable with the EN IEC 60068 constant amplitude methods. The test severities can be tailored but the amount of guidance information is less than in other military standards. The French standard also contains a Thermal Cycles procedure as well as a Climatic Cycles procedure. The former is a cycle test which includes a coarse cycle similar to the IEC procedure as well as more representative "sinusoidal" type cycle. This is more representative than the IEC cycle but not as representative of real conditions as in Def Stan 00-35, STANAG 4370 or Mil Std 810. The climatic cycles procedures combine hot and cold cycles and it is essentially a derivative procedure.

NATO STANAG 4370 contains a high temperature procedure (Method 302) and a low temperature procedure (Method 303). Each includes three procedures the first two of those related to storage and operating. The storage procedure allows both cyclic testing as well as constant amplitude testing, the operating procedure is a cyclic test. In both cases the cyclic conditions are based upon a realistic daily thermal cycle. The use of the storage procedure at constant amplitude is very much a secondary option and this aspect is not written in a particularly firm manner which would allow its use on COTS equipment. The third procedure for the hot test is used when the effects of solar radiation need to be included in the cycle but

when the equipment only experiences indirect heating from solar radiation viz. solar radiation is not experienced directly. Specifically, the effects of solar radiation are included by modifying the temperature cycle rather than using lights. The third procedure within the cold test is used to determine whether equipment can be manually operated, assembled or disassembled. A benefit offered by NATO STANAG 4370 is its reasonably comprehensive guidance information. This supplies information to the test specifier to tailor the procedure keeping in mind the following aspects; effects of high temperature on materiel, heat transfer physics, choice of test parameters and determination of test severities.

The US National defence Mil Std 810 procedures for high and low temperature testing are similar to Method 302 & 303 of AECTP 300, but not identical. In this case the “storage” procedure is constant temperature only, whilst, the “operating” procedure allows cyclic or constant temperature testing. The hot test includes a third procedure for “tactical standby to operation” which is essentially a cyclic test allowing the inclusion of the temperature effects of solar radiation (by adjustment of the temperatures rather than using lights). The cold test includes a “manipulation” procedure.

The Mil Std procedures are essentially technically similar to the NATO STANAG tests. The severities are those of the UK Def Stan and the NATO STANAG. Nevertheless, the Mil Std procedures are open to some interpretation and misuse. Neither of the constant temperature test procedures are sufficiently firmly written to use for COTS equipment.

As already indicated the main difference between defence standards and civil standards with regard high and low temperature testing is that the former includes more extensive procedures, which allows temperature cycling rather than essentially constant temperature test. Whilst, some defence systems require verification of operation at constant elevated temperature, determining the degradation effects of temperature cycling is frequently also a strong requirement. Historical experience has indicated that temperature cycling procedures identify, in-service failure modes that cannot be determined from essentially constant temperature testing. Experience also indicates that, unrepresentative cycles induce unrealistic damage and degradation. Whilst, the use of temperature cycling rather than constant temperature testing has frequently been driven by national requirements, it is becoming more commonly specified. For this reason the deficiencies in the civil procedures preclude their recommendation with regard temperature cycling. Of the military procedures STANAG 3470 Method 302 contains methods that are a combination of the national defence standards. Whilst, not particularly well written, STANAG 3470 Method 302 does technically encompass the national defence standards.

As the latest issue of the US Mil Std 810 now includes the UK and STANAG climatic conditions, all the severities (excepting the French GAM EG 13) now align. However, the severities of the climatic conditions can be interpreted in different ways. As a consequence, a much greater the commonality of severities now exists but that does not preclude some differences in requirement occurring. This is particularly the case with regard the duration of testing.

Notwithstanding the above constant high and low temperature testing procedures are required for COTS equipment to demonstrate an operational capability. For this purpose, the IEC 600068 procedure appears to be common with the Def Stan 00-35 or GAM EG 13 tests and generally suitable for COTS testing. It is a common observation that the existing constant temperature test procedures are not necessarily appropriate for equipment, which are self generating significant levels of thermal output.

A.5.2.2 Solar Radiation Test Procedures

For most defence equipment, the simulation of the thermal effects of solar radiation is usually far more common than simulating the actinic effects. For defence equipment subject to solar radiation the induced temperatures can be significantly greater than the climatic temperatures. Moreover, operational military requirements may preclude the use of protection against solar radiation. This notwithstanding civil and military test procedures has historically been quite similar.

The International civil standard EN IEC 60068 contains both a solar radiation test procedure EN IEC 60068-2-5 as well as associated guidance EN IEC 60068-2-9. The latter provides extensive guidance information, but some parts are outdated. The guidance, originally published in 1975, gives information on the radiation sources: carbon arc, xenon, tungsten lamps and mercury vapour lamps. However, there has been progress in lamps technology since 1975 (metal halide sources can be used for heating effects for instance) which are better reflect in more recent standards (the US Mil Std 810 containing the most up to date information).

The UK National military standard Def Stan 00-35 Test CL3 Solar Radiation Test is technically similar to 60068-2-5 and also the NATO STANAG 4370. Extensive guidance and bibliography are given.

The French national military standard GAM EG 13 method is comparable with the EN IEC 60068 method and the guidance is not particularly up to date.

The solar radiation procedure of the US National military standard Mil Std 810 has been significantly updated since in the recent issue. Not only is it compatible with STANAG 4370 but includes much better guidance than any of the other standards reviewed. The Mil Std states that due to the possible change in irradiance, the US procedure is not intended to be used for space applications. This is the case for all the other standards also it is just that they do not say so.

NATO STANAG 4370 contains extensive guidance and bibliography in Annexe A. Most this information is similar to EN IEC 60068-2-9 but is more up to date. Guidance paragraphs address the following topics to conduct the tailoring process; effects of solar radiation, rationale for the choice between the two procedures, specification of the test severities and warning on the health hazards.

The various military solar radiation test procedures are generally comparable and technically similar. The procedure and severities of Def Stan 00-35, Mil Std 810 and NATO STANAG 4370 can be considered identical for all practical purposes. The main difference between them is the duration of testing (for which little guidance is given in any standard) and guidance on how to conduct the test. The latter mostly relates to the inclusion of the latest technology. Some care needs to be taken with the use of EN IEC 60068 as it is no longer as compatible with the military standards as it was historically.

A.5.2.3 Thermal Shock

The thermal shock test is a relatively specialist test replicating only a few real world conditions. Historically the test has not been particularly easy to undertake and tailoring the procedure to specific applications has previously had advantage. Real world conditions producing thermal shock exist which are essentially unique to a small range of defence equipment. Generally, in those cases, the rate of change of temperature is greater than experienced by civil equipment. Nevertheless, in many cases electronic equipment experience greater thermal shock during manufacture and use (switch on and switch off) than is induced by climatic conditions.

Civil International standard EN IEC 60068-2-14 Tests Na and Nb allows a form of thermal shock test to be undertaken. It is firmly written and useful for COTS equipment

The Def Stan 00-35 Part 3 Chapter 3-14 Test procedure A and B incorporates the test methods of EN IEC 60068-2-14 Change of Temperature Tests Na and Nb respectively. However, it changes the rate of change of temperature for defence use. The scope of the Def Stan 00-35 sets out a range of applicable equipment and systems, which is broader than set out in any of the other standards, reviewed here. The range of equipment is very wide, practically encompassing most items systems.

The French national Defence standard GAM EG 13 method is broadly comparable with the IEC method. It allows different rates of temperature change and multiple cycles.

The International NATO STANAG 4370 method 304 encompasses a procedure able to be used for defence applications but is limited to air to air thermal shocks. The method does not address

the temperature shock experienced by materiel transferred between air and liquid or two liquids. The procedure restricts applicability to three broad categories all of which are encompassed by the more broadly specified UK Def Stan. The applicability of two of the categories would generally be accepted as reasonable. However, the third, transfer to a temperature controlled conditions to an extreme climatic condition, could be considered as unnecessary for the majority of systems.

The US Mil Std 810 is not compatible with the EN IEC 60068 test. However, it is technically similar to the, NATO STANAG.

Rapid change of temperature can induce damage mechanisms not exercised by slower temperature cycling tests. The military test procedures include a procedure specifically for this purpose, the civil standard EN IEC 60068-2-14 is a slower temperature cycle and not really comparable. The UK Def Stan has a much greater range of applicability than either the NATO STANAG or the US Mil Std procedure. In comparison to other standards the NATO STANAG is incomplete. The UK Def Stan procedure includes air to air, air to liquid and liquid to liquid thermal shocks. For this reason the UK Def Stan procedure would appear the most applicable.

A.5.2.4 Humidity

As was the case for high and low temperature testing, two forms of humidity test exist; one at essentially constant temperature / humidity and the other in which temperature and humidity cycle. In this case not only is the constant temperature / humidity test applicable to COTS. Nevertheless, the cyclic temperature / humidity is also very commonly adopted for defence systems as it replicates the effects of equipment "breathing" in moisture. It also is a commonly adopted extension of the hot temperature cyclic test. Mostly for defence systems a realistically profiled daily temperature / humidity cycle is adopted.

International civil procedure EN IEC 60068 has two humidity tests; the first EN IEC 60068-2-30 damp heat cycling and the second EN IEC 60068-2-38 temperature humidity cycle. The EN IEC 60068-2-30 damp heat cycling test uses a simple two level temperature cycle during which the humidity is kept at nearly a constant high relative humidity (RH) level. The test allows a user defined upper temperature but not a user defined temperature profile. The EN IEC 60068-2-38 temperature humidity cycle uses a slower rate of rise and fall of the temperature levels and a modest change of humidity. This is to stimulate "breathing" failures caused by the ingress of moisture. However, the test does not readily allow user defined profiles as severities are embedded into the procedure. The procedure is firmly written and can be used for procurement of COTS equipment.

The French national military standard GAM EG 13 Damp Heat test method is comparable with the EN IEC 60068 constant amplitude methods. The test severities can to be tailored but the amount of guidance information is less than in other military standards. The French standard also contains a Thermal Cycles procedure as well as a Climatic Cycles procedure. The former is a cyclic temperature test but with constant humidity. The Climatic Cycles procedures combines hot and cold cycles but again with constant humidity and is essentially a derivative procedure.

The UK National Standard Def Stan 00-35 Part3 Issue 4 recommends the CL7 test that was applicable to materiel stored or operated in locations where the ambient temperature and humidity are high and remain at a substantially constant level. As the diurnal cycle test within CL6 is most appropriate to the natural environment, CL7 has been incorporated into CL6 as a specific subset of the full conditions.–The CL6 test proposes two of tests if it is needed to simulate as close as possible the conditions experiences in service for qualification test for example, or if it is needed to assess function or survivability for design and reliability assessment for example. For each approach (qualification vs design/reliability assessment), Def Stan 00-35 procedures indicates three procedures. The first procedure ("climate test procedure") uses a realistic diurnal cycle of humidity and temperature (including if required the indirect effects of solar radiation). The second procedure ("Temperature/Humidity test procedure"), intended to replicate the highest typical humidity at the highest typical temperature and excludes fluctuations

found in the natural environment, is a course cycle intended to be equivalent to IEC EN 60068 Test Db And Guidance: Damp Heat, Cyclic. The third procedure, is not a different test procedure from "Climate Test Procedure" or "Temperature/Humidity Test Procedure", but deals with test items that can modify the temperature surrounding them, usually when operated and generating heat. In term of test duration, Def Stan 00-35 proposes guidance depending on the duration of exposure. Quite deliberately no aggravated cycles are recommended as is the case in the US Mil Std 810 or NATO STANAG 4370.

The US national defence standard Mil Std 810 includes a humidity test. Until the latest issue this was essentially a constant humidity level test. However, the latest issue has included a new (preferred) procedure which adopts the same cycling strategy as the UK Def Stan 00-35 and NATO STANAG 4370 procedures. The new procedure allows both "Storage and Transit" cycles and the "Natural" or "Metrological" cycles. It offers advice on the use of both in terms of conducting the test and application. The guidance does include good information concerning the most severe conditions that can occur. The old constant humidity (aggravated) temperature cycle remains as procedure 2. This cycle would allow the stimulation of "breathing" failure modes. The Mil Std 810 test procedure is not definitive allowing the user a fair degree of latitude in undertaking the test and selection of severities.

The high humidity (Method 306) test within NATO STANAG 4370 proposes steady state test, diurnal cycle test and aggravated test. The constant humidity test is mostly intended for replicating in-service conditions but could equally be used for COTS equipment. The procedure is reasonably firmly written and could be used for COTS purposes. A major benefit offered by NATO STANAG 4370 is its very comprehensive guidance information. Moreover, NATO STANAG 4370 proposes a test duration depending on the duration of exposure (short term effects, 3 years storage, and long-term storage mainly for package testing) and if it is mostly protected or not protected. Excepting that NATO STANAG 4370 proposes aggravated cycles, test severities and durations are equivalent between STANAG 4370 and Def Stan 00-35.

Broadly the observations for humidity testing are similar to those for temperature testing. For defence equipment a cyclic test has been found to be more representative and commonly used for defence systems. On the other hand firmly written constant amplitude tests are also required for COTS equipment. This is reflected in the various standards reviewed here, with the defence standards encompassing a far broader range of procedures than the civil standard. To some extent this reflects a difference in overall philosophy between the documents. That is EN IEC 60068 is more concerned with setting a standard for OEM and COTS equipment rather than evaluating systems against in-service use. Although the various defence procedures are incorporated in different ways, the STANAG encompasses the majority of the overarching requirements and contains a useful amount of guidance. As constant amplitude humidity testing is also an in-service defence requirement this aspect is reasonably well written and could be used for COTs equipment with a reasonable degree of confidence. However, it is still not as good as the EN IEC 600068, or the Def Stan 00-35, except the fact that NATO STANAG 4370 proposes aggravated, test severities and durations are quite equivalent, in term of qualification tests, between NATO STANAG 4370 and Def Stan 00-35. The STANAG is the best procedure in many areas and acceptable in others, consequently it is recommended.

The recent update to the US Mil Std 810 now includes the same severities as the NATO STANAG 4370 and the UK Def Stan 00-35. This notwithstanding, it is fairly common for the misinterpretations of these severities to occur. This is because the worst case temperatures occur during the Storage and Transport cycles whilst the worst case humidity arises from the metrological cycles. One of the humidity related cycles (B3 Storage and Transport) is suitable for temperature assessment whilst a different cycle (B1 Metrological) is applicable for humidity assessment. The latest US Mil Std includes the more recent guidance on this issue, although the requirements are less clear than the next (currently unpublished) issue of UK Def Stan 00-35. EN IEC 600721 (the environmental aspects of EN IEC 60068) defines conditions in terms of

climatograms (plots of humidity and temperature). This seems a better way of relating temperature and humidity conditions than currently contained in any of the military standards.

A.5.2.5 Pressure

The low pressure test exists in civil and defence standards for several reasons. The most common is to demonstrate that equipment survives and / or operates at elevated locations (high ground) and transported by air. For this purpose a constant pressure test is required. However, for defence applications such as air carried missiles, change of pressure can also be significant. For equipment carried inside aircraft the effects of rapid or explosive decompression is also required. Generally the equipment will be required to remain safe and serviceable after rapid decompression but only remain safe following explosive decompression. High pressure also has a few applications in military applications specifically for submarine and diving applications where specific severities apply.

The international civil standard EN IEC 60068-2-13 test for low air pressure is a simplistic test allowing demonstration that equipment will survive and / or operate at elevated locations and can be transported by air. It comprises subjecting the equipment to constant low pressure without excessive change of pressure. This test may be used for COTS equipment.

The UK national military standard Def Stan 00-35 contains a number of pressure tests some of which overlap with each other. Additionally not all the applications appear to justify separate procedures. Three procedures are primarily used. Test CL21 - Low Air Pressure and Air Transportation Test is technically equivalent to EN IEC 60068-2-13. The second test CL20, Rapid Pressure Change Test is intended for defence related applications related to applying rapid rates of change of pressure associated with manoeuvres of guided weapons and high performance aircraft. The third test is CL09 Rapid or Explosive Decompression test which imposes a very rapid change of pressure to simulate rapid or explosive decompression of aircraft compartments.

The US national defence standard Mil Std 810 encompasses four procedures for equipment; stored and/or operated at high ground elevation sites, transported or operated in pressurized or unpressurized areas of aircraft, exposed to a rapid or explosive decompression and carried externally on aircraft. For each of these procedures, test duration are well described.

The NATO STANAG procedure includes four test procedures; Storage/Air Transport, Operation/Air Carriage, Rapid Decompression and Explosive Decompression. Whilst the procedure is based upon the US Mil Std 810 procedure it incorporates the main components of the UK Def Stan. The UK Def Stan 00-35 contains the most application specific objectives and as a result has the greatest number of pressure testing procedures. With that said it is difficult to see why so many different procedures are really required. The basic procedures of EN IEC 60068 are compatible with other procedures but do not encompass all defence requirements. Nevertheless, the NATO STANAG test is not as firmly written as the EN IEC 60068 procedure or the basic constant altitude Def Stan 00-35 procedure. For COTS equipment, either of these two tests may be preferable.

A.5.2.6 Temperature, Humidity Altitude

The various standards reviewed contain procedures allowing the simultaneous application of various aspects of temperature, humidity and altitude (and in some cases vibration also). The objective behind subjecting equipment to such a combined test arises when combining several environmental conditions produces damage or degradation that would not be found by applying the environments singularly. When the effects of several environments combine in this way is often referred to as synergism.

The reason for subjecting equipment to combined environmental conditions will very much depend upon the type of failure expected. Compromises in the way combined conditions are applied can lead to some tests being able to exercise some failure modes better than others. For this reason selecting a specific procedure may be dependent upon the identified failure modes.

Combined temperature, humidity and altitude testing is notoriously difficult to accomplish especially when all three parameters are required to vary in a predefined way (such occurs in an aircraft during decent).

For the most part the various procedures adopt those of the individual environmental conditions. As these have largely already been addressed it is not intended to reiterate earlier comparisons. Nevertheless, some of the combined procedures, usually encompassing a pair of environments, are intended to be firmly written for specific applications. Conversely, others are intended as a model, which a user can make specific amendments for specific equipment.

Procedures intended primarily for equipment located in unheated and unpressurised areas of aircraft (subject to low temperature and low pressure) include EN IEC 60068-2-40, Def Stan 00-35 CL12 and GAM EG 13 method 05. For aircraft equipment subject to the effects of kinetic heating or imposed thermal conditions tests at altitude may adopt the procedures in EN IEC 60068-2-41, Def Stan 00-35 CL11 and GAM EG 13 method 05. For equipment subject to a cold soak at high altitude and then rapid decent to lower altitude (higher pressure & temperature) which includes humidity applicable procedures are those of EN IEC 60068-2-39, Def Stan 00-35 CL13. These condition are frequently encountered by missiles were optical sensor systems as well as control surfaces may be degraded by the effects of these environments.

The majority of procedures specifically exclude space applications, however, the French GAM EG 13 includes two specific procedures methods 10 and 11.

The US Mil Std 810 and NATO STANAG 4370 procedures offer generic procedures which can be adopted by the user to allow the simulation of specific conditions. In this regard the NATO STANAG 4370 test in particular can be used as a model for the majority of applications set out above. As it is the most flexible procedure it is generally recommended. However, this strategy may not be contractually acceptable for every application. In those cases the EN IEC 60068, Def Stan 00-35 and GAM EG 13 procedures are all firmly written and application specific. As such in those cases would be recommended.

A.5.2.7 Icing

Traditionally the icing test procedure has been used to demonstrate the ability of equipment to survive and / or function when exposure to icing conditions when subjected to water, spray, fog or mist at sub-zero temperatures. The procedure also provides a means for evaluating the effectiveness of de-icing equipment and techniques.

The UK national military standard Def Stan 00-35 icing test procedure includes two methods. The first general method requires a specified depth of ice to be produced on the equipment. This is achieved by spraying water (or salt water solution). The second method in the Def Stan 00-35 is included specifically to comply with EEC Directive 78/317/EEC to determine the effectiveness of vehicle windscreen de-icing systems.

The French national military standard GAM EG 13 includes an icing test very similar to the general procedure in Def Stan 0-35. Both procedures reduce the test item temperature before spraying with water or salt water solution. For ice thickness up to 13 mm this is done at -10 °C whilst for thicknesses of between 25 to 75 mm the test item is at -25 °C. The purpose of the lower temperature appears to be to allow large ice build in a sensible time.

The US Mil Std 810 procedure is again similar to the general method of the Def Stan and the procedure of GAM EG 13. However, the procedure only uses a temperature of -10 °C regardless of ice thickness. The procedure requires at least 4 hours for the ice to harden.

The icing procedure with the international NATO STANAG 4370 effectively uses the US Mil Std 810 procedure rather than the European methods. Although it has to be said the difference is not that significant. However, the NATO STANAG does incorporate a procedure intended to incorporate the EEC Directive 78/317/EEC to determine the effectiveness of vehicle windscreen de-icing systems.

A.5.2.8 Freeze Thaw

The Freeze Thaw test exists mostly in European procedures. The test is applicable to equipment which may experience temperature cycling through 0°C combined with high humidity, producing a mixture of ice and water and where alternate freezing and melting, may induce stress or cause interference between components and moving parts.

The UK national military standard Def Stan 00-35 includes a Freeze Thaw test procedure. This procedure reduces the temperature of the equipment to -4 °C and then water is sprayed on the item until ice 3 to 6 mm deep is produced. The equipment is then subject to temperature cycle between -4 °C and +2 °C.

The procedure within the French national defence standard GAM EG 13 is markedly different from the UK approach. The French procedure reduces the temperature of the equipment (between -10 °C and -40 °C) and then raises it to 0 °C whilst subject the item to high humidity. The temperature is then reduced again to harden the ice and then brought up to +20 °C.

The NATO STANAG 4370 contains a Freeze Thaw procedure comprising three methods. These appear to be enhanced variants of the methods in the two European standards. Although the three methods are clearly loosely based upon the GAM EG 13 procedure, they have marked differences. These differences appear to be intended to better simulate actual conditions causing Freeze thaw induced damage.

A.5.3 Conclusions of Review of Temperature, Humidity and Pressure Test Methods

A summary of the recommendations is shown in the table below which is expanded in the following paragraphs.

Summary of Recommendations for Temperature, Humidity and Pressure Tests					
	NATO STANAG 4370 AECTP	International EN IEC 60068	UK Def Stan 00-35	US Mil Std 810	France GAM EG
High Temperature – Constant (for COTS equipment)		Recommended			
High Temperature –Diurnal or cyclic	Recommended		Cyclic test Equivalent to STANAG	Cyclic test Equivalent to STANAG	
Low Temperature – Constant (for COTS equipment)		Recommended	Equivalent to STANAG Test		Equivalent to STANAG Test
High Temperature –Diurnal or cyclic	Recommended		Cyclic test Equivalent to STANAG	Cyclic test Equivalent to STANAG	
Solar Radiation (<i>encompassing thermal and actinic degradation</i>)	Recommended	Similar to STANAG but does not include actinic degradation	Similar to STANAG	Similar to STANAG & good guidance	Similar to STANAG
Thermal Shock	Incomplete	Useful for COTS equipment	Recommended		
Humidity – constant cyclic and aggravated	Recommended	Acceptable for COTS equipment	Equivalent to STANAG	Equivalent to STANAG	Equivalent to STANAG
Pressure	Recommended	Suitable for COTS	Essentially equivalent to STANAG but	Essentially equivalent to	Essentially equivalent to

Summary of Recommendations for Temperature, Humidity and Pressure Tests					
	NATO STANAG 4370 AECTP	International EN IEC 60068	UK Def Stan 00-35	US Mil Std 810	France GAM EG
		equipment	includes a greater range of application specific procedures	STANAG	STANAG
Combined Temperature, Humidity Altitude	Recommended as general procedure	Recommended for specific applications related to aircraft & space equipment			Essentially equivalent to STANAG
Icing (not including impact of ice on aircraft and missiles in flight)	Recommended		Cyclic test Equivalent to STANAG	Cyclic test Equivalent to STANAG	
Freeze / Thaw	Recommended enhanced from Def Stan & GAM versions		Older version of STANAG		Older version of STANAG

A.5.3.1 High and Low Temperature Test Procedures

The main difference between defence standards and civil standards with regard high and low temperature testing procedures is that the former include procedures which allow temperature cycling rather than essentially constant temperature test. Whilst, some defence systems require verification of operation at constant temperature, determining the degradation effects of temperature cycling is also a strong requirement. Historical experience has indicated that temperature cycling procedures identify in-service failure modes that cannot be determined from essentially constant temperature testing. Experience also indicates that constant temperature and unrepresentative cycles can induces unrealistic damage and degradation. For this reason the deficiencies in the civil procedures preclude their recommendation. Of the military procedures NATO STANAG 3470 Method 302 contains methods that technically encompass those of the national defence standards for that reason it is recommended. However, for COTS equipment the NATO STANAG 4370 is far from sufficiently firmly written and for this purpose the EN IEC 600068 procedure is recommended, with Def Stan 00-35 or GAM EG 13 as acceptable alternatives.

A.5.3.2 Solar Radiation Test Procedures

The various solar radiation test procedures are comparable and technically similar. No practical differences exist between the military procedures. Up to date guidance is the only real difference. The procedure of EN IEC 600068 is not as applicable for simulating actinic degradation.

A.5.3.3 Thermal Shock

Rapid change of temperature can induce damage mechanisms not exercised by slower temperature cycling tests. The military test procedures include a procedure specifically for this purpose, the civil standard EN IEC 60068-2-14 is a slower temperature cycle and not really comparable. The UK Def Stan has a much greater range of applicability than either the NATO STANAG or the US Mil Std procedure. In comparison to other standards the NATO STANAG is incomplete. The UK Def Stan procedure includes air to air, air to liquid and liquid to liquid thermal shocks. For this reason the UK Def Stan procedure would appear the most applicable.

A.5.3.4 Humidity

The observations for humidity testing are similar to those for temperature testing. For defence equipment a cyclic test has been found to be more representative and commonly used for defence systems. On the other hand firmly written constant amplitude tests are also required for COTS equipment. This is reflected in the various standards reviewed here, with the defence standards encompassing a far broader range of procedures than the civil standard. To some extent this reflects a difference in overall philosophy between the documents. That is EN IEC 60068 is more concerned with setting a standard for OEM and COTS equipment rather than evaluating systems against in-service use. Although the various defence procedures are incorporated in different ways, NATO STANAG 4370 encompasses the majority of the overarching requirements and contains a useful amount of guidance. As constant amplitude humidity testing is also an in-service defence requirement this aspect is reasonably well written and could be used for COTs equipment with a reasonable degree of confidence. However, it is still not as good as the IEC 60068 or Def Stan 00-35, except that STANAG 4370 proposes aggravated cycles. The IEC 60068 and Def Stan 00-35 procedures have a deliberate intent of commonality, which is not apparent in the STANAG. Nevertheless, the NATO STANAG is the best procedure in some areas and could be considered acceptable in others, consequently it is recommended.

A.5.3.5 Pressure

The NATO STANAG procedure includes four test methods; Storage/Air Transport, Operation / Air Carriage, Rapid Decompression and Explosive Decompression, to encompass the defence requirements for low pressure testing viz. for equipment; stored and/or operated at high ground elevation sites, transported or operated in pressurized or unpressurised areas of aircraft, exposed to a rapid or explosive decompression and carried externally on aircraft. Whilst the procedure is based upon the US Mil Std 810 it incorporates the main components of the UK Def Stan and the applicable EN IEC 60068 test procedure. However, the latter does not encompass all defence requirements. Nevertheless, the NATO STANAG test is not as firmly written as the IEC EN 60068 procedure and for COTS equipment that test procedure may be preferable. The UK Def Stan 00-35 includes a far greater range of application specific procedures beyond the basic four test methods in the NATO STANAG, for those specific applications the UK Def Stan 00-35 may be more applicable.

A.5.3.6 Temperature, Humidity Altitude

The US Mil Std 810 and NATO STANAG 4370 procedures offer generic procedures which can be adopted by the user to allow the simulation of specific conditions. In this regard, the NATO STANAG 4370 test in particular can be used as a model for the majority of applications set out above. As it is the most flexible procedure it is generally recommended. However, this strategy may not be contractually acceptable for every application. In those cases the EN IEC 60068, Def Stan 00-35 and GAM EG 13 procedures are all firmly written and application specific. In those cases the following are recommended;

For equipment located in unheated and unpressurised areas of aircraft (subject to low temperature and low pressure; EN IEC 60068-2-40, Def Stan 00-35 CL12 and GAM EG 13 method 05.

For aircraft equipment subject to the effects of kinetic heating or imposed thermal conditions tests at altitude; EN IEC 60068-2-41, Def Stan 00-35 CL11 and GAM EG 13 method 05.

For equipment subject to a cold soak at high altitude and then rapid decent to lower altitude (higher pressure & temperature); EN IEC 60068-2-39 and Def Stan 00-35 CL13.

For equipment in space applications, GAM EG 13 methods 10 and 11.

A.5.3.7 Icing

The icing procedure within the international NATO STANAG 4370 effectively uses the US Mil Std 810 procedure rather than the slightly different European methods. Although it has to be said the difference between the European and US procedures is not that significant. The NATO STANAG 4370 procedure incorporates a method (from the UK Def Stan) intended to incorporate EEC Directive 78/317/EEC to determine the effectiveness of vehicle windscreen de-icing systems. As NATO STANAG 4370 effectively encompasses all aspects of the need for icing testing, it is recommended.

A.5.3.8 Freeze Thaw

The NATO STANAG 4370 contains a Freeze Thaw procedure comprising three methods. These appear to be enhanced variants of the methods in the two European standards Def Stan 00-35 and GAM EG 13. Although the three methods are clearly loosely based upon the French GAM EG 13 procedure, they have marked differences. These differences appear to be intended to better simulate actual conditions causing Freeze Thaw induced damage. As a consequence the NATO STANAG 4370 procedure is recommended.

A.6 Review and Comparison of Natural & Man Made Contaminate Test Methods

A.6.1 Standards Under Consideration

The standards reviewed and compared with regard natural & man made contaminate test methods are set out in the following table.

Matrix of Environmental Test Methods					
	NATO STANAG 4370 AECTP (Method No)	International EN IEC 60068 Part 2 (60068-2-xx)	UK Def Stan 00-35 Part 3 (Chapter / test)	US Mil Std 810 (Test No / Procedure)	France GAM EG 13 (Method / Procedure)
Immersion	307	17 18	3-29 / CL29 4-05 / CN5	512	1st Part method 15
Mould Growth	308	10	4-01 / CN1	508	1st Part method 13
Salt Fog	309	11 52	4-02 / CN2	509	1st Part method 04
Rain and Water Tightness	310	18	3-27 / CL27	506 Procedure I & II	1st Part methods 12, 20
Condensation and Dripproofness	310 Procedure III	18 Test R & Ra Method 2	3-28 / CL28	506 Procedure III	
Sand And dust	313	68	3-25 / CL25	510	1st Part method 18
Contamination By Fluids	314	74	4-04 / CN4	504	1st Part method 16
Explosive Atmosphere	316			511	1st Part method 24
Acidic Atmosphere	319	60	4-03 / CN3	518	

A.6.2 Technical Comparison

A.6.2.1 Immersion

The immersion test procedures are intended to demonstrate the ability of equipment to operate whilst submerged or to survive accidental immersion in water. The test procedures are not intended to replicate the effects, such as corrosion, of long term immersion. The test procedures are relatively simplistic submerging a pre-heated specimen a specified depth below water for a specified period. Mostly the differences between the test procedures relate to severities.

The UK national Def Stan 00-35 procedure and international civil test procedure in EN IEC 60068 are technically similar. The specimen is pre-heated to between 5 and 15 °C above the water temperature. A range of partial or fully submerged depths are allowed although 1 m is suggested as the usual case, a duration of immersion is also suggested.

The French national defence standard GAM EG 13 very similar to the UK Def Stan 00-35 and EN IEC 60068 procedures exception the specimen is pre-heated to either 10 or 27 °C (± 2 °C) above the water temperature. The immersion time is generally longer than the previous procedures although a common 1 m / 2 hour test severity appears. The GAM EG 13 appears to have commonality with the US Mil Std procedure.

The US national military standard Mil Std 810 procedure includes an immersion and a fording test which appears to be a particular case were the item is driven into the water rather than lowered into it. The Mil Std uses the same pre-conditioning temperatures as the French national standard, although the severity is stated in the guidance rather than in the mandatory section. The depth & duration of immersion are specified as 1 m for 30 minutes.

The NATO STANAG 4370 immersion test appears to be a barely modified copy of the Mil Std procedure. It has the same problem with regard including pre-heating temperatures in guidance and only one recommended severity.

Essentially the test procedures fall into two groups those compatible with EN IEC 60068 and those compatible with the Mil Std. However, as the French standard falls into the latter the differences are not polarised between the US and Europe. For COTS / MOTS equipment compatibility with EN IEC 60068 is important for that reason the Def Stan and IEC EN 60068 procedures are jointly recommended for immersion whilst the NATO STANAG 4370 procedure is recommended for fording aspects.

A.6.2.2 Mould Growth

The fungal growth tests are intended to determine whether materials are susceptible to fungal growth. Given the right climatic conditions (warm and wet), spores and nutrients that are commonly present will give rise to fungal growth. The purpose of this test is to determine whether material will be damaged or degraded by this growth. The test accelerates growth of selected species to determine whether damage arises. The species are selected as those that will damage particular ranges of material. Normally the test is done on samples of material rather than on defence systems. Over the years the historical tests has generated databases of materials which are susceptible or resistant to fungus induced damage. In the first instance a designer would select material from these databases. In this regard the test is really a means of obtaining design information.

The test procedure has potential health risks particularly with certain species. As the test needs to be done under controlled conditions the number of facilities that commonly undertake the test is today very limited.

Until very recently the international civil standard IEC EN 60068-2- 10 Test J, the UK national Defence standard Def Stan 00-35 and the French national defence standard GAM EG 13 all aligned and utilised a common group of mould species. As this has been the case for many years a reasonable base of data has accumulated in Europe.

The US national Defence standard Mil Std 810 uses an entirely different group of species from the IEC, UK and French standards. Again these have been used in the US for some time and reasonable base of data has accumulated in the US. However, it has been observed that access to the listed species outside the US can be difficult.

The last update to IEC EN 60068-2-10 Test J has changed the species to a group which are claimed to be as equally effective as the previous species in both the IEC EN 60068 procedure and those of Mil Std 810. However, these species are intended to be more readily available and constitute a lower health risk. Obviously no base of data has yet accumulated.

The NATO STANAG 4370 test procedure lists both European and US species. However, it has been indicated that next edition may include the new IEC species.

If the purpose of this requirement was entirely related to the test then the IEC EN 60068 procedure should be recommended. This is because the procedure has demonstrated technical innovation in the change of species. However, if the purpose is to generate a database for use by designers, then the NATO STANAG 4370 procedure has the greatest value. As existing databases will undoubtedly continue to be used then the overall recommendation must currently be the IEC EN 60068 procedure.

A.6.2.3 Salt Fog

The group of salt fog environmental test procedures intended for several objectives. For military purposes the most common usage is to evaluate the resistance of the material to a salt laden atmosphere. The procedure used for that purpose is not necessarily suitable to establish corrosion resistance, which generally requires some form of cyclic test in a salt laden wet / warm atmosphere. The majority of test procedures used for the first of these objectives quite specifically include the phrase "to evaluate" the resistance of the material to a salt laden atmosphere. This is largely because the salt concentrations are quite high and the test represents an accelerated exposure to actual conditions in order to provide a stressful situation that may reveal potential problem areas in materiel. However, the relationship to actual conditions is far from clear.

The international civil standard EN IEC 60068 includes two procedures for salt atmosphere. The first procedure (Ka) is intended to be used to evaluate the resistance of the material to a salt laden atmosphere. The second procedure (Kb) is a cyclic test (salt mist sprayed followed by exposure to Relative Humidity) used to stimulate corrosion. The two test procedures have a clear common base and both procedures are clearly and firmly written allowing them to be set contractually. However, neither test procedure includes any significant guidance on the test procedure and none on severities. The civil standard EN IEC 60068 quotes cyclic test durations depending on the type of exposure, continuous presence near the sea and occasional presence near the sea.

The UK Def Stan 00-35 contains a single salt atmosphere test which contains two sub-procedures. The procedure explicitly states that the two sub-procedures are technically similar to the Ka & Kb procedures of EN IEC 60068. Unlike the EN IEC 60068 procedure, the Def Stan procedure supplies guidance on both test procedure and test severity. The 6 or 7 severity options included in the EN IEC 60068 procedures are reduced to two specific options for each of the two sub-procedures. Salt Mist Tests are undertaken for 24h (to evaluate short term effect) or 28 days (for long term exposure). Salt Corrosion Tests (salt mist sprayed followed by exposure to Relative Humidity) are undertaken for 3 days (for occasional exposure) or 28 days (for long term exposure). Although the Def Stan procedure is both clearly and firmly written it is annoyingly incomplete. In order to determine the salt composition and concentration the user has to refer to the EN IEC 60068 procedure.

The French national defence test procedure GAM EG 13 also includes a single procedure which fulfils both the objects addressed previously. The GAM EG 13 procedure differs from that of EN IEC 60068 although whether the effects of the differences are significant is debatable. Like the Def Stan test the GAM EG 13 procedures sets two specific severities and supplies advice on their applicability. Unlike the earlier test procedures addresses the GAM EG 13 gives advice on what to inspect following the application of the test.

The US national Defence Standard Mil Std 810 contains a single test procedure. The test is broadly similar to the EN IEC 60068 procedure. Mil Std 810 does not specify a specific duration only 48hr cycles (24hr of aspersion followed by exposure to relative humidity). Thus, it is quite different to the UK Def Stan 00-35. Moreover, Mil Std 810 specifies 48h cycles which are quite different to the Def Stan cycles. The test duration specified by Mil Std 810 is 2 cycles of 48h minimum. Long term and short/occasional effects are not clearly mentioned as it is in Def Stan 00-35 or EN IEC 60068. The procedure does contain significant amount of information on how to undertake the test. Indeed in this respect is undoubtedly the best information available. However, this guidance is at the cost of firmness of the text. The latest version of the Mil Std procedure aligns much better to the international test than did some earlier versions.

The international NATO STANAG 4370 is better written than the Mil Std but is not as firmly written as the Def Stan 00-35 or EN IEC 60068 procedures. Test severities and test durations defined in STANAG 4370 are equivalent to those defined in the US Mil Std 810. Long term and short/occasional effects are not mentioned as it is in Def Stan 00-35 and EN IEC 60068. The test

duration specified by STANAG 4370 is 2 cycles of 48hr minimum. The severities are unclear and this also suggests a degree of unresolved compromise. The procedure does not indicate it is technically similar to EN IEC 60068 but is probably very close to achieving that.

The test severities and test durations of STANAG 4370 and US Mil Std 810 are comparable. The test severities and test durations of IEC 60068 and DEF STAN 00-35 are also comparable. However, the two groups have different test severities and test durations. Only IEC 60068 and DEF STAN 00-35 use propose test duration linked to short / occasional term and long term exposures.

In this case all the different test procedures seem to have some aspects which is better than the others. The EN IEC 60068 procedures are the most firmly written, the UK Def Stan 00-35 procedure is explicitly technically similar to the EN IEC 60068 procedures (equivalent test severities; equivalent test durations and reference to short or long exposures) but has defined severities for defence equipment. The UK Def Stan 00-35 procedure also allows extended corrosion testing. The US Mil Std 810 has the best advice on how to undertake the test. Whilst, the STANAG seems a credible compromise it also seems to have missed the best parts of the national standards. The UK Def Stan 00-35 procedure is recommended as it has a better cycle and duration information than the STANAG, is better written and has explicit commonality with EN / IEC 60068 for COTS and MOTS equipment.

A.6.2.4 Rain and Water Tightness

The rain and water tightness tests are attempting to replicate a highly variable environmental phenomenon. The rain test procedures generally are based upon historical methods which are in turn based around specific equipments. All the procedures reviewed go into some details of the arrangement of the test equipments and nozzles to be used. They also embed aspects of the test severity within the procedure. As the various procedures define the equipment to be used quite differently, direct comparison of the procedures is not really practical or useful. Excepting to note that almost all the national standards use different equipment and none (except the STANAG) seem to attempt to correlate their procedure with any other.

Notwithstanding the above no real evidence seems to exist that one approach is better than another. Generally the procedures are intended to ensure a degree of reproducibility rather than an accurate replication of environment that is quite difficult to fully replicate. Generally, the UK national Defence Standard spray's the equipment with droplets whilst the US and French national standards allow drops to fall on the equipment.

The NATO STANAG procedure comprises a composite of the national standards and attempts to put some logic and methodology around the use of each. In short the STANAG has already attempted a comparison and appears to have come to the conclusion that all the approaches need to be included. The STANAG does not make a conclusive recommendation between procedures but rather includes an extensive annex on guidance for tailoring rain. This includes information on the natural environment.

None of the tests indicate compatibility with EN IEC 60529 (Degree of Protection Provided by Enclosures) which would seem essential for COTS / MOTS equipment. Also the EN IEC 60529 contains severities which are more severe than the military standards. As this relates to power wash it is particularly applicable to military equipment.

A.6.2.5 Condensation and Dripproofness

The UK national standard Def Stan 00-35 is the only standard that contains a specific test to replicate the effects of water and condensation dripping on equipment that may be otherwise protected from water. This would particularly include most equipment located inside vehicles and transportable cabins where condensation and indirect water could occur. Although the UK national standard Def Stan 00-35 is the only standard that contains a specific test it is based upon an earlier version of the international commercial standard EN IEC 60068-2-18 Test R and Test Ra Method 2. The only differences between the two is that the Def Stan has a higher

minimum total flow rate, only one specific height of the nozzles above the item and only one duration. Additionally the geometry of the equipment used for the test differs slightly. Nevertheless, both the UK Def Stan and the international EN IEC 60068 procedures are well and firmly written and have remained largely unchanged for many years.

The US Defence standard Mil Std 810 Method 506 Procedure III is not firmly written and allows the user a fair amount of latitude in how the test is performed. In one particular aspect the test approach differs from the UK defence standard and the international commercial standard in that its aim is to ensure a specific droplet velocity at the test item. The international NATO defence standard STANAG 4370 Method 310 procedure III was clearly originally based upon the US Mil Std test but has been modified to accommodate some aspects of the international approach. However, this has not been undertaken particularly well and the procedure is not firmly written leaving the user a fair amount of latitude as to the test applied. Although the NATO defence standard STANAG 4370 could produce an identical test to the UK defence standard and the international commercial standard, that outcome could not be guaranteed by the procedure alone.

None of the defence standards or the international commercial standard EN IEC 60068-2-18 are compatible with EN IEC 60529 (Degree of Protection Provided by Enclosures) which would seem essential for COTS / MOTS equipment. Indeed the use of COTS / MOTS equipment, at the partly protected locations that this test is aimed at, is particular likely to be the case.

As the only stand alone test the UK national standard Def Stan 00-35 is recommended. This recommendation is also made as it has a clear severity, unlike any of the other standards, and aligns with the international commercial standard EN IEC 60068. Nevertheless, the adoption of IP code requirements for this type of defence equipment would have considerable advantage.

A.6.2.6 Sand and Dust

It is difficult with the sand and dust tests, like many in the group, to cleanly separate test procedure and test severity. The test procedure has aspects of test severity embedded within it. The sand and dust tests generally comprise three different test procedures viz. blowing dust, blowing sand and settling dust. The severities are broadly defined by composition in terms of material and size distribution of the dust and sand as well as the concentrations of sand and dust utilised. Other aspects such as duration, air velocity and temperature also are defined as severities.

In addition to the commercial standard EN IEC 60068 addressed throughout this comparison, a more commonly used commercial standard is EN IEC 60529 (Degree of Protection Provided by Enclosures). This latter specification is very commonly used by suppliers of both COTS and MOTS equipment.

The international commercial standard EN IEC 60068-2-68 provides the three previously indicated procedures viz. blowing dust, blowing sand and settling dust. The blowing dust test is indicated as equivalent to that of EN IEC 60529.

The UK Defence Standard CL25 also offers the same three procedures and explicitly states that the blowing dust test is equivalent to IP5X of EN IEC 60529. The procedure explicitly sets out the severities that need to be defined to achieve a repeatable test as well as defining the material composition, with several options available, size content and concentrations to be used. The procedure is clearly defined and its use should ensure a test as repeatable as those of EN IEC 60529 and EN IEC 60068-2-68. The procedure offers good guidance which is clearly distinguishable from the mandatory aspects. The procedure indicates specific differences in severity between the UK procedure and the NATO STANAG 4370 procedure. The severities and the associated guidance are related to military applications and service use.

The French Defence standard GAM EG 13 Method 18 is a dust test which appears to be intended to be technically similar to the EN IEC 60529 procedure but this is not explicitly indicated. The procedure contains less guidance than the previous procedure and is less explicit

in definition of the severities. The method has the look and feel of the same test as the UK Def Stan 00-35 and the NATO STANAG 4370 but slightly older in layout and format.

The US Defence standard Mil Std 810 Method 510 has the same three procedures as many of the other procedures viz. blowing dust, blowing sand and settling dust. The general procedures and severities appear to be technically similar to those of the other tests. However, that is neither explicitly stated nor is the information presented in a way that gives any positive indication the procedure was intended to align with international procedures. The guidance and mandatory aspects are not particularly well separated and the firmness of the procedure is seen as a potential issue.

The international NATO defence standard STANAG 4370 Method 313 is much better laid out than Mil Std 810 although essentially identical paragraphs can be easily identified. The three procedures appear to encompass aspects of UK Def Stan 00-35 and are technical to the other tests compared. The procedure is weaker than some others with regard firmness of the standard but not to the extent that it could not be called within a contract. Although a user would need to ensure all aspects of the severity are explicitly defined (the UK Def Stan is more specific in this regard). The procedure refers to EN IEC 60529 but does not state how it relates to that procedure.

The Sand and Dust tests are used extensively on military items particularly land vehicles land and equipment. The dust test is also very commonly used for commercial equipment and the stated capability against EN IEC 60529 is commonly quoted for many COTS and MOTS equipments. Generally military severities are quite onerous frequently requiring at least two of the three procedures. All the comparable procedures appear to be technically similar. However, the way severity conditions are embedded differently within the various procedures does makes establishing similarity particularly difficult. The sand and dust procedures are a good example of when statements on technical similarity are particularly useful to a user.

Generally the UK Def Stan 00-35 appears to have the clearest and best layout and procedure. Nevertheless the NATO STANAG 4370 has sufficient commonality to the others for it to form a reasonable international consensus. However, two particular caveats needs attaching to any recommendation, the firmness of standard is not particularly good and its absence of explicit correlation to EN IEC 60529 for COTS and MOTS equipment may have equipment procurement cost penalties.

A.6.2.7 Contamination by Fluids

The contamination by fluids test procedures are intended to determine if materiel is unacceptably affected by temporary exposure to contaminating fluids (liquids) such as may be encountered during its life cycle, either occasionally, intermittently, or over extended periods. Generally the procedures used samples of material rather than systems. As such material databases are generated this allows historic information to be used in the design process. Generally the test procedures place the material in the in potential contamination fluid and undertake an inspection for degradation.

Mostly the test specifications supply only a general guidance on the fluids to be considered. This is reasonable as different equipments may experience expose to different fluids and different fluids could arise at any time. The US national defence standard does include the most comprehensive list but is obviously US service life related.

The various test procedures are almost entirely identical. This is useful as databases of material reactions from all the standards are interchangeable. The only exception is the French GAM EG 13 procedure which is different from the others. Mostly it appears to be more severe as it subjects the material to longer periods of exposure. As the NATO STANAG 4370 is compatible with the majority of standards it is recommended.

A.6.2.8 Explosive Atmosphere

The explosive atmosphere test is performed to demonstrate the ability of materiel to operate in fuel-air explosive atmospheres without causing ignition or to demonstrate that an explosive or burning reaction occurring within encased equipment will be contained, and will not propagate outside the test item. Only three procedures exist in the standards reviewed and the US national standard Mil Std 810 and the NATO STANAG 4370 procedures are almost identical. The only other procedure is in the French national defence standard GAM EG 13. That procedure is defined slightly differently but appears to be technically similar to the other two.

A.6.2.9 Acidic Atmosphere

The acidic atmosphere test procedures are intended to determine the resistance of materials and protective coatings to acidic atmospheres. Like the contamination by fluids test this procedure is intended to evaluate material rather than attempting to simulate actual conditions. The test severities included in the defence standards represent a highly accelerated evaluation. The defence standards all include a choice of two severities replicating occasional expose to acidic atmosphere and the other to prolonged expose. The test procedures available are all very similar excepting that the temperature for the UK Def Stan 00-35 test is 40 °C compared to 35 °C for the others. This would suggest the UK standard is somewhat more severe. Other than this the only real differences are firmness of text and guidance. The UK Def Stan 00-35 procedure is firmly written with little guidance except an explicit severity, the US Mil Std 810 contains significant guidance but the firmness of the standard is poor. The NATO STANAG 4370 is compromise between the two and includes an explicit severity.

A.6.3 Conclusions of Review of Natural & Man Made Contaminate Test Methods

A summary of the recommendations is shown in the table below which is expanded in the following paragraphs.

Summary of Recommendations for Natural & Man Made Contaminate Tests					
	NATO STANAG 4370 AECTP	International EN EC 60068	UK Def Stan 00-35	US Mil Std 810F	France GAM EG 13
Immersion (including accidental immersion and vehicle fording)	Recommended for Fording aspects	Jointly Recommended for Immersion aspects		Technically similar to STANAG for Immersion	Technically similar to STANAG
Mould growth	Recommended - compatible with three national defence standards	The most recent procedure addressing availability of species and health and safety issues	Requirements encompassed within STANAG but they are not necessarily compatible with each other.		
Salt fog	Recommended but not compatible with commercial standards.	Not fully compatible with STANAG. Commonly used for COTS equipment.	Similar to STANAG Unlike STANAG contains recommended duration	Similar to STANAG	
Rain and water tightness	Recommended. Procedure encompasses national standards. Needs to be made compatible with	EN IEC 60529 (IP Protection codes) commonly used for equipment rather than EN			

Summary of Recommendations for Natural & Man Made Contaminate Tests					
	NATO STANAG 4370 AECTP	International EN EC 60068	UK Def Stan 00-35	US Mil Std 810F	France GAM EG 13
	EN IEC 60529 (IP Protection codes)	IEC 60068			
Condensation and Dripproofness.	Could be compatible with other standards but so weakly written this cannot be guaranteed.	EN IEC 60529 (IP Protection codes) commonly used for equipment rather than EN IEC 60068	Recommended Needs to be made compatible with EN IEC 60529 (IP Protection codes)	Not entirely consistent with standards	
Sand and dust	Recommended but needs to be made compatible with EN IEC 60529 (IP Protection codes)	EN IEC 60529 (IP Protection codes) commonly used for equipment rather than EN IEC 60068	Compatible with STANAG		
Contamination by fluids	Recommended	Technically similar to STANAG			
Explosive atmosphere <i>(Safety regulation may require a specific rating from EN IEC 60529 rather than this test)</i>	Recommended but needs to be made compatible with EN IEC 60529	EN IEC 60529 may be more applicable to many items		Technically Similar to STANAG	
Acidic atmosphere	Recommended		Technically Similar to STANAG		Technically Similar to STANAG

A.6.3.1 Immersion

Essentially the test procedures fall into two groups those compatible with EN IEC 60068 and those compatible with the Mil Std. However, as the French standard falls into the latter the differences are not polarised between the US and Europe. For COTS / MOTS equipment compatibility with EN IEC 60068 is important for that reason the Def Stan and IEC EN 60068 procedures are jointly recommended for immersion whilst the NATO STANAG 4370 is recommended for fording aspects.

A.6.3.2 Mould Growth

If the primary aim of this review was to identify the most technical innovation procedure, then the EN IEC 60068 procedure should be recommended. This is because the procedure has demonstrated technical innovation in the change of fungal species. However, if the aim is to generate a database for use by designers, which would necessitate compatibility with all existing defence standards then the NATO STANAG 4370 has the greatest value.

A.6.3.3 Salt Fog

The international NATO defence procedure STANAG 4370 is better written than the Mil Std but is not as firmly written as the UK Def Stan 00-35 or EN IEC 60068 procedures that propose continuous salt mist test and cyclic salt corrosion test with test duration linked to the type of

exposure (short; long). The severities are unclear and this also suggests a degree of unresolved compromise. The procedure is not technically similar to EN / IEC 60068.

In this case all the different test procedures seem to have some aspects which is better than the others. The EN IEC 60068 procedures are the most firmly written, the UK Def Stan 00-35 procedure is explicitly technically similar to the EN IEC 60068 procedures (equivalent test severities; equivalent test durations and reference to short or long exposures) but has defined severities for defence equipment. The UK Def Stan 00-35 procedure also allows extended corrosion testing. The US Mil Std 810 has the best advice on how to undertake the test. Whilst, the STANAG seems a credible compromise it also seems to have missed the best parts of the national standards. The UK Def Stan 00-35 procedure is recommended as it has a better cycle and duration information than the STANAG, is better written and has explicit commonality with EN / IEC 60068 for COTS and MOTS equipment.

A.6.3.4 Rain and Water Tightness

The NATO STANAG 4370 procedure is recommended as it has attempted to reconcile the diverse methods of test procedure included in the various standards. These national standards are almost impossible to compare as they define important aspects of the test by setting out physical details and arrangements of the equipment to use to create the rain. The NATO STANAG 4370 solution is essentially to encompass the various national standards and give guidance on how to select the most appropriate. Despite this it seems likely that users will continue to use the method they have historically used and this is possible within the NATO STANAG 4370.

None of the tests indicate compatibility with EN IEC 60529 (Degree of Protection Provided by Enclosures) which would seem essential for COTS / MOTS equipment. Also the EN IEC 60529 contains severities which are more severe than the military standards. As this relates to power wash it is particularly applicable to military equipment.

A.6.3.5 Condensation and Dripproofness

The UK national standard Def Stan 00-35 is the only standard that contains a specific test to replicate the effects of water and condensation dripping on equipment that may be otherwise protected from water. This would particularly include most equipment located inside vehicles and transportable cabins where condensation and indirect water could occur. The UK national standard Def Stan 00-35 is based upon an earlier version of the international commercial standard EN IEC 60068-2-18 Test R and Test Ra Method 2. Both the UK Def Stan and the international EN IEC 60068 procedures have remained largely unchanged for many years. The US Defence standard Mil Std 810 Method 506 Procedure III has a somewhat different strategy than any other standard reviewed. The international NATO defence standard STANAG 4370 Method 310 procedure III was clearly originally based upon the US standard but subsequently (and poorly) adapted to accommodate the requirements of the UK defence standard and international commercial standard. Neither the NATO or Mil Std procedures are well or firmly written, with severities difficult to identify and partly embedded within the procedure. Potentially, the STANAG procedure could result in the same test as the UK Def Stan and CEN international commercial standard. However, that could not be guaranteed by the test procedure as currently set out.

None of the defence standards or the international commercial standard EN IEC 60068-2-18 are compatible with EN IEC 60529 (Degree of Protection Provided by Enclosures) which would seem essential for COTS / MOTS equipment. Indeed the use of COTS / MOTS equipment at partly protected locations is particularly likely to be the case.

As the only stand alone test the UK national standard Def Stan 00-35 is recommended especially as it aligns with the international commercial standard EN IEC 60068. Nevertheless, the adoption of IP code requirements for this type of defence equipment would have considerable advantage.

A.6.3.6 Sand and Dust

The Sand and Dust tests are used extensively on military items particularly land vehicles land and equipment. The dust test is also very commonly used for commercial equipment and the stated capability against EN IEC 60529 is commonly quoted for many COTS and MOTS equipments. Generally military severities are quite onerous frequently requiring at least two of the three procedures. All the comparable procedures appear to be technically similar. However, the way severity conditions are embedded differently within the various procedure does makes establishing similarity particularly easy. The sand and dust procedures are a good example of when statements on technical similarity are particularly useful to a user.

Generally the UK Def Stan 00-35 appears to have the clearest and best layout and procedure. Nevertheless the NATO STANAG 4370 has sufficient commonality to the others for it to form a reasonable international consensus. However, two particular caveats needs attaching to any recommendation, the firmness of standard is not particularly good and its absence of explicit correlation to EN IEC 60529 for COTS and MOTS equipment may have equipment procurement cost penalties.

A.6.3.7 Contamination by Fluids

The various test procedures are almost entirely identical. This is useful as databases of material reactions from all the standards are interchangeable. The only exception is the French national defence standard which is different from the others. Mostly it appears to be more severe as it subjects the material to longer periods of exposure. As the NATO STANAG 4370 is compatible with the majority of standards it is recommended.

A.6.3.8 Explosive Atmosphere

The NATO STANAG test is recommended as essentially identical to the procedure in the US Mil Std 810 and technically similar to the procedure in the French national standard GAM EG 13.

A.6.3.9 Acidic Atmosphere

The test procedures available are all very similar excepting that the temperature for the UK Def Stan 00-35 test which would suggest it is somewhat more severe. Other than this the only real differences are firmness of text and guidance. The UK Def Stan 00-35 is firmly written with little guidance except an explicit severity, the US Mil Std 810 contains significant guidance but the firmness of the standard is poor. The NATO STANAG 4370 is compromise between the two and gives explicit severities, as such it is recommended.

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ANNEX B

Overview of Each Standard Group

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Overview of Each Standard Group

An overview of the primary environmental test procedures, severities and methodologies addressed by Expert Group 8 are set out below.

B.1 International Civil Standard EN / IEC 60068 & 60721

Standard 60068 is the IEC procedure for environmental testing, which is also adopted by CEN and embedded into national standards by many international and most European countries. IEC 60068 has an associated standard, IEC 60721, which sets out environmental severities.

The two sets of standards, IEC 60068 & 60721, are designated by IEC as so called “horizontal” standards for all electro-technical products. Its procedures are adopted by a many “vertical” product standards either by direct reference or using a reformatted version of the text. As a consequence a large number of test procedures are based upon the IEC 60068 test methods. This is particularly the case for components and OEM items which are supplied as Commercial off the Shelf (COTS) equipment. In accordance with the guidelines for the workshop, the expert group focused upon the the base standards, 60068 & 60721, in this work.

The 60068 & 60721 documents have existed, in some form, for in excess of 50 years. They have been managed by IEC for this entire period and the responsible IEC technical committees (now a single committee for both 60068 & 60721) have also been active for the entire period. Prior to the merger of the 60068 & 60721 committees many inconsistencies had arisen between the two documents.

The main advantage of the 60068 test procedures is that they are consistently formatted with a very clear distinction between guidance information and mandatory requirements. The procedures frequently also contain guidance on how to undertake the test. This guidance is clearly separated from the mandatory portions of the procedure. The mandatory portions of the test procedures are firmly written and ensure repeatable results regardless of the tester, test facility or test equipment utilised. For this reason the test procedures are ideal for setting as contractual requirements.

A perceived disadvantage of the 60068 standard is that its test procedures are mostly intended for components and sub-systems. Many of the test procedures are quite old and can lack technical innovation. They do not always utilise up to date & cost effective facilities, techniques or methodologies. Although IEC adopt a maintenance procedure these can be slow and even then do not always bring a test procedure up to the same level of technical innovation as the defence standards.

The two standards can be purchased, in individual parts, from IEC and CEN (in both English and French) and from most national standards agencies, in the appropriate national language.

B.2 National Defence Standard Def Stan 00-35 (UK)

The national defence standard Def Stan 00-35 is the United Kingdom standard for environmental proving of defence equipment. The origins of this standard (Def Stan 07-55) have a clear historic root with older versions of EN / IEC 60068. It appears that interaction between the two test standards occurred in the late 1960's. The United Kingdom national test standard still attempts to keep a reasonable degree of consistency with EN / IEC 60068. Indeed within the scope of every procedure a statement is made as to the commonality with EN / IEC 60068.

The test procedures adopt a clear distinction between guidance information and mandatory requirements. The procedures are firmly written but also supply additional test guidance information on both test conduct and severity derivation. The tests are written to facilitate consistency of testing and can be called in contractual requirements. The tests frequently used for COTS equipment are included in a manner such that they are common to many “vertical” standards.

Although Def Stan 00-35 has made some effort to indicate, if not achieve, commonality with EN / IEC 60068, it has also incorporated additional, defence specific, procedures and includes a number of technically innovative enhancements to existing tests. The procedures mostly encompass the use of up to date & cost effective facilities, techniques and methodologies. The UK was one of the three national standards considered in the generation of NATO STANAG 4370.

The UK Def Stan 00-35 is still maintained and updated and is supported by the D Stan standards organisation. The defence standards organisation operates professionally and ensures discipline in the form of consistency of style and format.

The UK national defence standard Def Stan 00-35 includes an environmental management strategy that is consistent with defence procurement approaches used in the United Kingdom. It also includes and maintains credible, up to date, test severities which are specific for defence usage.

The UK Def Stan 00-35 is available in English and is issued by the UK D Stan organisation which make the documents publicly available at no cost, the individual parts of the document can be downloaded free of charge from the DSTAN web site.

B.3 National Defence Standard GAM-EG-13 (F)

The national defence standard GAM-EG-13 was the French national standard for environmental proving of defence equipment. The French Defence Standardisation Authority decided, a decade ago, to stop development of GAM-EG-13 and to refer as much as possible to NATO STANAG 4370. Although the French national standard is no longer supported, it was included in the considerations of Expert Group 8 as it contains aspects not addressed elsewhere. The French standard was one of the three national standards considered in the generation of NATO STANAG 4370.

The French Defence Standardisation Authority does still support work, were it considers NATO STANAG 4370 is weak or has no equivalence. This has included aspects of the environmental engineering process (CIN EG 1) and guidelines for deriving test profiles for mechanical tests (NORM DEF 01-01). Current work includes guidelines for deriving test profiles for climatic tests (ASTE-PR-01-02), although this was not published at the start of the work of Expert Group 8. Neither of the two guideline documents (NORM DEF 01-01 & ASTE-PR-01-02) have, as yet, been fully approved by CND, French Defence Standardization Body.

The GAM-EG-13 test procedures adopt a clear distinction between guidance information and mandatory requirements. The procedures are firmly written and also supply additional test guidance information.

The test methods from Part 1 of the French national defence standard GAM-EG-13 are available in English.

B.4 National Defence Standard Mil Std 810 (US)

The US national defence standard Mil Std 810 has previously been adopted, for testing defence equipment, by a number of European countries which have not generated their own national defence standards. This US standard has its origins in the late 1960's and over the years has undergone several very radical changes of approach and strategy. These changes are not always backward compatible with earlier versions.

Historically the procedures within the US national defence standard Mil Std 810 have exhibited technical inconsistencies with other group of standards, in particular EN / IEC 60068. The US Mil Std 810 procedures has, at various times, adopted different tolerances, procedures & approaches to those of other standards.

Procedures within Mil Std 810 have not always adopted a consistent style. Moreover, many are not firm written with no clear distinction between guidance information and mandatory

requirements. US companies and DOD organisations frequently refer to Mil Std 810 for guidance but for contractual purposes use specifically versions in product related procurement requirements.

In the early 1980's the Mil Std 810 broke the traditional mould of using simplistic test severities by advocating severities derived for specific applications. This was part of a radically different environmental engineering management strategy. Unfortunately, that management strategy does not fit well with procurement practices used today in Europe.

The main advantage of Mil Std 810 is that historically the standard has included technically innovative approaches adopting up to date & cost effective facilities, techniques and methodologies. In the defence field Mil Std 810 has frequently been at the fore front of introducing new techniques and ideas. As a result the Mil Std 810 has broadened its range of environmental conditions encompassed such that it now addresses most of those required for defence applications. However, some of these are not particularly well integrated. Some new chapters relate entirely to the derivation of specific severities, with the procedures themselves not always that different from existing chapters. These "enhancements" of the standard has resulted in further degradation of the distinction between mandatory test procedures and guidance information.

The Mil Std is controlled by the US DOD organisation. However, that control appears to impose little editorial control over consistency of style and enforces no clear distinction between guidance information and mandatory requirements. Overall, the document indicates an absence of the rigorous editorial control seen in the IEC standards or the UK and French military standards.

The Mil Std 810 is publicly available, in English, and can be freely downloaded free of charge from the US DOD organisation web site. It is also available on many public domain websites.

B.5 International Defence Procedure STANAG 4370 (NATO)

The NATO standard STANAG 4370 and its Allied Publications (designated, in this case referred to as AECTP's) contains a significant amount of identifiable content from the UK Def Stan 00-35, the French GAM EG 13 and the US Mil Std 810. As such it takes cognisance of a range of national standards. The NATO STANAG is also the newest of the horizontal standards reviewed.

Having extracted procedures from various national standards STANAG 4370 does include tests for virtually all defence environments likely to be encountered. Although, the generation of STANAG 4370 took cognisance of a range of national defence standards, it did not take into account European commercial standards as required by the European Defence Procurement Directive.

STANAG 4370 contains a basic environmental management strategy which is broadly based upon the defence procurement approaches used in the US, UK and France. However, achieving that commonality has required considerable compromise.

In theory the STANAG is controlled by the NATO organisation. However, that external control appears to be minimal with little editorial control. Controlling secretariat support, such as applied by professional standards bodies, is largely absent. The procedures are not firmly written with poor distinction between guidance and mandatory requirements. As a consequence the requirements cannot always be relied upon to produce a repeatable or reliable test. As is the case with a number of NATO standards, concerns have been raised over the lack of industrial participation in generating the standards and the narrow reviewing procedure.

The latest versions of the various AECTPs that form NATO STANAG 4370 are available, in English and French, free of charge on the NATO Standards Agency website.

ANNEX C

Additional Information On Environmental Standards

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Additional Information On Environmental Standards

C.1 The Environmental Control and Management Process

The objectives of the environmental control and management process are those that can be adopted for any task control and management process, and may be listed as follows;

- to ensure that concise and unambiguous requirements are defined,
- to ensure that a strategy is in place for undertaking the task,
- to ensure that the task is adequately controlled and managed,
- to ensure that an approach exists for demonstrating compliance with the requirements.

These objectives are translated and developed to form the basic elements of the process. The elements are described as follows;

- establish the environmental requirements for the materiel,
- formulate a strategy for demonstrating the adequacy of the materiel against the environmental requirements,
- define the environmental tasks and the programme necessary to allow the strategy to be implemented,
- undertake the defined environmental tasks to the authorised work programme,
- demonstrate, through assessment of the reported information generated by the environmental tasks, that the materiel meets the environmental requirements.

The environmental control and management process is normally supported by a series of documents. The process and its documentation should interface directly with the overall design verification process. In particular, the inputs to the environmental control and management process are derived directly from requirements emanating from the design requirements process. Moreover, the outputs from the environmental control and management process integrate directly into the design verification process evaluating the suitability of the materiel for service use.

C.2 The Environmental Test Tailoring Process

The term “tailoring” is often used to mean the process by which test methods and particularly their severities are adapted to improve the simulation of specific environmental conditions. “Tailoring” in this limited sense is an accepted environmental engineering process. Its development was stimulated by the realisation that conservative test methods and excessive test severities can result in increased materiel development costs with no compensating increase in materiel performance or reliability.

The tailoring process has broader application to materiel development programmes. Therefore, for the purpose of this report “tailoring” is also considered to encompass the optimisation or refinement of the environmental engineering task, to meet the specific needs of a particular materiel development programme.

It should be noted that although the application of tailoring to environmental testing programmes can provide significant benefits with regard to materiel development costs, it can also restrict the user’s operational flexibility to those Service environmental conditions originally specified.

C.2.2 The Use of Tailored Test Methods and Severities

Tailored environmental test methods and severities are adopted to permit a more accurate simulation of the anticipated in-service environments and allow the performance and integrity of the test specimen to be examined whilst being stressed only to representative in-service environments. Such tailoring reduces the probability that the test specimen will incur unrepresentative failures.

Although the use of tailored test methods is technically preferred, alternatives, known typically as minimum integrity test methods, are often acceptable. These alternative test methods are generally relatively unsophisticated tests that can be adopted when a precise simulation is not necessary to establish suitability for service use and when a degree of over testing can be tolerated. Usually generalised (sometimes termed fallback) test severities are used in combination with minimum integrity test methods.

To encompass all levels of materiel sophistication, test methods of both types, i.e. tailored and minimum integrity, are needed. Both tailored and minimum integrity environmental test methods, covering all significant and relevant environments to which materiel may be expected to be subjected, are contained in many of the standards compared by Expert Group 8.

The increasing complexity and availability of advanced laboratory test equipment provides the test specifier with a choice of tailored and minimum integrity test methods for accommodating a particular environment. Tailored test methods are generally no more expensive to conduct than minimum integrity test methods. However, they usually require more sophisticated test equipment which may limit the choice of available test facilities. It is also often more difficult to reproduce the test results should a repeat test be required at a later date. Repeatability is an important consideration should the test be undertaken for Environmental Stress Screening or In-Service Surveillance purposes.

The adoption of tailored test methods and severities is usually essential for materiel whose performance, cost, reliability, mass or configuration could be adversely affected by tests which significantly exceed the stresses produced by the related Service environments. The degree or extent to which tailoring is to be applied should be agreed with the materiel designer, who is usually the best placed to quantify the consequences of over testing.

When conducting tailored test methods in the earlier phases of a materiel development programme, adequate information may not be available to allow the use of project specific severities. Therefore the suitability of a design may need to be evaluated using generalised or fallback test severities from national or international standards, or from applicable data derived from similar earlier programmes. These generalised test severities should be replaced for Qualification or Type Approval tests by tailored severities from project specific data acquisition programmes.

The adoption of generalised test severities throughout the development programme is acceptable and possibly advantageous where the deployment, location or usage of materiel is difficult to quantify. It is also relevant when the intended usage or role may be expected to change during its Service life. Consequently, for such materiel, the adoption of severities from national or international standards should be considered in comparison with available measured data from appropriate Service environments.

The adoption of generalised test severities can provide a useful means by which a procurement authority ensures the removal of design weaknesses in components and subassemblies before they are incorporated into more sophisticated systems. However, the application of generalised test severities to remove design weaknesses should be tempered with consideration of the potential overdesign penalties in terms of performance limitations, programme costs and delays that could be incurred through their use.

C.2.3 Tailoring the Environmental Test Requirements

The aim of this aspect of tailoring is to generate an Environmental Test and Assessment Specification that provides sufficient evidence for materiel certification together with a cost effective series of tests and assessments. To this end the tailoring process involves making decisions on which environmental tests can be merged together or even eliminated. It also includes making decisions on the balance to be achieved between testing and assessment for demonstrating compliance.

A reason for merging environmental tests is that collectively they exercise the same potential failure modes of the materiel when it is in the same operational state. A reason for eliminating tests is that the materiel exhibits no failure modes associated with that environmental condition.

Tailoring the environmental test and assessment requirements involves knowledge of the likely failure modes of the materiel associated with its exposure to specific environmental conditions. In general, tests should concentrate on the environments to which the materiel is sensitive rather than those to which it is likely to be robust. This advice would not apply to safety tests which are undertaken to demonstrate that a munition is not sensitive to an environment condition. In some instances environmental design aid tests may be needed to generate evidence for the elimination of some conditions and the combination of others.

C.2.4 Tailoring the Test And Compliance Programme

Tailoring the Test and Compliance Programme develops further the tailoring process to address sequential testing and combined environments testing.

The purpose of sequential testing is to replicate the cumulative ageing and degradation that the materiel would experience as a result of exposure to the environmental stresses arising from its planned Service life. In particular the environmental stresses induced by sequential testing should be representative of the conditions set out in the Manufacture to Target or Disposal Sequence (MTDS).

Sequential testing should not induce in the materiel any excessive environmental stresses that could cause unrepresentative failures, but should include environmental stresses that exercise long term damage mechanisms. There is always some risk that sequential testing will result in over-testing as a consequence of the cumulative effects of the marginal over-testing that arises from each test within the sequence.

Sequential testing is usually adopted for ordnance and one shot devices, even though it is only at the end of the test sequence that satisfactory operation can be demonstrated. For these applications sequential testing can be relatively costly and time consuming, because the test sequence may take many weeks to complete. Also, because a failure during the test sequence usually means starting all over again, it imposes a significant risk on completing the materiel development programme on schedule. To minimise this risk, an approach known as "cascade" testing is often adopted, where a relatively large number of test specimens are subjected to the test sequence, and where after each appropriate test stage a number of items are withdrawn for functional testing.

During Service use the materiel will be subjected to several environmental conditions simultaneously, but few environmental tests replicate simultaneously more than one environment. Combined environment testing is necessary when the damaging effects of two or more environments applied simultaneously are envisaged to have greater damaging effects than when the environments are applied separately. The deterrent to undertaking combined environments testing is, almost always, cost. For effective decisions to be made regarding the inclusion of combined environments testing into the Test and Assessment Programme, the Environmental Requirement document should identify when environmental conditions occur simultaneously or when they are expected to do so at a credible level of statistical probability. Based on this information the sensitivity of the materiel to combined environments can be evaluated and suitable tests incorporated into the programme.

C.3 Environmental Engineering and Reliability Tests

The following address the relationships between the reliability assessment process and the environmental engineering process. Although reliability is addressed by a different Workshop 10 Expert Group, reliability tests and environmental tests are frequently related. Indeed for defence equipment the reliability of equipment will almost always need to be assessed but it may also be

necessary to incorporate testing activities aimed at demonstrating the ability of the materiel to meet specific reliability targets.

The reliability assessment process should generally be able to utilise information from both the environmental test and the design verification processes. However, the testing undertaken for those purposes may not satisfy all the needs for reliability assessment. The primary intent of environmental testing is usually to demonstrate that the equipment will function at the extremes of the specified operational conditions throughout service life. To this end qualification tests generally aim to replicate time dependant effects of ageing and degradation. While, the environmental conditions causing ageing and degradation are commonly incorporated into qualification test programmes, the environmental conditions are applied at severity levels which can significantly accelerate the rate of degradation. Accelerating the rate of degradation circumvents the main aim of reliability assessment which is to quantify the failure rate (or its inverse, such as time between failures).

Many of the problems associated with defining tests from which failure rate can be quantified are similar to those associated with replicating ageing and degradation for Life Assessment purposes. In particular the setting of test requirements, able to replicate degradation credibly, inherently dictates the inclusion of assumptions and knowledge of likely failure modes. The value of the resultant estimates of failure rate may be significantly influenced by errors and limitations in those assumptions.

The reliability requirement (including statistical confidence level) will largely influence the approach used for reliability assessment. However, reliability assessment is influenced by the type and cost of the equipment, along with the character of its operational usage

Reliability testing generally commonly adopts two categories of environmental testing, namely Reliability Growth testing to develop improved equipment reliability and Reliability Demonstration testing to ensure that the reliability requirements have been achieved. The purpose of the two categories is stated below:

(a) **Reliability Growth:** The purpose of Reliability Growth testing, also known as Reliability Development testing, is to improve equipment reliability. In particular it is intended to identify equipment sensitive to environmental conditions. It is important that any failures induced during Reliability Growth testing are realistic and typical of those that are liable to occur during Service use. Consequently, Reliability Growth testing should adopt test severities that are only marginally higher than the mean levels for a specific environmental condition.

(b) **Reliability Demonstration:** The purpose of Reliability Demonstration testing, also known as Reliability Acceptance testing, is to demonstrate that during Service usage equipment reliability will be compliant with the specified requirements. When this type of testing is conducted on production standard hardware it is often termed Production Reliability Acceptance testing. Reliability Demonstration testing normally adopts severities slightly lower than those selected for Reliability Growth testing. Ideally the severities should be nominal unfactored values for a specific environmental condition, which will ensure that any induced failures are representative of those from Service conditions.

Reliability standards ensure that the deliverable equipment is well designed, free of manufacturing process defects and are demonstrably meeting the contracted reliability levels. The techniques for demonstrating and improving the reliability of complex, high-value electro-mechanical products, such as modern weapon systems, typically involve the prolonged application of vibration and temperature stresses, either separately or in combination to represent the effect of many product lifetimes.

C.4 Environmental Engineering and Safety Tests

Standards containing procedures for environmental test of commercial and defence equipment are usually against environments that that can be expected in normal service use. However, environmental test programmes may also contain tests intended to replicate abnormal environments. In defence procurement reference to abnormal environments is usually used to encompass extreme normal environments, environments occurring as a result of hostile conditions and accidental events. Whilst, equipment is usually expected to be safe and serviceable following the application of tests replicating normal environments, it may only be required to remain safe following the application of testing against abnormal environments. In some cases the only difference between normal and abnormal testing is the severity and the criteria used to determine whether the item has "passed or failed". In many cases the actual test procedure are identical or at least very similar to those used for replicating normal environments.

The acceptance criteria of safe and serviceable against normal environments and remain safe against abnormal are not necessarily the only two criteria in current use. Safe for immediate disposal is used in extreme cases and safe for use if no visible damage may be used in limited extreme normal cases. Moreover, for dangerous items and particularly energetic materials a whole range of different levels of reaction to the test may be used as the criteria. In such cases the acceptable level will depend upon usage requirements and policy as well as the degree of procedural protection that can be offered.

Whilst, in some cases the actual test procedure used for testing against abnormal environments are identical or very similar to those used for replicating normal environments. Nevertheless a few tests do exist which do not necessarily have an equivalent in normal testing. For Defence Procurement the most commonly encountered tests are those used for safety testing of items which could have significant consequences including loss of life. Such tests, which usually use quite severe severities, do not necessarily have a firm "pass or fail" criteria but rather the resultant effects are used to establish safe working practices and hazard procedures.

The most obvious group of safety tests are those used for energetic materials including explosives and propellants. This group of safety tests are used to verify the sensitivity of Defence Systems to extreme accident and hostile conditions. The purpose is to establish how the system reacts to allow the appropriate safety procedures to be developed. In recent years a number of this group of safety tests have become known as the Insensitive Munitions (IM) tests. However, most of these tests have existed for many years (some dating back to the early years of the Vietnam war) prior to the introduction of IM policy only the level of acceptable reaction has changed.

The usual safety tests for energetic materials are; the fire test, the slow cook off test, the bullet attack test, fragment impact tests, the sympathetic reaction test, the shaped charge jet test, electro-static discharge and the drop test. All of these are designated as IM tests under some policies but some such as the drop test and ESD test are not included in others. As would be expected for safety procedures the tests are firmly written and are written to ensure consistency of use. However, by the nature of these severe tests repeatability is not always easy to ensure and a few are notoriously difficult to repeat exactly. Many of the tests should be preceded by a safety assessment to determine sensitivity i.e. so the item can be tested in its most sensitive orientation, impacted at the most vulnerable point etc. Potential variability is essentially taken into account when assessing the level of acceptable reaction. In recent years environmental objections have been raised against the fire test and some effort has been made to develop modelling approach in place of this and some of the other tests.

Safety tests appear at both national and international level although in recent years a degree of alignment has started has become apparent. In the NATO countries the STANAG safety tests appear to have broadly replaced most top level national procedures or the national procedure intentionally aligns with the STANAG procedure. In some cases lower level nation procedures still exist which have slight differences to the STANAG, this seems to be a matter of historical

baggage rather than indicating deliberate intent. However, these do not necessarily appear to be primary source procedures rather this may be the MURAT tests.

Another group of safety test procedures which affects Defence Procurement are the United Nations (UN) recommendations on the transport of dangerous goods. In this case dangerous goods encompass a wide range of materials as well as energetic materials. United Nations document ST/SG/AC.10/11/Rev.2 is a manual of tests and criteria. It contains a number of separate test procedures as well as test programmes for various classes of dangerous goods. Some of these tests are broadly similar to the safety tests used for energetic materials, although, no specific attempts appears to have been made to align the two procedures. Also differences exist in acceptance criteria. Most countries have incorporated these UN recommendations into their national laws, and mostly this implementation encompasses military equipment.

The United Nations (UN) recommendations on the transport of dangerous goods does not include nuclear materiel which is covered by IAEA (International Atomic Energy Agency) which has produced recommended tests for packaged nuclear material. These test procedures do align well with the Safety tests for energetic materials although the acceptance criteria do differ. Again most countries have incorporated these IAEA recommendations into their national laws, and generally this implementation encompasses military equipment.