Confederation of
European Environmental
Engineering Societies CEEES

CEEES Technical Advisory Board Reliability & ESS

-Reliability-
For a Mature Product
From the Beginning of
Useful life

The Different Type Of Tests And Their Impact On Product Reliability

Publication N° 9 - 2009 -

ISSN 1104-6341

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FOREWORD

The challenges to which the industry is confronted today requires consideration of innovative design, technologies and conditions of use. The reliability or maturation of such products could only be achieved experimentally, either by tests during the development or during the operational deployment. The risks associated with the second approach are unacceptable; to the ultimate users who demand a reliable product and to the supplier because of the detrimental image and associated costs unreliable products can cause.

This document presents Recommended Practices, which represent the current best practices in matter of building the product maturation during product development and highlighting the role of experimental testing in this maturation growth.

The document has been generated by the Reliability and Environmental Stress Screening (R & ESS) Technical Advisory Board (TAB) of the Confederation of European Environmental Engineering Societies (CEEES). The co-ordination of this work by the R & ESS TAB of CEEES allowed the participation of a wide range of specialists covering a lot of expertise and experiences.

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INTRODUCTION

The maturity of a product should be reached when its development has ended. However, the state of the art technology in most industries reveals an imperfection of this maturation. Very often this immaturity creates non-qualitative costs especially for innovative product development. Essentially, the causes of this can be bound to deficiencies;

- in the analysis of the product life profile (i.e. from leaving the factory to service withdrawal, including service mission and maintenance),
- in the analysis of the technical specification at the system level and its hierarchical make-up at lower sub-system levels,
- in engineering of the piece parts,
- in the relevance of the design choices that take into account the real conditions of use,
- in the elimination of the weak points of design and technologies,
- in the validation of the technical functions (internal justification to the manufacturer) as in those of the service functions (justification in front of the client)
- in the efficiency to disclose the latent defects in production

The branches of industry which by necessity require to have mature products, and especially those not to perform maintenance on the site, space industry sector of activity and the medical sector when patient's safety is paramount (pacemakers etc.): The designs and technologies implemented are mature because they are based on validated technologies, with design margins, and consideration of field experience. The design of those products may also give preference to evolutionary designs rather than revolutionary design. Furthermore redundancy and possibilities of reconfiguration may be incorporated into the design.

The space industry sector of activity has to put in-orbit complex reliable satellites required to operate reliably, with no maintenance, for many years. The approach to development is generally very conservative, de-rating systems and giving preference to evolutionary design. However, competition is changing these rules and even the space industry is using more revolutionary designs.

THE PRODUCT LIFE PROFILE

The Product Life Profile is the chronological profile of the product, which starts when it leaves the factory and ends at service withdrawal. The chronological profile will encompass product use, missions and maintenance. A Product Life Profile is characterised by; its environmental factors (or constraints of employment in the wider sense), by the nature and severity (amplitude and duration) of the environment and the products anticipated usage profile with associated performances. The environmental factors for which a given performance must be achieved constitute the normal environments for a product. Some situations can induce reversible damage for this performance level, such environmental conditions can be said to represent “limit” cases. In some instances products may be required to withstand extreme situations, causing irreversible damage of some operational performance criteria, but without raising safety concerns. The corresponding environment can be said to be an extreme case.

It is important in a life profile analysis to consider the input of the customers and other stakeholders. This can be achieved by going to the customers site and meeting the end users, field operators, and the people involved in maintenance. This should take into account operator’s concerns in more stringent applications and in the consideration of environmental factors which not be anticipated by the designer. Such conditions may include rain, sand and dusts and the humidity arising the periodicity of opening the containers or the periodicity of monitoring the manometers indicating the gas proofness of the seals.

The life profile analysis should not neglect the transitory situations which are very often the most significant. It is also necessary to consider the possible degradation in conditions of use which could shift from the normal or reversible domain into the limit or extreme domain. For example, putting a screwdriver in an unintended opening in order to secure the product in a particular phase of maintenance could induce the deterioration of an electronic circuit located in the heart of the opening. Also materials may degrade due to repeated exposure to hot, cold or humid conditions.

THE PRODUCT TECHNICAL SPECIFICATION

The product Technical Specification is a contractual document, established by the customer and given to the supplier. It expresses the needs of the customer in terms of requirements. The Technical Specification also gives the conditions and strategy of compliance validation.

The Technical Specification must; express what the customer wants from the product, how the product will be used, constraints for the design and production or the logistic support. The Technical Specification must be passed down through the product assembly tree to the lower level of assembly (the part, the coat of paint etc. that will be specified by corresponding technical specifications).

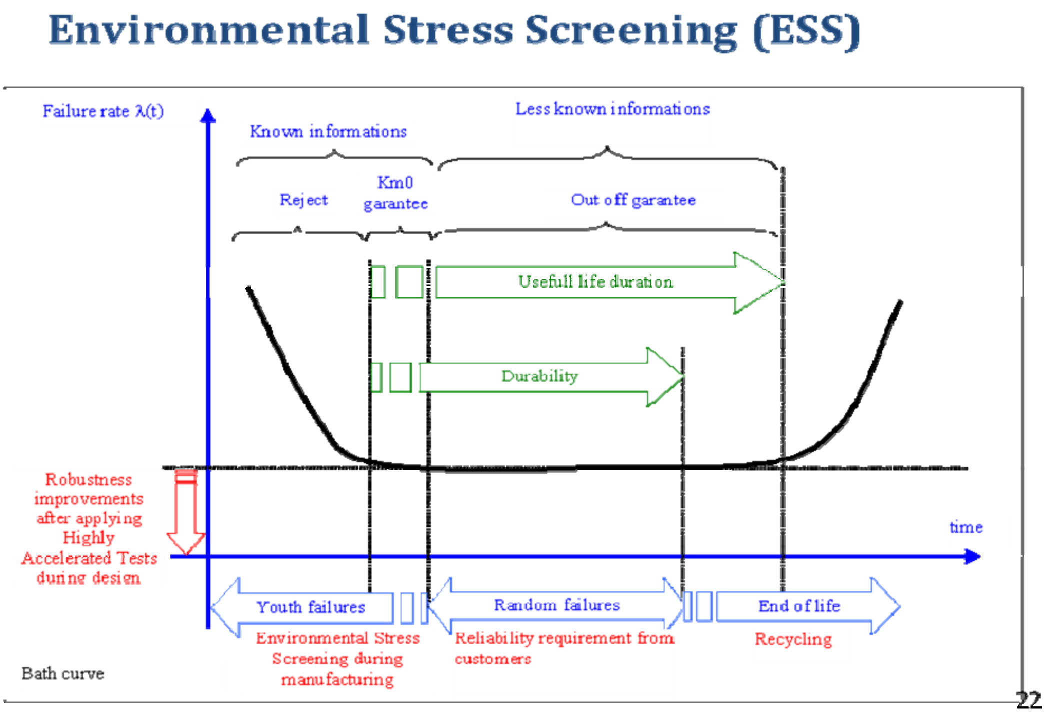

Figure 1 Classical ESS, ESS Mitigates The Youth Failures

A difficulty is to echo the Technical Specification system into the lower levels of assembly. To help this process, models can be developed and used; moreover, if a design choice leads to a particular effect that has not been taken into account (for example a sensitive frequency beyond the specified domain, or effects induced from an external level of assembly), the Technical Specification of the product may have to be updated.

The general requirements set out in Technical Specification are related to either the functional performance or to the operational performance. The latter will determine the product dependability. Consideration of reliability is one part of the Technical Specification, it encompasses the ability of a material to produce the functions required in given conditions of deployment and for a specified duration. However, this definition is not always perceived exactly in the same way by the end user of the material or by the contractor in charge of the development.

The end user has a perception that overall reliability should integrate consideration of all the defects (deterministic or unpredictable) leading to a failure of the function. The developer has a perception that is not as critical of the material. In electronics, the general requirements in reliability concern the proportion of the defects, which have an unpredictable occurrence. It is this part that is frequently calculated from the standards on reliability such as MIL STD 217. An experimental verification may not be easy because of the unpredictable character of the defects. This may call for testing on a greater number of products in a brief time or on a more limited number of products during a time proportionally longer (ten times the expected MTBF in the case where a single product is tested). For mechanical systems, the reliability requirement is specified as the life duration of the product, it will generally be considered in a deterministic way throughout the product development and engineering. The verification test will usually be dedicated to the assessment of the life duration. It usually achieves this by applying an accelerated fatigue test, the level of acceleration being obtained by increasing the test level.

The reliability operational requirements in their current contents do not address explicitly the fact that the product is immature at the start of its development. The customer supposes that the state of the art technology leads to a mature product from the beginning of its development.

THE PARTS (OR COMPONENTS) ENGINEERING

The fast evolution of the components to market is a fundamental issue and the result of a reduction in the development cycle. A consequence of reducing the development cycle is the corresponding reduction in the number of windows of opportunity to improve maturity. The development costs of an emerging technology are growing and have to be shared between several companies and stakeholders.

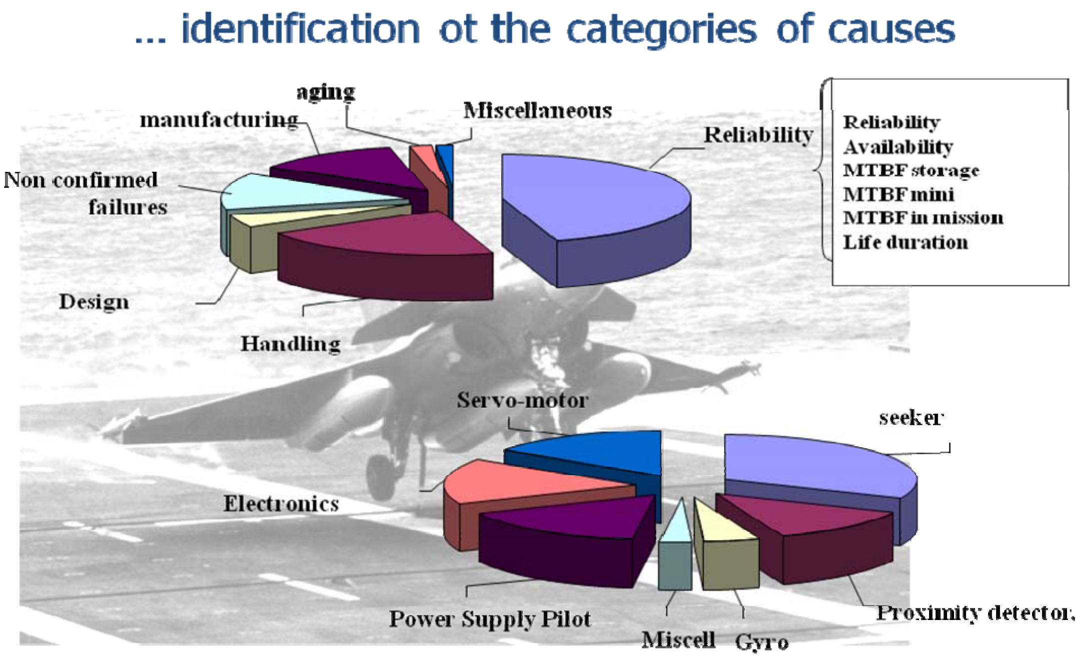

Figure 2 Breakdown Of Origin Of Failures Experienced On Missile Equipments.

During the five last years, there have been marked technological evolutions which have resulted in the increased complexity of electronic circuits and increased speed of operation; all at the cost of reduced design margins. There has been a decrease in the power supply voltages (5 V to 3,3 V then 2,5 V), an increase of the thermal dissipation, an increase in chip size within new circuit packaging. The continuous improvement in the manufacturing processes leads to a very low failure rate of the components and negates the need for final electrical tests. Qualified Part List (QPL) approach is now being replaced by the Qualified Manufacture List (QML) approach, this puts the responsibility on the manufacturer to maintain their Qualified Manufacture List and to strive for continuous improvement.

The traditional approach for component life qualification and establishing component reliability are now considered inadequate for current products. The process of qualification must be reinvented.

From the viewpoint of the component manufacturer, it is necessary to;

- qualify the manufacturing processes by means of a test “vehicle”,
- implement a Computer-Aided Design with databases of manufacturing processes reliability models,
- implement models of reliability for particular mechanisms such as electro-migration, injection of electrical charges simulating the thermal agitation, the loss of dielectric performance,
- use of the definite and complete models of simulation to confirm features,
- realise electric tests to characterise and evaluate the applications.

The manufacturer of components would also have to;

- administer the potential mechanisms of wear by maintaining the state of the art in design and by controlling the manufacturing processes,
- recognise that the interactions between the design and the reliability of the component should be considered during the design,
- administer the interactions between the manufacturing processes and reliability by a follow up of the manufacturing processes. This will include implementing life duration tests to characterise the effects in the time, of evolutions of definition or of manufacturing processes.

From the viewpoint of the components user (prime, sub contractor etc.), a structure of engineering components support must;

- help the design teams in the choice of their components, of technologies, strategic circuits and suppliers, and thus from the beginning of the phase of preliminary design to evaluate test data bases of the suppliers,
- carry out specific studies of the critical processes and components,
- generate follow-up sheets of performances,
- realise technological audits,
- assure that the parameters determining the objectives of long term reliability are established and followed,
- assure that the rules of design and of component employment exist and are well applied and that the models of design and of manufacturing processes exist and are relevant.

The estimated equipment reliability is still widely based on the use of the constant rate of failure supplied by general standards (MIL HDBK 217 or RDF CNET 93 for the electronic components). This is despite numerous opinions which have attempted to put into perspective the validity of forecasts derived in this way. This is particularly significant for plastic components, which are still attached to very pessimistic values (in the case of MIL HDBK 217) related to their problematic behaviour at extreme temperature (below 0 °C and above 85 °C). Conversely, the use inside the temperature range 0 °C to 85 °C they can be as reliable as similar components in metallic package.

A promising alternative school of to this approach has been developing a body of information for some years by implementing the mortality rates and the statistical laws. Supporters of this school consider that the defect of components arise from the deterministic consequence of physic-chemical phenomena, which are accessible by modelling. This school is represented by the Maryland University (USA), which, for several years, has driven a software package entitled CALCE EPRC (Computer Aided Life Cycle Engineering - Electronic Packaging Research Centre). The CALCE EPRC's mission is to supply support to industry to assist it develop faster (5 to 10 times) competitive electronic products. This support includes; the supply of the methods of design and of manufacture, of techniques of simulation, of models, of experimental methods, of guides and of supports of training.

Multidisciplinary researchers are driven to determine, estimate and update the methods and the practices for the design, manufacture as well as the evaluation of reliable and competitive electronic products through studies in collaboration with manufacturers. These studies, carefully chosen, encompass;

- failure component modelling,
- the accelerated tests,
- the methods of characterisation,
- high temperature components,
- software, modelling and automation,
- connectors and electrical contacts,
- modelling and characterisation of the manufacturing processes,
- the optoelectronic circuits
- the encapsulated plastic micro circuits.

The technological innovations, which result from these studies, are the object of a transfer between the universities and the manufacturers. Research has led to very significant progresses for the flexible printed circuits, the cards of printed circuit, the integrated hyper frequency monolithic circuits, the plastic components, the mastery of the metal migration, the optical and electric connectors, high density inter connectors and the classical connectors.

Advanced models of thermo mechanical fatigue were developed more particularly for surface mounted technology (SMT) components.

Knowledge from research into physics of failure, in material characterisation, and the effects of the temperature on the electronics, are used to develop guides and procedures of accelerated tests. Furthermore the analysis of finished elements are used to estimate the reliability of the advanced high technologies of interconnection and the last techniques of packaging. These research works were transformed successfully into industrial processes, into methods and recommended practices, given concrete expression by the implementation of software on the industrial sites. Some of these companies incorporated this software into their own tools.

Future developments will be aimed towards reducing the impact of the production costs but maintaining the quality and the reliability of the electronics. The domain of application covers the Multi Chip Modules (MCM), the electronics and opto-electronic at high temperature, a particular effort concerns the development of new electronic products.

For more information on the Calce program; www.calce.umd.edu.

The Reliability Analysis Centre (RAC) is a Department of Defence Information Analysis Centre (IAC). Since its inception in 1968, the RAC serves as a government and industry focal point for efforts to improve the reliability, maintainability and quality of manufactured components and items. To this end, the RAC collects, analyses, archives in computerised databases and publishes data concerning the quality and reliability of equipment and systems as well the microcircuit; discrete semiconductor and electromechanical and mechanical components. The RAC also evaluates and publishes information on engineering techniques and methods. Information is distributed through data compilations, application guides, and software tools. Public and private training courses and consulting services are also provide. The US Air Force Research Laboratory provides technical management of the RAC.

For more information on the the Reliability Analysis Centre;
www.rac.alionscience.com/InfoResources/Rac_ReliabilityData.html

THE PERFORMANCE-BASED REQUIREMENT IN DESIGN

Performance-based requirements of a product must be in terms of real conditions of use. The requirements should flow down from system to subsystem and component. Each item may be an existing evolution (i.e. no novelty of design, configuration or technology) or be new and innovative. Performance based requirements can be based either on calculations or on validated models. Such calculations and tests need to take into account the variability of the product resistance to its environment by a Strength / Resistance approach.

The following table compares performance-based requirements with non-performance based requirements.

Area of Comparison	Performance-based Requirements	Non-performance-based Requirements
Purpose	Describe functions product is to perform and level of performance	Describe how product is to be designed and manufactured
Key Criteria	Describe means for verifying performance	Describe means of- ensuring specified processes are followed
Design Latitude, Given to Contractor	Allow contractor to determine best ways to achieve results	Force the contractor to use prescribed methods and approaches
Responsibility	Responsibility for results clearly belongs to contractor	Responsibility for results shared by customer and contractor

Table 1 Comparison of Performance and Non-performance Based Requirements

THE ELIMINATION OF WEAKNESS IN DESIGN AND TECHNOLOGIES

One of the most effective recognised methods for revealing the weak points of design and/or technologies (and then create margins) is the application of aggravated tests. These are sometimes also called “highly accelerated tests” (see Figure 3). The principle consists of applying to the product step by step loadings (climatic, mechanical as vibration, electrical), and increasing the levels until appearance of a failure. Then failure analysis must be conducted to identify the appropriate corrective action (at the level of design, manufacturing process, condition of use). The testing then continues by increasing the levels of loading. The process terminates when the loading amplitudes are higher than the one resulting from the performance based requirement. That loading should include any coefficients of conservatism necessary to address product resistance variability and strength variability.

Once a failure occurs, the technological analysis must identify if the failure is the consequence of a latent weakness or whether a technological limit has been reached. According to Hewlett Packard, the limit is reached when a small increase of the constraint produces a high increase of the number of failures.

The expected result of aggravated testing is to bring the product near to its inherent technological limits. Product maturity is then be reached before the beginning of the production cycle. As a consequence the operational performances and life duration margins are increased. The operational reliability is also improved and life cycle costs reduced.

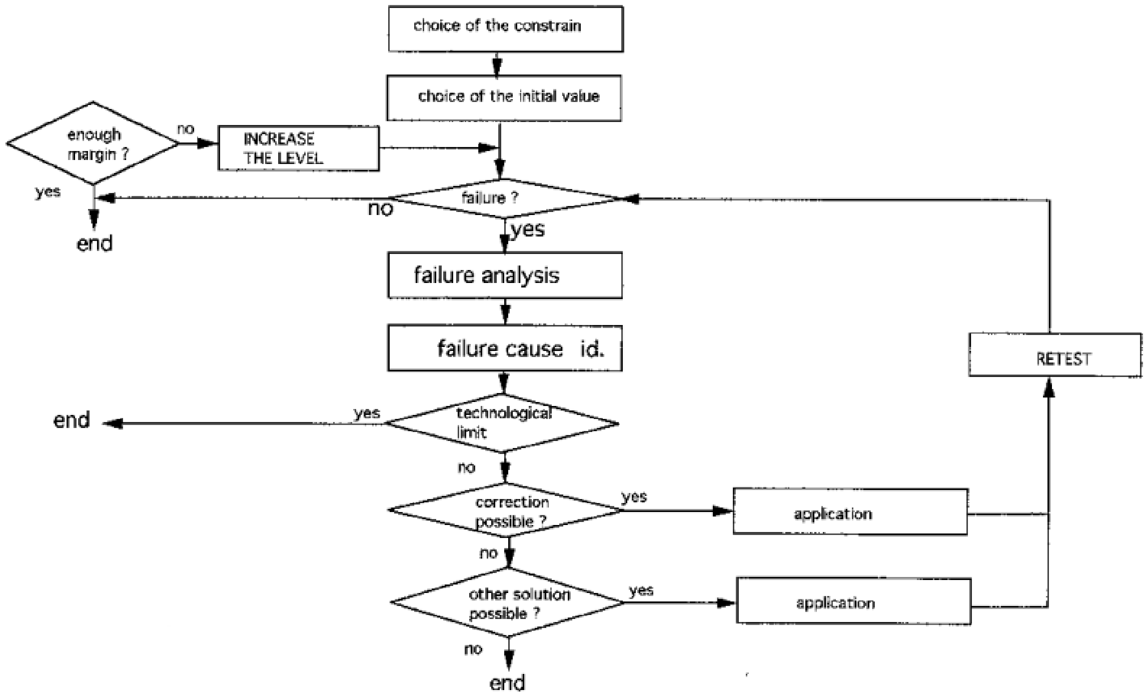

Figure 3 Logical Process Of Carrying Out Aggravated Test Process

The number of units submitted to aggravated testing is depending on the fraction of the population which is affected by a potential defect to be eliminated. As an example, if 2 % of the population are affected by a considered defect and that one likes to precipitate it with a level of confidence of 95 %, it will be necessary to test 145 units. On the contrary if the whole population is affected, a single unity wilt be sufficient.

UNCERTAINTY AND TEST FACTORS

Uncertainties and approximations can exist for various reasons. Typically these can be grouped into environmental variability and equipment strength variability. The latter may be degraded as a result of product and material ageing. These aspects are addressed in the following sections.

Environment Variability

Environment variability arises as a consequence of the relative dispersion of the amplitudes of loading in the real environment. Variabilities exist in loadings from natural climatic (thermal and, humidity) conditions as well as mechanical conditions such as vibration.

There are many sources of uncertainty in vibration environmental prediction. The main one is the variation of the vibration levels from one point to another one on complex structures, in particular at high frequencies. For a given situation, the real environment is defined by a single sample resulting from a short duration measurement, a factor C_E can be applied to cover the possible dispersion on this value. Depending on the situation, C_E can vary between 1.15 and 1.5 [3]. In the case of road transport, to compensate the uncertainties related to variation of the characteristics of the vehicle, the terrain, the speed, the time of year, the driver and the measurement point. Holmgren suggests applying a factor of 1.15 to the overall rms value. In the case of the environment relative to a missile flight, a higher factor applies, equal to 1.4. If statistical results are used (frequency spectrum defined by a mean curve plus a few standard deviations), a factor of unity is applied.

Equipment Strength Variability

For reasons of cost, a single test is generally conducted. The specimen selected belongs to a population whose mechanical strength has a statistical distribution. A factor therefore needs to be applied to the real levels to make sure that the weakest item of equipment will be capable of withstanding the same environment. A factor of 1.15 is commonly employed for this purpose.

Ageing of Equipment

Ageing of equipment is the alteration of strength over time (excluding fatigue and wear). Certain equipments are required to operate after a long storage period. To take this ageing into account, a higher initial mechanical strength may be required by increasing the test levels by a certain factor, such as 1.5. If the test is conducted on equipment that is already aged, a factor of unity applies.

Testing generally requires conducting the vibration loading to be applied sequentially on each axis in turn. In most cases the real vibration environment is an instantaneous vector of loading arising in the three orthogonal axes. In some cases, a multiplier of 1.3 is applied to take into account the fact that each component is necessarily less than or equal to the modulus of the resulting vector.

It has been observed that in the case of two resonances, which are not coupled but simultaneously excited in two different axes, a failure can occur in the real environment even though the product survived the test applied axis by axis. In such cases a factor applied during the test does not necessarily solve the problem.

As will be realised from the preceding paragraphs there are many reasons for applying a conservatism factor. However, simply accumulating all the factors may lead to a large, non-realistic factor, as the conditions they represent never occur simultaneously. That is the total conservatism coefficient is not derived by multiplying directly all the individual components.

This caution in determining the test specifications cannot not be exaggerated. Lawrence, discussing vibration-isolating systems, considers that for structures, a factor of 2 often leads to a dimension and weight penalty of around 20 %. However, in the case of random vibrations, a factor of 2 commonly leads to penalties of 100 %. Nevertheless, such factors have been applied in the past. Generally realistic total conservatism coefficients are;

- For acceptance tests: factors between 1 and 2 are applied to the real environment depending on the confidence in the data, with limited test duration to preserve the equipment but sufficiently long to allow functional testing,
- For qualification tests: increase of the acceptance test levels from 3 to 6 dB and of the test duration by a factor of 3 to 5, resulting in a test that is globally four times more severe and five times longer than the mission.

Any test will more accurately represent reality if an understanding of the real environment and material behaviour is used instead of conservatism used out of “ignorance”. This is possible for example by performing the tests on an aged equipment, if necessary or on a three simultaneous axis test facility if no axis is excited predominantly over the others in the field.

The Purpose of Uncertainty Factor

The environmental factor characterising a given life profile situation, will generate a different amplitude at each new occurrence. These amplitudes are randomly distributed, with a distribution law (in general normal or log normal) and the associated statistical parameters; mean, variance (standard deviation), skewness and kurtosis. These parameters are characterising the environmental factor variability.

The product resistance limit (characterising the product subjected to the considered environmental factor) is also a random variable, representing the variability of the product to withstand environmental and imposed loading. In the absence of measurements this variability can be characterised by considering an estimate of the corresponding coefficient of variation (that is the ratio of the resistance standard deviation to the resistance mean).

For each non-negligible environmental factor, it is possible to characterise the environmental factor variability and the corresponding material resistance variability.

The existence of these two variabilities will establish a risk of failure (see following Figure 4), indicated by the area of intersection between the two probabilities density curves respectively associated to the two above variabilities. The exact value of this risk can be calculated from the parameters characterising the two probability density functions.

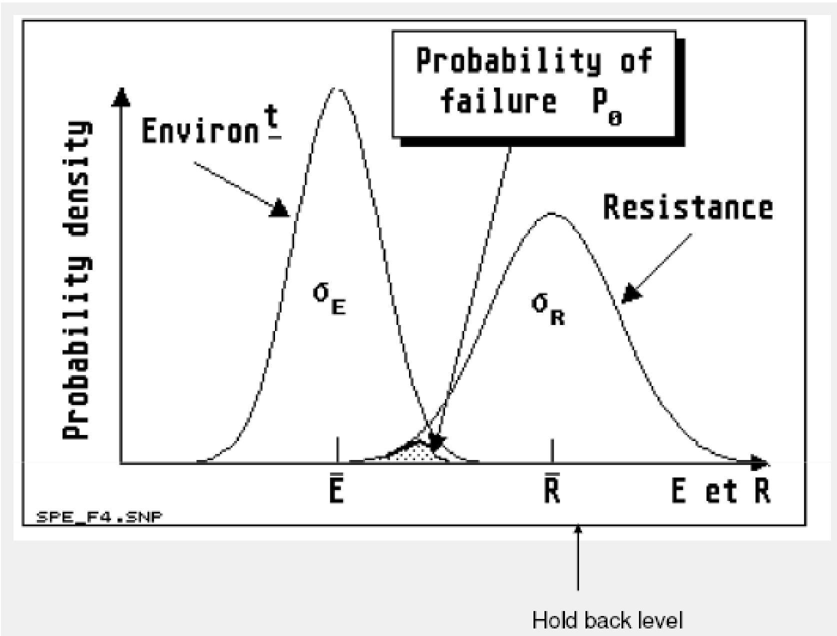

Figure 4 Relationship Between Distributions in Product Strength and Environment

It will be noticed that in the case of the material resistance variability, it is not normal to assume knowledge of the material mean resistance but only the ratio between the standard deviation to the mean resistance. This scalar value can be multiplied by the environmental factor mean value, to permit the user to identify what should be the material mean resistance (to the considered environmental factor) required to meet the accepted risk of failure. This scalar is called the uncertainty factor. The result of this operation, which is still expressed in the same quantity as the original considered environment (or its representative) is referred to as the hold back environment.

The Purpose of Test Factor

The aim of the test is to demonstrate that; if the products under test passes the test then the total deployed population in the field will disclose the rate of failure equal to the probability of failure taken for the calculation of the uncertainty factor (or safety factor). This would be simple if the population submitted to the test were infinite. In general, the items submitted are a small number (sometimes only one!). When the numbers of items submitted to the test are limited, the product strength (resistance) is located within an interval of confidence that becomes larger when the number of test items is reduced. The remaining part of this interval of confidence is the test factor.

In reality it is not practical to undertake an infinite number of tests and generally only few are utilised. When the number of tests is decreased, the interval of confidence, for a given probability, will become wider. To achieve the same guarantee of material resistance from a reduced number of tests then the test severity must be increased by a new factor which is equal to the left part of the above interval of confidence. This new factor is usually referred to as the test factor. It is equal to one for an infinite number of tests and increases when the number of tests is reduced.

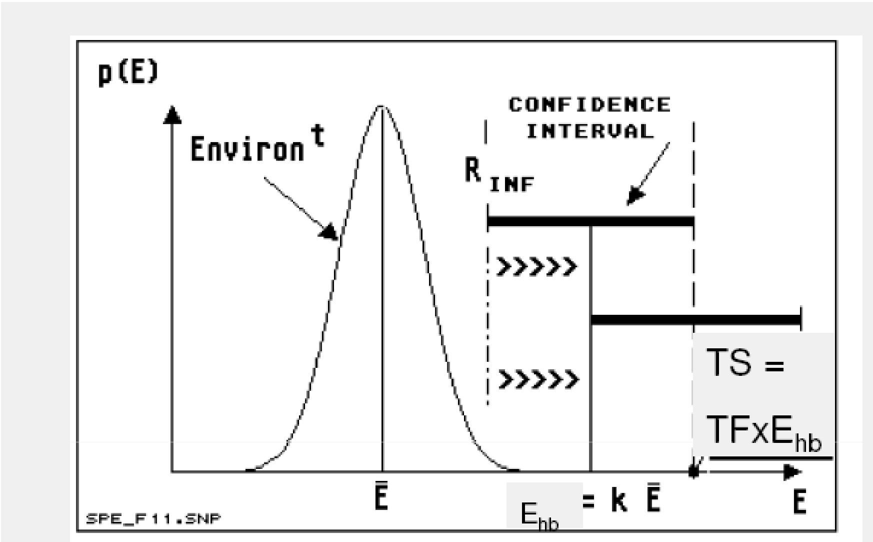

Figure 5 Uncertainty Interval

The above uncertainty and test factor approach supposes, for every performance sensitive to an environmental factor, the accepted probability of corresponding failure. In the absence of data the accepted probability is 10^{-3} when safety is not an issue, when safety is an issue then 10^{-6} is appropriate.

VALIDATION OF THE FUNCTIONS

The process of validation is a set of tasks where the engineer responsible for the product or the process recognises that the product complies to the defined technical specification. This process leads to the validation of the functions and must be carried out in a progressive ascending way.

Whether the material is an evolution (no novelty of design, of configuration, of technology, of the conditions of employment) or a revolution (novelty of design, etc.), the validation will be based on calculations, models (validated by previous return of experience) or on experimentation. The validation calculations and / or tests have to take into account the variabilities characterising the component and / or material strength to resist the loading by an approach that will define the uncertainty factor and test factor.

The actions of design and of validation can be carried out concurrently within the of design phase. If the calculations and models used in the design phase to size a product are validated, and used within their validated area, then the corresponding action can be presented as an action of product validation.

The steps of the process leading to the validation plan consists of establishing a list of the tests and of simulations, these are;

- in optimising it,
- in building the logical chain of the withhold tests and simulations,
- in defining the necessities to materials to test,
- in confirming the global validation rationale at all the levels of assembly,
- in defining the needs in test equipments,

- in establishing tests and simulation work sheets,
- in elaborating and in optimising the test plans,
- in establishing, in spreading and in updating the tests plan.

ENVIRONMENTAL STRESS SCREENING AND HA-ESS

The principle of Environmental Stress Screening (ESS) consists of subjecting the units, during the production cycle, to various stimulations (vibrations, rapid variation of temperature etc.) in order to precipitate latent defects inherent to the manufacturing processes, weak components and, in new products, weaknesses of design.

Mass production of equipment or highly integrated components (in general mature components) does not require Environmental Stress Screening but rather is replaced by manufacturing processes evaluation and control. ESS is essentially only a stop gap action, necessary as long as the variability exists in the production processes. Environmental Stress Screening can be superfluous for some types of components, such as the capacitors (except tantalum), resistors, diodes (generally), quartz, transistors. Some components may screened either by the component supplier or the component user. Such components include some diodes, high power transistors, logic integrated circuits, tantalum capacitors and some relays.

Environmental Stress Screening of electronic equipment has become essentially a classic strategy. The rate of defect precipitation for a product having a mature design and mature manufacture processes is generally ranged between 0 and 1 %. Most of the manufacturers who implement ESS maintain it because they try to gain every tenth of percent on the defects in the field. On the hypothesis that 10 to 50% of the precipitated defects during ESS would be disclosed in field deployment.

The application of Environmental Stress Screening at component level requires specific care as it can be expensive and is not without risk to the components. The choice of ESS program for a new component supposes an electric and physical characterisation, accelerated tests and step stress approach. Abandoning an ESS approach may necessitate a compensatory component surveillance exercise.

For complex systems such as missiles; cycles of rapid change of temperature combined with vibrations constitutes only 2 actions of typically 9 different applications of Environmental Stress Screening experienced by an electronic item before its integration at full system level. It is only after this number of separate applications of ESS that the rate of defect stabilises between 0 and 1 %.

There are now more Aggressive form of Environmental Stress Screening available which are known as HA-ESS (Highly Accelerated – Environmental Stress Screening) is preceded by HAT (Highly Accelerated Testing), which tests the product limits for a state of the art equipment in areas of design, technologies and product operation. The knowledge of these limits permits the application of more severe conditions than in classical ESS. However, care must be taken to prevent consumption of a significant part of the products potential useful life.

Highly Accelerated Testing has found a particular implementation known as HALT (Highly Accelerated Life Test), which applies several types of stimulation set by different test equipment suppliers. Similarly, HA-ESS has also found a particular implementation, known as HASS (Highly Accelerated Stress Screening), which applies several types of stimulation set by different test equipment suppliers.

The advantages put forward by users of the HASS method are;

- a simultaneous application of multi-axial random vibrations (typically generated by pneumatic hammers producing structural responses in 6 degrees of freedom),
- thermal cycling with a rapid change of temperature typically of 20 °C/min to 60 °C/min,

- functional equipment activation varying the power, the frequencies and the tensions,
- functional monitoring during the stimulations.

A relatively recent study 'Environmental Stress Screening on 2000' was led by 'National Centre for Manufacturing Sciences' and the results presented during the IEST Annual meeting in 2001. The objective was to compare the cost/efficiency of various methods of ESS , either classical or more aggressive methods. The study reviewed;

- the approach referred to MIL STD ESS (traditional approach based on NAVMAT 9492)
- the approach of HALT/ HASS (highly accelerated life test /highly accelerated stress screen)
- the approach of ED/ACLT/ACSS (electro-dynamic accelerated life test /Accelerated Stress Screen); it should be said the same that HALT/HASS but by using electro-dynamic shakers instead of electro-pneumatic shakers
- ESS by thermal liquid /liquid shocks, LESS (Liquid Environmental Stress Screen)

The application of thermal shocks is often employed to precipitate latent defects in mechanical, electronic products and assemblies. The efficiency of this form of ESS loading is limited by the speed of the temperature variation. However, liquid/liquid thermal shocks are able to produce rates of 10000 °C/min. Nevertheless, considering some components are not waterproof, the application may have limited application.

The results of the National Centre for Manufacturing Sciences study were;

- it allowed a better understanding of the failure mechanisms, easier choice of the screening method and its tailoring,
- the products that contain electronic components defects then the liquid/liquid ESS will be adapted to precipitate them,
- on the other hand the product contains more manufacturing defects and the HA-ESS approach is more effective,
- no one method among the four above is determined as the most efficient, irrespective of the product, the processes of manufacture or the packaging technologies which are used,
- military and commercial products can be subjected to the HALT/HASS without any risk of damage.

For the products subjected to the liquid/liquid ESS, there where no defects bound to this method. The capacity of the product to be screened with this method depends of the materials of the product, which will not be damaged by the fluid medium.

CONCLUSION

The maturation of products can be achieved at the beginning of their exploitation. This corresponds and aligns to a legitimate and implicit user expectation. Methods exist to assist towards this objective and many are presented in this document. The methods have in common that they assume ongoing efforts to improve maturity in all the phases of the development and of the manufacture of products. Experience indicates that to achieve a mature product it is necessary to mobilise resources and numerous methodologies that are sometimes new.

REFERENCES

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[3] CIN EG 1/French Ministry of Defense “ Tailoring a product to its LCEP during the development”

ANNEX 1 Types Of Test

Accelerated Tests

During accelerated testing a product is subjected to loading and conditions above those it would be expected to experience in service in order to accelerate the occurrence of failures but in reduced duration.

They are three types of accelerated tests;

Type 1: Those based on acceleration by reducing the number of experiments, based on design of experiments,

Type 2: Those where the acceleration is based on statistical models,

Type 3: Those where the acceleration is based on physical models of failure.

Reliability Growth Tests

Reliability growth is the improvement in the reliability of a product (component, subsystem, system) due to a well structured process of finding reliability problems and monitoring the increase of the product's reliability through successive phases in time. A comprehensive reliability growth program is developed based on three important factors;

- management, where the decisions are made to keep the program moving,
- testing, where all the weaknesses and failure modes are found in the design and manufacturing process,
- Failure Identification, Analysis and Fix (FIAAF), where the cause of failure is isolated, analyzed and then fixed.

Reliability growth can be characterized after a small amount of tests and improvements (e.g. by the model of Duane).

Highly Accelerated Test

A development Test where the applied constraints rose in a progressive way in very upper values in comparison to the qualification specified values and the essential objective of which being to investigate the limits of functioning and of destruction of the product in order to push them away, by suited actions, in the limits imposed by the state of the art of technology of its constituents. This is defined as the stress level at which a small increase in stress causes a large increase in the number of failures. Highly Accelerated Test brings robustness or design margins to the product.

Development Tests

Development tests are used to determine the aptitude of components, materials and/or designs to meet the requirements (functional and operational) of a given specification. These tests may prepare for the qualification, the Reliability Growth Test (RGT) or the Reliability Demonstration Tests. However, they also can contribute to prepare product development decisions.

Qualification Tests

The qualification test is a series of tests realised on one or several examples of a product, to demonstrate compliance complying with the requirements (functional and operational) of a given specification.

Reliability Demonstrations

A Reliability Demonstration Test (RDT) is the demonstration of the reliability of a product. In particular the RDT will generate data from which it will be possible to establish the average time before the product fails.

ROSE Robustness Testing

ROSE means Robustness Specification for Environmental test. The test objective is to find weaknesses at an early design phase particularly at the conceptual design and component specification phase. The key element is that components and products are tested until they fail in order to identify the relevant environmental test severity. With the knowledge of this severity estimates can be made of the behaviour, reliability and risks involved in using the design in-service.

Robustness Testing

MEOST means Multiple Environmental Overstress Testing and is described by the book of K.K. Bothe, World Class Reliability. The intention is to address multiple environments in terms of mutual influences and synergism. This is different from sequential testing, where tests are done in a certain order.

Environmental Stress Screening (ESS)

ESS is a test or a set of tests intended to remove defective items or those likely to exhibit early failures. The applied stress levels are normally similar as those expected in field operation.

ESS is often performed at assembly level (PCB) or equipment level on a 100 % basis to find defects and/or systematic failures during a preproduction phase or to provoke early failures during the series production and therefore to improve the reliability of a lot of items by elimination of the defectives one. To be efficient and cost effective, ESS has to be tailored to the kind of item and the used production process.

Highly Accelerated Life Testing (HALT)

HALT is a commercial variant of Highly Accelerated Test (HAT). Both are intended for the identification of design weakness by applying a series of environmental tests that typically include: thermal, vibration, power cycling and a combination of these environments. The thermal conditions can include very rapid variations of temperature (often with nitrogen cooling). Whilst, the vibrations are applied in multi-axes sometimes (but not only) by multi input pneumatic hammer excitations.

During HAT and HALT the item under test must be operational and its performance monitored. Contrarily to ESS, HALT is not a screening method but a test intended to verify the result of a development or the quality of the preproduction item. The results of HALT are used to define the stress limits for HA-ESS. Not surprisingly the applied stress levels for HALT are higher than for HA-ESS. To reduce the test time for the items to be tested, the applied stresses are much higher than those expected in field operation. Indeed the applied stresses may bear little or no relationship with those experienced in field conditions. For this reason HALT is essentially a destructive test.

Highly Accelerated Environmental Stress Screening (HA-ESS)

HA-ESS is a screening method, like ESS, but the applied environmental severities are far above the field requirements while staying below the destructive limits. The aim of HA-ESS is to increase the reaction rate of the failure mechanisms and consequently to reduce test time.

The purpose of HA-ESS is not to highlight design problems, but to detect any defects in the unit that have arisen during the manufacturing / production process before the unit comes into use. The advantage of HA-ESS, compared to ESS, is partly the time factor but also the ability to detect weak points which would not be detected by normal ESS. Typically the test severities for HA-ESS are determined by the HAT results.

Acceptance Tests

Acceptance testing is performed on a system (e.g. software, lots of manufactured mechanical parts, or batches of chemical products) or sub-system prior to its delivery. In some engineering sub-disciplines, it is known as functional testing, black-box testing, release acceptance, QA testing, application testing, confidence testing, final testing, validation testing, usability testing, or factory acceptance testing. As the item has to go into service after the application of the severities, they are usually less than the qualification test severities, but set based upon consideration of the qualification test severities.

Production Reliability Acceptance Tests (PRAT)

Production Reliability Acceptance Test (PRAT) is a process to demonstrate that the production standard hardware continues to meet the reliability requirements throughout production. This is normally achieved by subjecting a selected sample of production hardware to environmental conditions and functionally tested as specified in the PRAT plan that will be developed during pre-production.

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ANNEX 2 Frequently Asked Questions on Reliability Test Types

Accelerated Tests

What Are the Objectives of the Test?

The prime objective of Accelerated testing is to achieve faster investigations by reducing the test duration.

The principle of accelerated testing is that the product is subjected to conditions of use or to constraints of environment amplified in order to accelerate the mechanisms of failure and to reduce the necessary duration to estimate some behavioral characteristics of the product in the normal conditions of employment. Accelerated testing should not be confused with “highly accelerate testing” whose aims are very different. Accelerated testing has nothing to do with ESS or highly accelerated testing.

In order to successfully apply an accelerated testing strategy certain conditions of application must be adhered to;

- the relation between the mechanism of failure with the amplitude and duration of the applied conditions and the parameters involved.
- The induced mechanisms of failure have to be representative of those arising in the normal conditions of use.
- synergism and interactions between several constraints of use and of the applied environment must be taken into account.

Testing is done until failures take place and the key is to understand the failures and their relationship to the applied stresses and to correct them. Accelerated life testing is performed to obtain information about the product (component, module, system etc.) lifetime distribution or a particular reliability parameter in a timely manner. This can be done in two different ways or in a combination of them;

- using time compression, for example by changing the length of on and off cycles
- accelerating the loading conditions

The purpose of life testing is to identify the relevant failure mechanisms that would occur, and correlate these with the point in the product’s life the failure would occur. All the stresses during the product’s whole life cycle need to be addressed e.g. transportation, storage and the actual use conditions. These conditions usually include different and changing temperatures, humidity, mechanical stresses (vibrations, shock, bumps etc.), electrical and electromagnetic phenomena etc.

What Are the Drivers For Choosing The Test?

The need to shorten time to marker is the main reason for adopting an accelerated testing strategy.

What Level Of Assembly Of The Product Normally Submitted To Test?

Quite often the greatest benefit of accelerated tests (in term of knowledge acquisition) is achieved by performing tests at the lowest level of assembly. Test should also be made early in the product development process. However, testing should be continued during the different phases of the product development and the production phases.

How Many Items are Normally Submitted To Test?

For statistical confidence the need is often higher than what is practically possible; about five being a minimum but few tens would be needed.

In general one; the application on higher amount might be a response for product variability considerations: see hereinafter.

What Type Of Product Are Appropriate For This Test Type?

All types of product may be submitted to accelerated testing

What is the Typical Duration of a Test Programme?

Accelerated stress test can be made variably in days or few weeks. Life testing typically requires several weeks, even some months.

Should Separate or Combined Environments be Considered?

Different types of stresses are needed to precipitate the different failure mechanisms. Their simultaneous combination is sometimes necessary. Proper combination of stresses may be used to realise synergistic effects – for example thermal cycling and vibration. Humidity is also usually applied with constant or varying temperature.

Are Variations In Product Strength And Environmental Stresses Considered?

The accelerated test can take into account variations of product strength.

Does The Test Supply Knowledge On Reliability Parameters?

Life testing aims at getting an estimate of for example of the failure rate (or MTTF, MTBF) or the on-set of wear-out mechanisms (life time) or at least the relevant failure mechanisms.

Does The Test Consume Product Life?

Accelerated stress tests and life tests are destructive.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

Additional relevant information can be found in;

IEC 60068-2 Environmental testing, accelerated stress tests.
IEC 60749 Mechanical and climatic test methods (semiconductor devices).
MIL STD 810 G
STANAG 4370
DEF STAN 00-35
GAM EG 13

Reliability Growth Tests

What Are the Objectives of the Test?

Reliability growth testing is performed to assess current reliability, identify and eliminate faults, and forecast future reliability. The reliability figures are compared with intermediate reliability objectives to measure progress so that resources can be directed to achieve the reliability goals in a timely and cost effective manner. Whenever a failure occurs, corrective action is undertaken to remove the cause. For hardware, growth testing is the process of testing the equipment under both natural and induced environmental conditions to discover latent failure modes and mechanisms to ensure that all performance, design, and environmental problems have been resolved.

Reliability growth is the improvement in the reliability of a product (*i.e*. component, subsystem or system) or service over a period of time due to changes in the product design and/or the manufacturing process. Reliability growth analysis (RGA) concerns itself with the quantification and assessment of parameters (or metrics) relating to the item's reliability growth over time. Reliability growth management concerns itself with the planning and management for the item's reliability growth as a function of time and resources.

Reliability Growth is a quantitative methodology; it is used to analyze the improvements made on a product design and verify whether a certain reliability goal has been reached. It is usually performed in normal conditions (unlike HALT which is performed in highly stressed conditions). In general, the first prototypes produced during the development of a new complex system will contain design, manufacturing and/or engineering deficiencies. Because of these deficiencies the initial reliability of the prototypes may be below the system's reliability goal or requirement. In order to identify and correct these deficiencies, the prototypes are often subjected to a rigorous testing program. During testing, problem areas are identified and appropriate corrective actions (or redesign) are taken. Reliability growth is the improvement in the reliability of a product (component, subsystem or system) over a period of time due to changes in the product's design and/or the manufacturing process. A reliability growth program is a well-structured process of finding reliability problems by testing, incorporating corrective actions and monitoring the increase of the product's reliability throughout the test phases. For more info about Reliability Growth, refer to: http://www.weibull.com/relgrowthwebcontents.htm#Introduction.

What Are the Drivers For Choosing The Test?

Reliability growth testing is performed to assess current reliability, identify and eliminate faults, and forecast future reliability.

What Level Of Assembly Of The Product Normally Submitted To Test?

In general, the first prototypes produced during the development of a new complex system will contain design, manufacturing and/or engineering deficiencies.

How Many Items are Normally Submitted To Test?

Usually several items typically 1 to 10.

What Type Of Product Are Appropriate For This Test Type?

Typically innovative mass volume products which can be revolutionary either in design, technologies used or conditions of usage. Also potential sensitive products or those with safety implications.

What is the Typical Duration of a Test Programme?

Typical duration of testing is measured in weeks.

Should Separate or Combined Environments be Considered?

This is mostly a combined. Test sequence.

Are Variations In Product Strength And Environmental Stresses Considered?

Product strength and environment stress variabilities are not considered.

Does The Test Supply Knowledge On Reliability Parameters?

Reliability information generated and recorded over time can be used to observe trends in the reliability of the product. The term "growth" is always used since you assume that the reliability of the product will increase over time as design changes and fixes are implemented. In other words, reliability growth is a projection of the reliability of a system, component, unit (or service) to some future development time. This projection is based upon information currently available from predictions or prior experience on identical or similar systems. Monitoring the reliability, the mean time between failures (MTBF) and the failure rate of the system, equipment or product also establishes a trend in the increase in the reliability, the increase in the MTBF or the decrease in the failure rate. This is achieved with engineering, research, development, test-analyze-and-fix (TAAF) and/or test-analyze-and-redesign (TAAR) procedures until it passes its acceptance tests and/or is delivered to the end-user.

Does The Test Consume Product Life?

Product life is consumed by this test.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

MIL-HDBK-189 Reliability Growth Management, February 1981. 155 Pages. This handbook provides procuring activities and development contractors with an understanding of the concepts and principles of reliability growth, advantages of managing reliability growth, and guidelines and procedures to be used in managing reliability growth. It should be noted that this handbook is not intended to serve as a reliability growth plan to be applied to a program without any tailoring. This handbook, when used in conjunction with knowledge of the system and its development program, will allow the development of a reliability growth management plan that will aid in developing a final system that meets its requirements and lowers the life cycle cost of the fielded systems. (This document describes the Duane method of reliability growth and becomes the Duane AMSAA methodology which today is described as the Crow-AMSAA reliability growth model.)

Highly Accelerated Tests

What Are the Objectives of the Test?

Test where the applied constraints rose in a progressive way in very upper values in comparison to the qualification specified values and the essential objective of which being to investigate the limits of functioning and of destruction of the product in order to push them away, by suited actions, in the limits imposed by the state of the art of technology of its constituents.

What Are the Drivers For Choosing The Test?

Reasons for using this test strategy include;

- time to market of the product
- safety consideration (avionics)
- maintainability costs
- technological limit: the limit of resistance imposed by the technology of a product or of a particular constituent, toward a given constraint (temperature, vibration, electric tension, etc.). This limit establishes so an unbridgeable barrier. Ex: melting point of a plastic building material, temperature the maximum of a functioning a semiconductor in the silicon, elastic limit of a building material, etc.

What Level Of Assembly Of The Product Normally Submitted To Test?

His type of test is normally undertaken on items at the lowest possible level of assembly.

How Many Items are Normally Submitted To Test?

The statistical aspects in relation with the number of realized Highly Accelerated Tests on a new product intervene to at least two levels:

- the capacity of the Highly Accelerated Tests to discover relevant causes of failing;
- the obtaining the limits of functioning and / or of destruction and the associated variableness.

With regard to the capacity of the Highly Accelerated Tests to discover relevant causes of failing, two cases are be considered:

- First Case: the relevant causes of failing presumed are of abstract nature and have for effect to reveal a problem on every copy subjected to attempt, since an applied constraint exceeds the specified value. It is translated generally by an incapacity of margins, typical case of the use of a badly calibrated constituent. In that case, the realized Highly Accelerated Tests on a very limited sample of copies, even on the single copy, turns out effective to reveal the existence of the relevant cause of defect and power so to correct it,
- Second Case: the relevant causes of failing presumed can affect a priori only a weak fraction of the complete population of the product (for example: less than 5 % of the population). In that case, it is not very probable that a limited number of Highly Accelerated Tests allows to reveal this relevant cause. As example, the use of the model binomial indicate us that if one hopes to reveal an relevant cause of failing affecting only 5 % of the population with a probability of the success of 80 %, it would be necessary to subject about 30 copies to the test of Highly Accelerated Tests. Such quantity is totally incompatible with the imperative manufacturers. Consequently, the Highly Accelerated Tests realized in the phase of conception / development on an always very limited number of copies can not have a great efficiency toward the revealing of this type of defects. Only, highly accelerated ESS (HA-ESS) in the phase of production will be susceptible to reveal, in addition to the manufacturing defects, these defects of the conception, which would affect only a weak fraction of the products during their profile of life.

With regard to the obtaining the limits of functioning and / or of destruction of the product, the major difficulty places itself in the statistical character associated to these sizes. So, the obtaining in a different way given value on the limit of functioning the single copy does not reveal inevitably the central value of the statistical distribution of this limit which could be associated to an important population of the tested product. In particular, this unit experimental value can be a value of tail of distribution, placed to the left or to the right of the distribution. It proves why it is hardly recommended, when it is compatible with the imperatives of development, to make the Highly Accelerated Tests on several copies and not on the single unity. The number of available copies always being very limited in the phase of development.

What Type Of Product Are Appropriate For This Test Type?

The majority of products are appropriate for this test type. For some products Highly Accelerated Testing may induce failures that do not occur during actual use. In such cases for some product types it may not be possible to rectify identified failures and meet other design and cost requirements.

What is the Typical Duration of a Test Programme?

The duration of a highly accelerated tests campaign is very brief: of the order of five days on average.

Should Separate or Combined Environments be Considered?

Combined environments are not normally employed but can be if necessary to disclose a failure. For example, we can gradually increase the vibration level for a given rate of temperature variation or by increasing gradually this rate for a given level of vibration.

Are Variations In Product Strength And Environmental Stresses Considered?

The test does not address variations in product strength and environmental stresses.

Does The Test Supply Knowledge On Reliability Parameters?

The test provides no evidence on reliability parameters.

Does The Test Consume Product Life?

Yes , the product under test is normally destroyed.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

None currently.

Development Test

What Are the Objectives of the Test?

Development tests are used to determine the aptitude of components, materials and/or designs to meet the requirements (functional and operational) of a given specification. These tests may prepare for the qualification, or the RDGT or reliability demonstration, but not only: they also can contribute to prepare R&D decisions.

Outgoing from the specified environmental requirements relating to operation, transportation and storage, the appropriate test procedures, the stress levels and the test duration shall be chosen, considering the experiences with earlier development and the know-how of the test specialists.

The test results are used to make design decisions as well as to evaluate the "Reliability" and/or the "Life Time" of a product and to prove the rightness of a design. Therefore the test results, methods, tools and conditions shall be documented and stored on such a way, that the probability of loosing or distracting then is very low.

What Are the Drivers For Choosing The Test?

The tests are done during the development and design phase of a project with two aims;

- to determine the ability of materials, components and/or designs to resist on effects of specified environmental conditions, where experience is missing and/or calculation or virtual simulation is not possible or not enough accurate.
- to determine the ability of a design solution to meet the functional requirements of a given specification. While being a substantial part of development costs and an important design tool, it is necessary to plan and to budget it at the very beginning of a development project. The principal input for this planning activity is the product specification

What Level Of Assembly Of The Product Normally Submitted To Test?

The test may be used on material, components and sub assemblies.

How Many Items are Normally Submitted To Test?

In general one. But several may be retained for qualification in order to reduce the duration of it: the sequence of tests applied to each of them must be in relation with the real sequence expected in the field

What Type Of Product Are Appropriate For This Test Type?

Not relevant for those constrains covered by other specified tests (which must be stated in the test plan) such as highly accelerated tests.

What is the Typical Duration of a Test Programme?

The duration of the test programme will depending on; what is the goal of the specific development test and the type of test: endurance (several hours or days), reliability (in general 10 times the specified MTBF for one equipment or 10/n for n equipments)

Should Separate or Combined Environments be Considered?

As much as possible the conditions should be separated. This may not be possible in some specific cases such as the presence of polymer material in a suspension (requires vibration and temperature).

To allow to determine the effect of single stress factors on a material or item respectively to avoid the reciprocal influence of several stresses, the test conditions are usually special lab conditions, not equal to the real environmental conditions of the product.

Combined tests (Humidity/Temperature; Vibration/Temperature etc.) are also often used, but normally applied on the final product and not for the purpose stated out.

Are Variations In Product Strength And Environmental Stresses Considered?

Variations in Product Strength And Environmental Stresses should be considered. The uncertainty (or safety) factor and test factor are the best way to manage these variabilities.

Does The Test Supply Knowledge On Reliability Parameters?

Yes if the test is dedicated to Reliability growth.

Does The Test Consume Product Life?

The sub assemblies, component, submitted to test are no more entering in the delivery for the customer. They might be used for mock up, study or prototype purposes.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

The results of these tests are normally only for internal use (in general not given to the customer) . So the reference to the standards is not mandatory. No known standards are related to the development tests.

Qualification Tests

What Are the Objectives of the Test?

The qualification test is a series of tests realized on one or several exemplary of a product, complying with the same definition file, in order to assure that it meets all of its design specifications. This is also referred to as:

Verification and Validation (V&V) Testing, or Design Approval. A series of tests conducted by the government procuring activity, or an agent thereof, to determine conformance of materials, or materials systems, to the requirements of a specification which normally results in a Qualified Products List (QPL) under the specification. Qualification under a specification generally requires conformance to all tests in the specification. It may however, be limited to conformance to a specific type, or class, or both.

Product certification or product qualification is the process of certifying that a certain product has passed performance and/or quality assurance tests or qualification requirements stipulated in regulations such as a building code and nationally accredited test standards, or that it complies with a set of regulations governing quality and/or minimum performance requirements. A formally defined series of tests by which the functional, environmental, and reliability performance of a component or system may be evaluated in order to satisfy the engineer, contractor, or owner as to its satisfactory design and construction prior to final approval and acceptance.

What Are the Drivers For Choosing The Test?

As soon as the first prototype is built, the product must begin testing to assure that it meets all of its specifications (verification). Once this is complete, it must then undergo further testing to assure that it works as the customer intends to use the product (validation).

What Level Of Assembly Of The Product Normally Submitted To Test?

Highest product level of assembly if the corresponding facilities exist and if the cost is reasonable. Otherwise, split in sub assemblies that are qualified separately.

How Many Items are Normally Submitted To Test?

One or several but generally less than 5.

What Type Of Product Are Appropriate For This Test Type?

All the products should be qualified .

What is the Typical Duration of a Test Programme?

In general, weeks for a whole system.

Should Separate or Combined Environments be Considered?

Separate environments. In some cases, combined environments should be used : for example in the case of elastomeric suspension where vibration and temperature should be combined.

Are Variations In Product Strength And Environmental Stresses Considered?

Variations in product strength and environmental stresses are considered.

Does The Test Supply Knowledge On Reliability Parameters?

The test does not supply knowledge on reliability parameters.

Does The Test Consume Product Life?

The test consumes product life.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

MIL STD 810 G
STANAG 4370
DEF STAN 0035
GAM EG 13

Reliability Demonstration

What Are the Objectives of the Test?

A Reliability Demonstration Test (RDT) is the process of demonstrating the reliability of a product. An RDT will be able to define in particular the average time before the product fails . We can run the RDT in an accelerated manner to obtain this information in order to decrease the development time.

There are in general 3 stages to a Reliability Demonstration

- Test – Planning,
- Testing/Monitoring,
- Final Analysis.

Planning the test Stage. In the planning stage, a reliability goal is established. Then, a reliability demonstration test model is chosen. We shall then develop a Decision Matrix and outline all of the parameters that we must decide on prior to writing the plan, including types of stresses, number of units, length of test, confidence, etc, along with advantages and disadvantages for each. From this matrix, we shall jointly decide on all of the parameters that will go into the RDT Plan.

Testing and Monitoring Stage In the testing and monitoring stage, the Reliability Demonstration Test is performed and the results are monitored to determine status compared with the goal. The test shall be set up so that the monitoring will only need to be performed a few times a week, once a day at most.

Final Analysis Stage. In the final analysis stage, the data is compiled and a report is written on the results. The report will compare the achieved results to the goal and will show how the data was calculated. It will contain detailed information about the models used.

Frequently, a manufacturer will have to demonstrate that a certain product has met a goal of a certain reliability at a given time with a specific confidence. Often, it will be desired to demonstrate that this goal has been met with a zero-failure test. In order to design and conduct such a test, something about the behavior of the product will need to be known, *i.e.* the shape parameter of the product's life distribution. Beyond this, nothing more about the test is known, and usually the engineer designing the test will have to study the financial trade-offs between the number of units and amount of test time needed to demonstrate the desired goal. In cases like this, it is useful to have a "carpet plot" that shows the possibilities of how a certain specification can be met.

This methodology requires the use of the cumulative binomial distribution in addition to the assumed distribution of the products' lifetimes. Not only does the life distribution of the products need to be assumed beforehand, but a reasonable assumption of the distribution's shape parameter must be provided as well. (Note: The exception to this is the exponential distribution, which does not have a shape parameter. This is equivalent to assuming a Weibull distribution with β = 1) Additional information that must be supplied includes the reliability to be demonstrated, the confidence level at which the demonstration takes place, the acceptable number of failures and either the number of available units or the amount of available test time. The output of this analysis can be the amount of time required to test the available units or the required number of units that need to be tested during the available test time.

Frequently, the entire purpose of designing a test with few or no failures is to demonstrate a certain reliability, R_{DEMO}, at a certain time. With the exception of the exponential distribution (and ignoring the location parameter for the time being), this reliability is going to be a function of time, a shape parameter and a scale parameter.

$$R_{DEMO} = g(t_{DEMO}, \theta, \phi) \qquad (3)$$

where:
t_{DEMO} is the time at which the demonstrated reliability is specified
θ is the shape parameter
ϕ is the scale parameter

Since required inputs to the process include R_{DEMO}, t_{DEMO} and θ, the value of the scale parameter can be "backed out" of the reliability equation of the assumed distribution, and will be used in the calculation of another reliability value, R_{TEST}, which is the reliability that is going to be incorporated in the actual test calculation. How this calculation is performed depends on whether one is attempting to solve for the number of units to be tested in an available amount of time, or attempting to find how long to test an available number of test units.

Designing reliability demonstration tests is an integral part of any reliability program. These tests are often required to demonstrate customer reliability and confidence requirements. While it is desirable to be able to test a large population of units to failure in order to obtain information on a product's or design's reliability, time and resource constraints sometimes make this impossible. In cases such as these, a test can be run on a specified number of units, or for a specified amount of time, that will demonstrate that the product has met or exceeded a given reliability at a given confidence level. In the final analysis, the actual reliability of the units will of course remain unknown, but the reliability engineer will be able to state that certain specifications have been met. In addition to analytical methods (such as the Parametric Binomial, the Non-Parametric Binomial and the Exponential Chi-Squared methods), a simulation method is also possible.

What Are the Drivers For Choosing The Test?

Reliability Demonstration Tests have tremendous value in many areas. They can;

- predict the life of the product in the field,
- determine if the product is ready to ship.

The RDT is based on a combined vibration/thermal stress environment, usually for a single stress cycle profile chosen to be typical of in-service. The actual stress level may be accelerated above “typical” in order to gain a corresponding reduction in test time. The eventual test profile and levels selected for the RDT are then agreed with the end user.

What Level Of Assembly Of The Product Normally Submitted To Test?

The test is normally undertaken at System level.

How Many Items are Normally Submitted To Test?

As the test is done at the system level, generally one.

What Type Of Product Are Appropriate For This Test Type?

Following the successful completion of the RGT programme, the design authority may implement a Reliability Demonstration Test (RDT) for complex and/or safety critical systems. The requirement for RDT for such systems is normally specified in the Quality plan prior to the start of Development. In such circumstances, it is necessary will initiate a robust RGT programme to minimise risk of ‘failure’ during RDT.

What is the Typical Duration of a Test Programme?

Typical test duration is months.

Should Separate or Combined Environments be Considered?

The RDT is based on a combined vibration/thermal stress environment, usually for a single stress cycle profile chosen to be typical of in-service. The actual stress level may be accelerated above “typical” in order to gain a corresponding reduction in test time. The eventual test profile and levels selected for the RDT are then agreed with the end user.

Are Variations In Product Strength And Environmental Stresses Considered?

Product strength and environment stress variability’s are not considered.

Does The Test Supply Knowledge On Reliability Parameters?

Yes the test does supply knowledge on reliability parameters.

Does The Test Consume Product Life?

The test does consume some of the equipments potential life.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

MIL-HDBK-781, Reliability Design Qualification and Production Acceptance Tests. No more maintained. Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production, April 1996. This handbook contains test methods, test plans, and environmental profile data presented in a manner which facilitates their use with tailorable tasks when appropriate. The testing of equipment procured for new military systems is an increasingly complex process. Test methods, test plans, and test environments must be selected which will ensure that contractually required reliability levels are attained in the field and early defect failures are removed prior to field deployment. MIL-HDBK-781 provides a menu of test plans, test methods, and environmental profiles. The most appropriate material may be selected for each program and incorporated into the tailored reliability test program. The handbook sections on reliability test methods and test plans present methods for growth monitoring, environmental stress screening, mean-time-between-failure assurance testing, sequential tests, fixed-duration tests, and all-equipment tests, including a durability/economic Life Test. The sections on test environmental profiles provide typical test environments for fixed-ground equipment, mobile ground vehicle, shipboard, jet aircraft, turboprop and helicopter, and missiles and assembled external stores equipment. The references provided will expand the user's knowledge and aid in the design and implementation of reliability test programs through more details data.

UK MOD, DEF-STAN –00-42 (part 3/1): Reliability and Maintainability (R&M) Assurance Guidance, Part 3: R&M Case, 1999.

MIL-STD-785-Rev B Reliability Program For Systems And Equipment, September 1980. 88 Pages. This military standard consists of basic application requirements, specific tailorable reliability program tasks, and an appendix which includes an application matrix and guidance and rationale for task selection. Effective reliability programs must be tailored to fit program needs and constraints, including life cycle costs (LCC). This document is intentionally structured to discourage indiscriminate blanket applications. Tailoring is forced by requiring that specific tasks be selected and for those tasks identified, that certain essential information relative to implementation of the task be provided by the procuring activity. Many of the tasks solicit facts and recommendations from the contractors on the need for, and scope of, the work to be done rather than requiring that a specific task be done in a specific way. The selected tasks can be tailored to meet specific and peculiar program needs. Although not all encompassing, the guidance and rational provided in Appendix A is intended to serve as an aid I selecting and scoping the tasks and requirements.

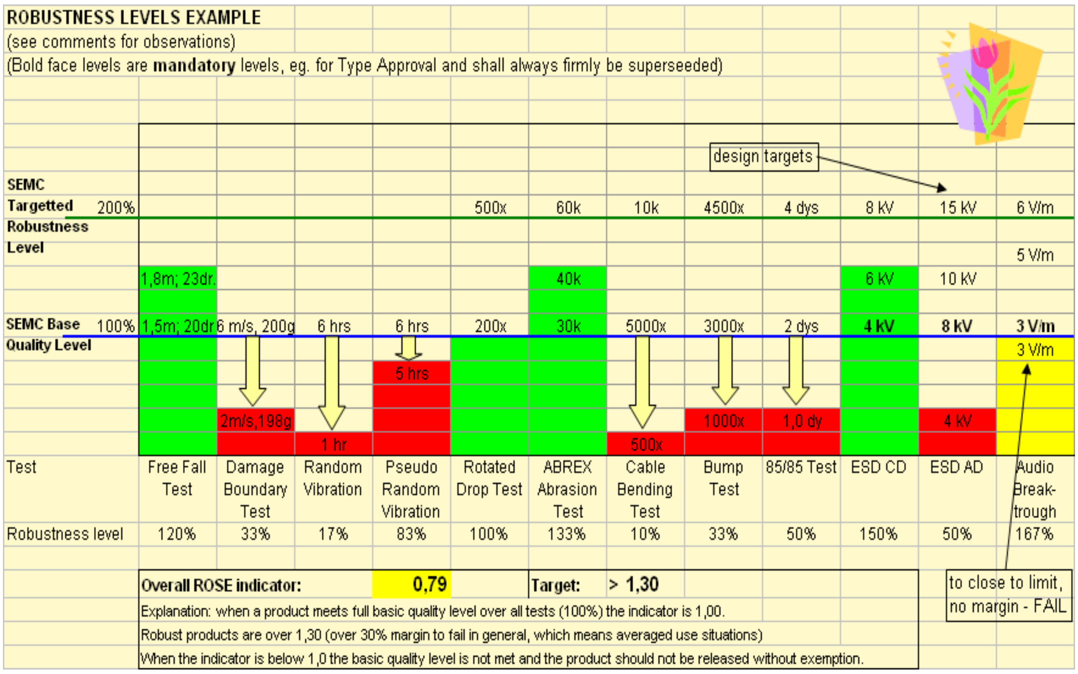
ROSE Robustness Testing

What Are the Objectives of the Test?

ROSE means Robustness Specification for Environmental test. The test objective is to find weaknesses in an early design phase, which could start already in conceptual design and component specification phase. The key element is that components and products will be tested until they break in order to find a destruct level. With the knowledge of this level estimations can be done for behaviour and reliability of the design where the components are use or for the risks you face in designs when in use.

Companies often are performing tests based on internal or external standards, like IEC. In that testing fail criteria are base on pass/fail because the levels are stated and subject of test. By using the ROSE test philosophy this approach is left and the product robustness is the subject.

When knowing the fail level, a translation to the base quality level or standard is easy made and the margin between both could be an indicator of product reliability. This enables quantification of reliability by means of this KPI (Key Performance Indicator)



ROSE is based on the step stress approach, where the stress is increased during test. This is very similar to HALT and HA-ESS testing, however conventional test methods, like vibration test, drop test, temperature/humidity tests, are used. As well single stress is applied in order to find the correct root causes. This is the main difference with HALT, where 6 axes omnidirectional vibration is combined with rapid temperature changes and power cycling.

Comparison between simulation testing, ROSE and HALT		
Simulation testing	ROSE testing	HALT testing
longer testing, pass/fail, proven, standards, non-destructive RCA when necessary existing tests Single stress good simulation field experiences 3 weeks	fast testing, levels, “new” based on standards destructive (TTF) RCA always necessary existing tests single stress 1 week	fast testing, levels, “new” no standards destructive (TTF) RCA always necessary new test combined stress 1 day

Within projects the graph shows a one page overview of the product quality level and visualises the amount of work to be done in order to meet base quality level. For economic reasons it could state too the overkill in design, is the quality level correct or to high and therefore costly. Where it come to trade of between costs, quality and time, this helps in discussion for tailored product quality. Often results are used as input for later production testing where the found levels are checked periodically and evaluated on stability.

What Are the Drivers For Choosing The Test?

ROSE gives you design information in the very early design stage, where the levels to margin are determined. These levels are compared with base quality specification or standards and can show overkill or risks in design.

What Level Of Assembly Of The Product Normally Submitted To Test?

ROSE is very helpful to rank components, boards and products.

How Many Items are Normally Submitted To Test?

For a test done with ROSE philosophy at least 3 samples should be used. This value is justified when using Weibull's distribution and when checking afterwards if same fail mechanisms are found. If not, the test should be re-done with 5 or more samples in order to isolate the correct fail modes.

What Type Of Product Are Appropriate For This Test Type?

Products that can be submitted are especially components, early designs/concepts and products. When applying ROSE in each stage the reliability growth can be tracked. It can be electronic as well as mechanical products.

What is the Typical Duration of a Test Programme?

Typical test duration is 1-2 days per test. For a full ROSE program it will always be within 1 week.

Should Separate or Combined Environments be Considered?

In order to find and isolate root causes ROSE testing need to be done in separate environments. Combination of tests in a test program is possible, where sequencing is part of consideration.

Are Variations In Product Strength And Environmental Stresses Considered?

Product strength is the topic of this test philosophy, especially in terms of robustness. Less in term of resistability to the use environment, there typical simulation tests are in place.

Are Variations In Product Strength And Environmental Stresses Considered?

Because of single fault conditions and variations of the severity of test and test conditions, for example pulse shape, it gives insight in the physics of failure and reliability parameters.

Does The Test Consume Product Life?

The tests are always destruction and consumes full life potential of the product. However because of nature of this philosophy it is not simulation of product life time.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

This type of testing is new, no standard available yet. Presentations available on www.ceees.org and www.plot.nl.

MEOST Robustness testing

What Are the Objectives of the Test?

MEOST means Multiple Environmental Overstress Testing and is described by the book of K.K. Bothe, World Class Reliability. Intention is to address multiple environments in terms of mutual influences. This is different from sequential testing, where tests are done in a certain order.

MEOST can be seen as successor of ROSE testing because the sequential testing can be addressed in ROSE, but not the mutual influences. MEOST could be more close to the real world environment. However it disables the tailored and direct root cause analysis.

Because of the overstress philosophy in MEOST it still gives design information in terms of robustness. Ranking of components and products is a good opportunity, but slightly influenced by the way of testing and influences.

What Are the Drivers For Choosing The Test?

MEOST gives you design information, with a blink towards real use environments. Still overstress testing is applied, so a matrix of stresses could help to find design weaknesses, but relation to standards is difficult.

What Level Of Assembly Of The Product Normally Submitted To Test?

MEOST is very helpful to rank components, boards and products. For systems it can be helpful to check these in a combined environment.

How Many Items are Normally Submitted To Test?

For a test done with MEOST philosophy at least 5 samples should be used. This value is justified when using Weibull's distribution and when checking afterwards if same fail mechanisms are found. It need to be noted that samples sizes are higher because of higher degree of freedom and variables in test.

What Type Of Product Are Appropriate For This Test Type?

Products that can be submitted are especially products and systems.

What is the Typical Duration of a Test Programme?

Typical test duration is 1-2 days per test. For a full MEOST program it can be about 2-3 weeks.

Should Separate or Combined Environments be Considered?

MEOST is especially focused on combined environments and their mutual influences.

Are Variations In Product Strength And Environmental Stresses Considered?

Product strength is the topic of this test philosophy, especially in terms of robustness and resistability to the use environment. Because of the product/system test and multiple environment there is a link to simulation testing.

Does The Test Supply Knowledge On Reliability Parameters?

The basic reliability parameters are not addressed.

Does The Test Consume Product Life?

Yes, although the test might not be destructive, the levels are that high that products cannot be sold anymore and need to be amortized.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

See the book of K.K. Bothe, World Class Reliability, Using MEOST to make it happen", ISBN10: 0814407927, ISBN13: 9780814407929

Conventional ESS

What Are the Objectives of the Test?

ESS means Environmental Stress Screening, where the keyword and main difference with ROSE and MEOST is in the word Screening. This is not a test in order to find product robustness level but a screen with the intention to check on product reliability stability. Therefore it is often more manufacturing oriented.

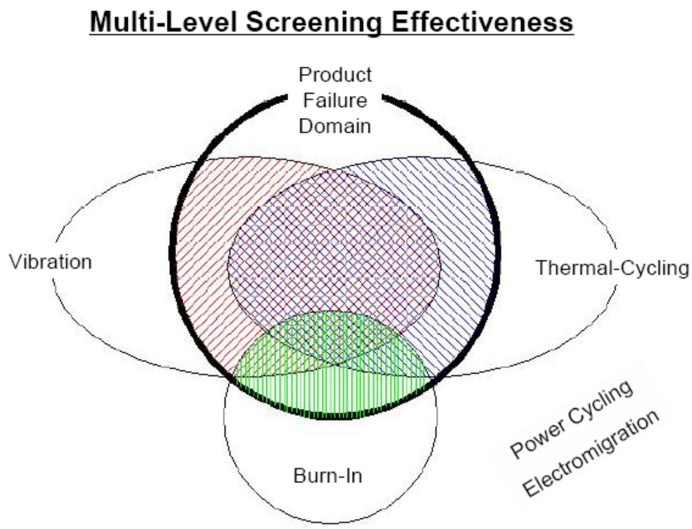
ESS is a Product Development Process which involves the “precipitation and detection of hidden defects” by applying accelerated stressed of vibration, thermal cycling or power cycling. However other definitions are known and often based on earlier test results.

ESS refers to the process of exposing a manufactured product or component (typically electronic) to stresses such as thermal cycling and vibration in order to precipitate latent defects in patent ones during the screening process. The surviving population, upon completion of screening, can be assumed to have a higher reliability than a similar unscreened population.

Developed to help electronics manufacturers detect product defects and production flaws, ESS is widely used in military and aerospace applications, less so for commercial products. The tests need not be elaborate, for example, switching an electronic or electrical system on and off a few times may be enough to catch some simple defects that would otherwise be encountered by the end user very soon after the product was first used. Tests may include the following:

- Temperature variations
- Vibration tests
- Pressure
- Flexibility tests

ESS can be performed as part of the manufacturing process or it can be used in new product qualification testing. An ESS system usually consists of a test chamber, controller, fixturing, interconnect and wiring, and a functional tester. These systems can be purchased from a variety of companies in the environmental test industry.



The stress screening from this process will help find infant mortality in the product. Finding these failures before the product reaches the customer yields better quality, lower warranty expenses, and happier customers.

What Are the Drivers For Choosing The Test?

Drive is to eliminate the products presenting early defects bound to manufacturing and to the components dispersion. It prevents weak products, especially with infant mortalities, first part of bath tub curve, from entering the field.

What Level Of Assembly Of The Product Normally Submitted To Test?

ESS is applied to final products, mainly boards, equipments and systems. Components can be subjected to ESS, but often subjected to a burn in or a pre-conditioning program.

How Many Items are Normally Submitted To Test?

Normally the number of items tested is 100% of the production

What Type Of Product Are Appropriate For This Test Type?

All electronic products should be submitted to ESS.

What is the Typical Duration of a Test Programme?

Normally the test duration is in Hours.

Should Separate or Combined Environments be Considered?

Both are popular. See the result of CEEES survey - Ref [1]

Are Variations In Product Strength And Environmental Stresses Considered?

Product strength and variabilities are not considered on product level. Variations in production and incoming product quality are covered.

Does The Test Supply Knowledge On Reliability Parameters?

The test does not produce knowledge on reliability parameters.

Does The Test Consume Product Life?

Very partially, and should be sufficiently low to be considered as acceptable.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

There is a good guideline in application of ESS in the NORTEL ESS guideline NT 011.

Highly Accelerated Stress Screening

What Are the Objectives of the Test?

The principle of the Highly Accelerated Environmental Stress Screening (HA-ESS) is to submit equipments coming out of production to levels of constraint far above the specified values while staying below the destructive limits which could have been revealed by a campaign of Highly Accelerated Life Tests

The most evident objective of screening is to discover and precipitate any weaknesses in the product; the consequences are to improve the operational reliability of the population of similar (same definition) items by precipitating latent failures and removing the weak items to improve the manufacturing processes to eliminate residual design defects

Its main objectives are to:

- Reveal more quickly the latent defects
- Detect more quickly the production process faults
- Identify the defects that may not have been revealed by a «conventional ESS” operation

- Reinforce the product maturity and robustness

Other objectives can be associated; either for the supplier, or for the customer:

- Detect an unacceptable change in product quality
- Reduce the manufacturing and guarantee costs.
- Lower the operational maintenance costs.
- Obtain a better profitability during the guarantee period.
- Establish or preserve the brand image of the manufacturer.

What Are the Drivers For Choosing The Test?

The drivers for choosing the test are; time to market of robust product, safety consideration (avionics, automotive…) and maintainability costs.

What Level Of Assembly Of The Product Normally Submitted To Test?

Typically sub assemblies (normally not at the component level)

How Many Items are Normally Submitted To Test?

The usual HA-ESS rule is to apply it to all the manufactured equipments. However in the case of high volume production, such as the car industry, apply HA-ESS to 100 % of the production is impossible for cadence as well as cost reasons. In that case HA-ESS will be applied by sampling to detect the quality drifts (machines, components). It can be based on a dynamic sampling size.

What is the Typical Duration of a Test Programme?

The duration of HA-ESS is product dependent, however because it is part of manufacturing process control, tests will not take longer then 1 day.

Should Separate or Combined Environments be Considered?

Combined environments are not a condition but can be employed if necessary to disclose a failure. For example, we can gradually increase the vibration level for a given rate of temperature variation or by increasing gradually this rate for a given level of vibration.

Are Variations In Product Strength And Environmental Stresses Considered?

Variations in product strength and environmental stresses are not considered.

Does The Test Supply Knowledge On Reliability Parameters?

The test does not supply knowledge on reliability parameters.

Does The Test Consume Product Life?

Yes , the product under test is normally destroyed, however the difference between upper operating and upper destruct level can be that high that for efficiency reasons the test is not performed destructively.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

ASTE guide on HA-ESS “Environmental Stress Screening for Electronic Equipment using Highly accelerated Tests”.

Acceptance Tests

What Are the Objectives of the Test?

Acceptance testing is black-box testing performed on a system (e.g. software, lots of manufactured mechanical parts, or batches of chemical products) prior to its delivery.

In some engineering sub-disciplines, it is known as functional testing, black-box testing, release acceptance, QA testing, application testing, confidence testing, final testing, validation testing, usability testing, or factory acceptance testing.

In most environments, acceptance testing by the system provider is distinguished from acceptance testing by the customer (the user or client) prior to accepting transfer of ownership. In such environments, acceptance testing performed by the customer is known as beta testing, user acceptance testing (UAT), end user testing, site (acceptance) testing, or field (acceptance) testing.

What Are the Drivers For Choosing The Test?

A confluent application of a series of tests on an exemplary of a production complying with a given definition specification file , permits to found the customer confidence in the quality of the product and is a green light to the transfer of ownership.

What Level Of Assembly Of The Product Normally Submitted To Test?

All levels of assembly for which exist a transfer of ownership.

How Many Items are Normally Submitted To Test?

Few, often one exemplary per period of production.

What Type Of Product Are Appropriate For This Test Type?

This test type is suitable for any product type.

What is the Typical Duration of a Test Programme?

The overall test duration is usually measured in days.

Should Separate or Combined Environments be Considered?

Environmental conditions are normally applied separately.

Are Variations In Product Strength And Environmental Stresses Considered?

This test type does not consider variations in product strength.

Does The Test Supply Knowledge On Reliability Parameters?

This test type does nor supply knowledge of reliability parameters.

Does The Test Consume Product Life?

The intent with this test is not to consume product life.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

No specific known norms.

Production Reliability Acceptance Test (PRAT)

What Are the Objectives of the Test?

Production Reliability Acceptance Test (PRAT) is a process to demonstrate that the production standard hardware continues to meet the reliability requirements throughout production. This is normally achieved by subjecting a selected sample of production hardware to environmental conditions and functionally tested as specified in the PRAT plan that will be developed during pre-production.

Its purpose is to demonstrate successful subsystem operation in simulated field environments, and to verify compliance with contractual reliability requirements. This aggressive testing also confirms consistency in the product’s manufacturing processes, and identifies changes in the component’s quality or supplier’s manufacturing processes.

Although performed at an accelerated rate, TAAF is a mirror image of the testing profiles used for PRAT, and its associated failure rates are based on the PRAT profiles observed. TAAF is conducted on equipment to promote reliability growth and identify areas for improvement within the current design. TAAF also identifies the operational limitations under which the equipment will work, which provides the company with a better assessment of design margins and a timely feedback of design, manufacturing process, test, and/or supplier shortcomings.

What Are the Drivers For Choosing The Test?

Control the quality of production by accepting or rejecting a lot based on PRAT criteria.

What Level Of Assembly Of The Product Normally Submitted To Test?

This process is applied at system level assembly, containing all major units. The system will be subjected to a PRAT profile that simulates temperature excursions, vibration, and application of power and functional tests at selected points in the cycle. The test profile is normally confirmed and proven during the Development trials and agreed with the customer as part of the overall Quality plan.

How Many Items are Normally Submitted To Test?

The PRAT process involves testing the selected sample number of production 'hardware' from each manufacturing production batch, dependant on the manufacturing throughput.

What Type Of Product Are Appropriate For This Test Type?

In general when there is a procurement policy requesting that type of test , i.e. Government Furnish Equipment.

What is the Typical Duration of a Test Programme?

The typical duration of PRAT testing is measured in weeks.

Should Separate or Combined Environments be Considered?

The test normally applies combined environments.

Are Variations In Product Strength And Environmental Stresses Considered?

PRAT testing does not address variations in product strength.

Does The Test Supply Knowledge On Reliability Parameters?

PRAT does not supply knowledge of reliability parameters.

Does The Test Consume Product Life?

It consumes partially and can consume totally the life potential of the equipment.

What Are The Main Norms, Standards, Technical References Relevant To This Test Type?

MIL-STD-785-Rev B

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ANNEX 3 Feasibility Test

Purpose of a Feasibility Study

A feasibility study is designed to provide an overview of the primary issues related to a technical and business idea. The purpose is to identify any "make or break" issues that would prevent the test from being successful. In other words, a feasibility study determines whether the technical issues make sense, as well as the business issues, but I am concerned with technical issues here.

A thorough feasibility analysis provides a lot of information necessary for the technical plan. For example, a good market analysis is necessary in order to determine whether the project is feasibility. This information provides the basis for the market section of the business plan.

Because putting together a technical and business plan is a significant investment of time and money, you want to make sure that there are no major roadblocks facing you when the test plan is finalized and you make the investment in time and equipment. Identifying such roadblocks is the purpose of a feasibility study.

A feasibility study looks at three major areas:

- Market issues
- Organizational/technical issues
- Financial issues

Again, this is meant to be a "first cut" look at these issues. For example, a feasibility study should not do in-depth long-term financial projections, but it should do a basic break-even analysis to see how much revenue would be necessary to meet your operating expenses.

The purpose of the business plan is to minimize the risk associated with a new business and maximizes the chances of success through research and maximizes the chances for success through research and planning. (cf. University of California)

Technological Issues

The cost and availability of technology may be of critical importance to the feasibility of a project, or it may not be an issue at all.

For example, a service organization, such as a childcare centre, will have a few equipment and other technology- related issues to address. A manufacturing enterprise, on the other hand, may have a number of complex technology questions to analyze in order to determine whether or not the business is feasible.

Key questions to answer include:

- What are the technology needs for the proposed business?
- What other equipment does your proposed business need?
- Where will you obtain this technology and equipment?
- When can you get the necessary equipment?
- How does your ability to obtain this technology and equipment affect your start-up timeline?
- How much will the equipment and technology cost?

Keeping in mind that technology doesn't necessarily mean complex machinery; if your business simply needs a personal computer, printer, and fax machine, those are your technological needs.

However, making wise decisions on even simple purchases such as office machines may require some research. Obviously there are numerous types of personal computers on the market. You many want to check Consumer Reports for their recommendations, do some comparative shopping, and ask acquaintances about their experiences with different companies. Your cost estimates will get plugged into your financial projections.

Naturally, the more complex the technology you need, the more research that will be required to make good decisions about it. This is important and should not be looked at trivially.

The Technical Issues to Look at During the Feasibility Study

In the commercial market we have to decide what we trying to achieve with a certain test. The main thrust is always the reliability of the product being manufactured.

The product life cycle begins at the component level and continues through assembly level; the life cycle includes exposure to the following environments :

- assembly/process ,
- testing,
- storage ,
- transportation,
- operating ,
- servicing (preventive and corrective maintenance).

Assembly/Process

During processing and assembly of electronic assemblies, temperature excursions take place, e.g. soldering including reflow, cleaning or imposed thermal cycling tests. These temperature excursions can be damaging to some parts of the assembly and consume some part of the available life. Keeping the number of excursions to a minimum should minimize this damage and the damage needs to be considered in the overall reliability estimates.

Testing

When devising the overall reliability test plan the frequency of applied test to the device and the fatigue that the testing induces into the product will be identified.

Storage

Storage tests will be defined by the product specification. The storage life of the product will be identified which may range from a few months to many years. A storage life cycle may include storage in a mobile unit to storage in a temperature-controlled warehouse.

Transportation

Transportation is not a single event that is simply defined. Each vehicle type may impose unique environmental loads. Each may also provide protection from certain environmental conditions. Duration and frequency of occurrence will influence how environmental effects are accumulated over time. The transportation configuration and degree of loading can also affect the loads imposed on the product.

Operating

It is assumed that the operational characteristics will not affect the reliability test, as the unit is a low power device and operational tests.

Environmental Stress Screening (ESS)

ESS has the potential to identify latent defects that may cause early failures in a product. ESS needs to be specifically designed to accelerate the failure of 'weak' elements in the assembly. ESS does not add to the number of such failures but causes them to occur in a significantly shorter period of time.

Effective ESS programmes should be supported by well-planned `Root Cause Analysis' (RCA) and corrective action resources. These enable timely corrective actions, elimination of latent defects and ultimate removal of the ESS process subject to continued monitoring and control of the manufacturing process.

Conclusion

All the above tests will be scrutinized during a feasibility study, equipment, infrastructure human resource and all the associated cost that go with these requirements. This is the first part in looking at a reliability test programme.

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ANNEX 4 Comparison of ESS and HA-ESS

This section evaluates the efficacy of the conventional ESS and of the Highly Accelerated ESS

Conventional Environmental Stress Screening Method

Environmental Stress Screening as defined in the ASTE document of 1986 is referred to as conventional environmental stress screening as opposed to the “Highly Accelerated Environmental Stress Screening” (HA-ESS). Experience shows that, for a serially produced items, some items are much more fragile than others. Essentially there are two statistical distributions, the one relative to good products, the other to fragile products. The healthy population is located around a mean value situated beyond the specification.

In the case of conventional ESS use, Highly Accelerated Tests are not necessarily conducted during the product development phase and the margin between the population and the specification is not known. In this method, the constraints are generally applied separately, and the laws of defects appearance are known in principle. It will be noted also that the constraint level is always lower or equal to the specification value.

It is recognised in electronics, that every product group will containing latent defects which will age faster than every healthy set (fuse effect). After conventional ESS testing, the healthy population has a slightly decreased life. On the other hand, the products with latent defects are mostly removed because the majority fail during test. The effects on an untested population shown in Figure 4-1 due to ESS are illustrated in Figure 4-2. However, as the constraints are relatively low and the technical margins unknown, the danger is that some products with latent defects (weaknesses) could still be identified as being good. This is shown

Highly Accelerated Environmental Stress Screening method

In this method, as previously mentioned, it is essential to have previously performed a campaign of Highly Accelerated Tests and to have establish a robust design and a robust manufacture.

It is certain, if not easy to demonstrate, that the consequences of this Highly Accelerated ESS on the product will be more important than the one generated by conventional ESS. The test will reduce the mean of the good product distribution towards the specification to a greater extent than conventional ESS. It will of course be necessary to verify that the consequential life reduction is not important.

For the products with latent defects, the high levels applied, increases the proportion of the failures revealed to a greater extent than with a conventional ESS.

The effects on the population due to HA-ESS are illustrated in Figure 4-3. That figure shows a greater shift of the population mean for the latent (abnormal) failure distribution than the one of the normal population. The latent failure distribution is rejected, as not being compliant with the specification. As the mean shift is greater than with conventional ESS, a greater number of weaknesses are revealed.

Comparison Of The Environmental Stress Screening Methods

The tab below puts in evidence the differences between the main characteristics of the conventional ESS and of the Highly Accelerated ESS.

	Conventional ESS	Highly Accelerated ESS
Objective	Eliminate the products presenting early defects bound to manufacturing and to the components dispersion	
Principle	The application of constraints within the limits of the product specification	The application of constraints beyond the specification NB: allows to detect the components dispersion
Input data	The product specifications and its life profile	Knowledge of the operation margins and of the product limitations NB: The product robustness has been improved by increasing the operation margins (tolerance increased in components dispersal)
Responsibility	Manufacturing only	R&D and Manufacturing
Constraints application mode	sequential type :Temperature, vibration.	Combined : temperature., mechanical shocks , electric constraints,…
Efficiency	Moderate or weak on the stabilized products	Good: increased efficiency in terms of control of the operation margins Maturation and faster mastery of the manufacturing process
Profile acquisition	Long and iterative because based on the return of experience 1 year or more	Fast due to the methodology Around 3 to 6 months
Speed	Indicative duration: 2 to 4 days	Indicative duration :2 to 8 hours (reduces the production cycles)

Other Advantages Of HA-ESS Related To ESS.

In addition to the benefits already mentioned previously, the implementation of the Highly Accelerated ESS presents the following advantages:

- A standard process applicable by the Company both internally and externally
- The facilitation of the dialogue between the design actors and the manufacturing factors
- The satisfaction for the employees to be better involved in the possibility to touch the state of the art of the manufacturing process ;
- A systematic approach of Quality.

Potential Problems And Precautions.

To set up an Highly Accelerated ESS operation within the manufacturing phase can be delicate, especially at the level of the communication within the company community. It therefore requires a certain number of pre-requisites. These include the prior implementation of Highly Accelerated Tests in order to establish the Highly Accelerated ESS profile. Within this it is necessary to involve the design teams early in the process. It is also necessary increase subcontractors awareness in the method, and to establish with them appropriate procedures.

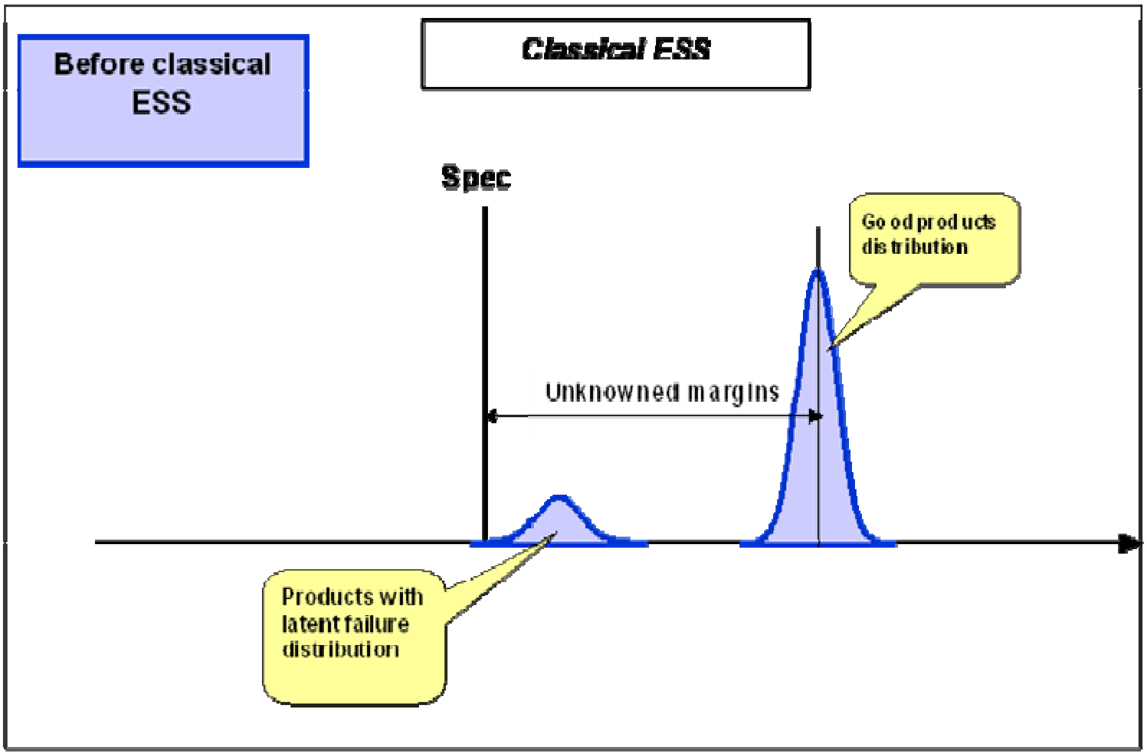

Figure 4-1 Product resistance distribution: normal and abnormal products.

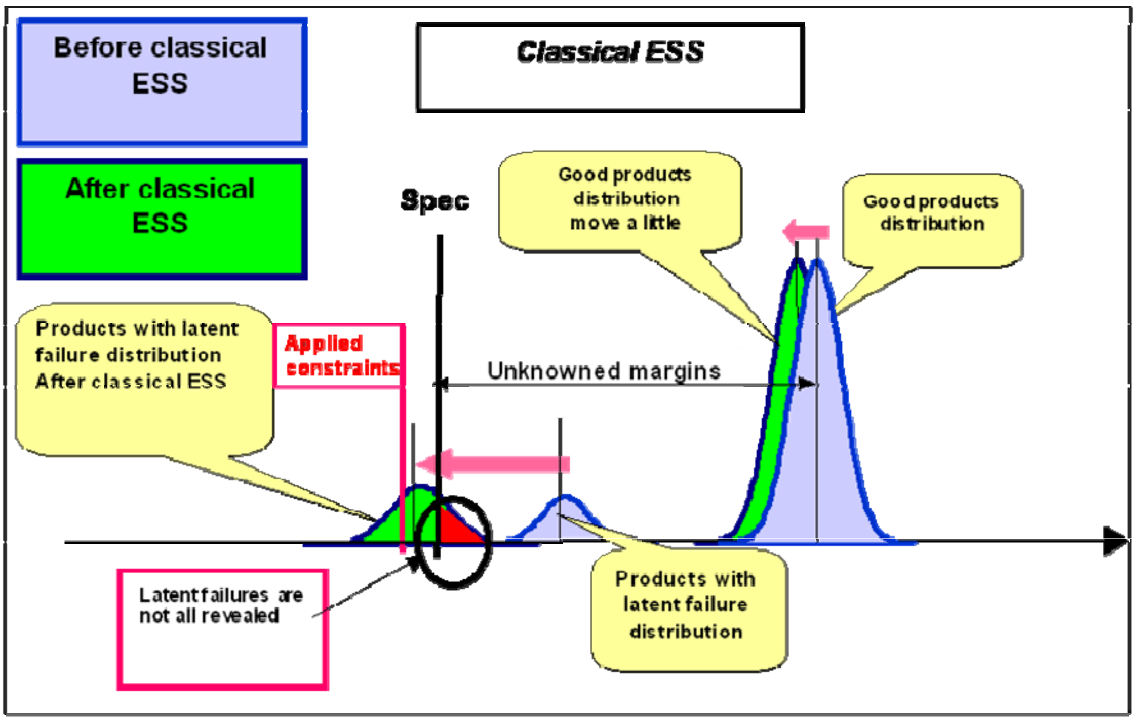

Figure 4-2 The effects on product population of Conventional ESS testing

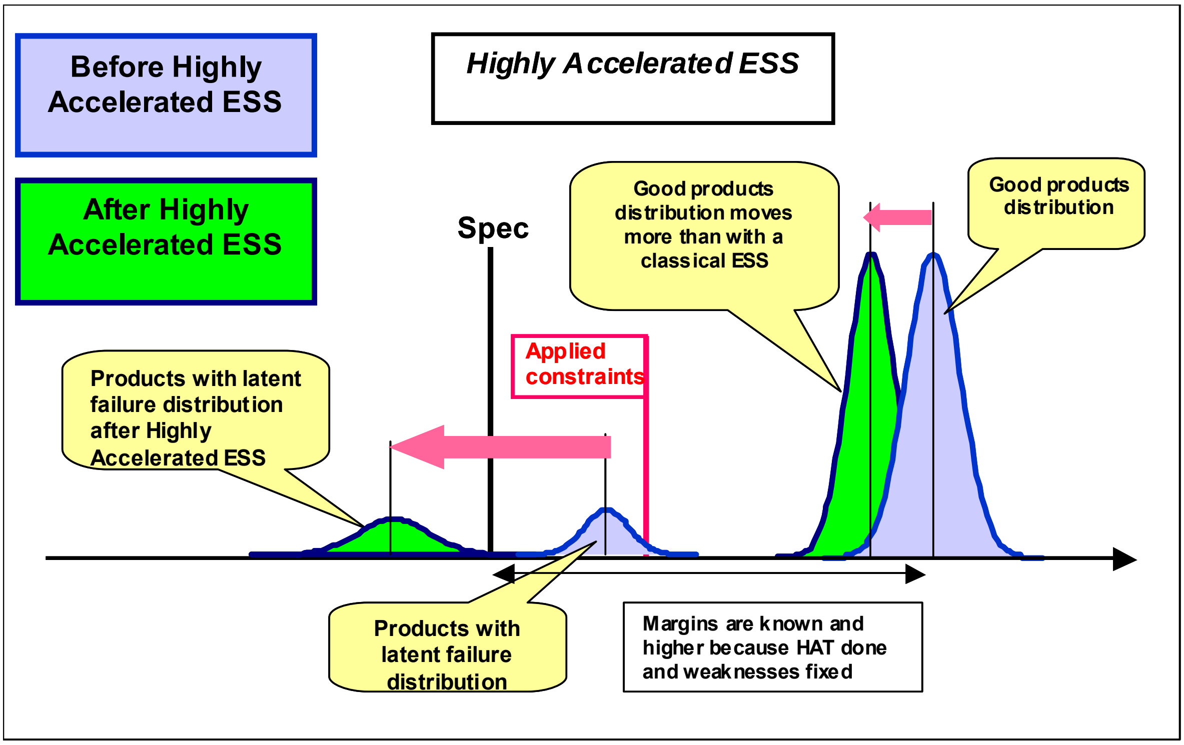

Figure 4-3 The effects on product population of Conventional HA-ESS testing

ANNEX 5 Definition Of Terms

The technical Terms given there are used in standards, technical books, technical papers ore technical documents like specifications, data sheets etc.

For the correct reading of such documents, it is very important to understand the exact meaning of those terms. Otherwise serious misunderstandings are for sure. For example, if a vendor accepts a Reliability of 500 hours in a customer- specification, he must know that such a value is only valid in correlation with a well defined life profile , with clear stated maintenance conditions and that the Reliability is represented by statistical values which can only be evaluated with a big amount of operating hours and that induces costs and consumes time . An other example is the use of MTBF and MTTF. The term "Mean Time Between Failures" MTBF can only be used for an item with constant failure rate. If the item is subject to wear out, only the term "Mean Time To Failure" MTTF is admissible.

Often different definitions exist for a given technical term. In such case it is of great importance to give the exact wording of the used definition to avoid misunderstanding.

Defect.

Non-fulfilment of an intended usage requirement or reasonable expectation, essentially present at time zero (may non-fulfilment of an intended usage requirement including one concerned with safety)

From a technical point of view, a defect is similar to a nonconformity, however not necessarily from a legal point of view. Defects do not need to influence the item's functionality. They are caused by flaws (errors, mistakes) during design, production, or installation. Unlike failures, which always appear in time (generally randomly distributed), defects are present at time zero. However, some defects can only be detected when the item is operating and are referred to as "dynamic defects". Similar to defects, with regard to the cause, are systematic failures; they are not necessarily present at time zero.

Defect- Immunity (only used for software)

The capability of the Software product to maintain a level of performance when used under specified conditions

Wear or ageing does not occur in software. Limitations in "reliability" are due to faults in requirements, design, and implementation. "Failures" due to these faults depend on the way the software product is used and the program options selected rather than on elapsed time.

Dependability

Collective term used to describe the availability performance and its influencing factors, such as reliability performance, maintainability performance, and logistical support performance

Dependability is used only for general descriptions in non-qualitative terms. Dependability is one of the time-related aspects of quality. The definition of dependability given above is taken from IEC 50(191), which also includes related terms and definitions.

Durability

Capacity of an Item to execute a required function in specified conditions of use and of maintenance until the end of useful life or until it does not meet any more with it's expected economical or technological requirements

ESS Environmental Stress Screening

ESS is screening process, based on a stimulation or a set of stimulations intended to remove defective items, or those likely to exhibit early failures. The applied stress levels are normally similar as those expected in field operation.

ESS is often performed at assembly level (PCB) or equipment level on a 100 % basis to find defects and/or systematic failures during a preproduction phase or to provoke early failures during the series production and therefore to improve the reliability of a lot of items by elimination of the defectives one. To be the most effective , ESS should be tailored to the kind of item and the production process.

Failure

Termination of the ability of an item to perform a required function.

Failure Rate $\lambda_{(t)}$

The failure rate of an item is the probability (referred to dt) of a failure in the interval (t, t +dt) under the condition that the item was new at t = 0 and did not fail in the interval (0,t).

Failure Identification, Analysis and Fix (FIAAF)

This is the general concept where the cause of failure is isolated, analyzed and fixed. A number of testing procedures can be used in this method. These procedures can be applied in parallel with existing development tests or as dedicated TAAF (test, analyze and fix) or TAAR (test analyze and redesign) procedures. These are closed-loop reliability growth methodologies. The purpose is not to prove that a reliability goal has been met, but rather to deliberately search out and eliminate deficiencies. In TAAF / TAAR, failures are welcome. The TAAF/TAAR concept is necessary because, even with the very best of modern engineering methods and design tools (CAD, CAE), initial designs for mechanical or electronic systems that are complex or that involve new technology have reliability deficiencies that are difficult to fully detect and eliminate through design analysis. To summaries, maturation of revolutionary product (which includes many news in design, technologies and conditions of use) requires experimentation.

Fault

State of an item, characterised by the inability to perform a required function, excluding inabilities due to preventive maintenance, other planed actions or lack of external resources.

A fault can be a defect or a failure, having thus as possible cause a flow (error, mistakes) during design, production or installation (for defect or systematic failure) or a failure mechanism (for failures).

FMEA Fault Modes and Effects Analysis

Quantitative method of reliability analysis which involves for each element of an item the investigation of possible fault modes, and of the corresponding effects on other elements as well as on the required function(s) of the item. (see also FMECA).

FMECA Fault Mode, Effect and Criticality Analysis

Qualitative/quantitative method of reliability analysis which includes the analysis of fault modes and effects (FMEA) while considering for each fault mode the probability of occurrence and ranking of its severity.

The Goal of an FMEA or FMECA is to determine all potential hazard and to analyse the possibilities of reducing their effects or their probability of occurrence. All possible failure- and defect-modes and -causes have to be considered from the lowest to the highest integration level of the item considered (FMECA was formerly used for "Failure Mode, Effect and criticality Analysis" by considering only the possible failure modes and corresponding effect and criticality).

FTA Fault Tree Analysis

Analysis to determine which fault modes of the elements of an item and/or which external event may result in a stated fault mode of the item considered, presented in the form of a fault tree.

FMEA is a top-down approach, which allows the inclusion of external causes more easily than an FMEA or FMECA.

Functionality (Capability, Technical Performance)

The capability of a product to provide the required function when it is used under specified conditions. Alternatively the ability of an item to meet a service demand of stated quantitative characteristics under given conditions.

Life Cycle LC

LC consist of all phases of the life of an item including acquisition, operation, storage, maintenance and disposal.

Life Cycle Profile LCP

The Life Cycle Profile LCP is the sum of all state of an item under given conditions over the complete Life Cycle of the item. (The Life Cycle Profile defines the required functions and the environmental conditions during the different Life Cycle Phases as a function of time).

Lifetime T_L

T_L is the Time span between the start of operating and a failure of a non-repairable item. For repairable items the term " Useful Life" is used.

Life Extension Analysis

Life Extension Analysis evaluates the ability of materiel to meet extended life, role and deployment changes. The process is presented in this AECTP, which is a framework document. The purpose of this document is to acquaint project (program) managers with the engineering principles involved when evaluating the implications of extended life requirements, and also with the outline of a management tool that systematically addresses the issues to be resolved. Additional leaflets are included to provide further guidance for the engineering practitioner when addressing the detailed technical issues.

Logistical Support

All activities undertaken to provide effective and economical use of an product during its operating phase.

Maintainability

Probability that preventive maintenance or repair of an item will be performed within a stated time interval for given procedures and resources.

A qualitative definition is: ability of a product to be retained in or restored to the ability to perform its required function in a given time interval under stated procedures and resources. Maintainability is subdivided in serviceability (preventive maintenance) and reparability (corrective maintenance or repair). The relationship between maintainability and other reliability measures is shown in Figure 5-1.

Mean Time Between Failures MTBF

MTBF= 1/ λ is the expected value (mean) of the item's failure-free operating time under the condition that the item was new by starting the operating time**.**

MTBF should only be used for items with constant failure rate λ. For items with a time dependent failure rate $\lambda_{(t)}$ the term MTTF= Mean Time To Failure shall be used.

Mean Time To Failure MTTF

MTTF is the expected value (mean) of an item's failure-free operating time under the condition that the item was new by starting the operating time.

Mean Time To Mission - Failures $MTTF_M$

$MTTF_M$ is the expected value (mean) of the operating time of an item without any failure which would prevent the fulfilment of a defined mission (failures not having an influence on the mission are not relevant for $MTTF_M$).

Mean Time To Preventive Maintenance MTTPM

MTTPM is the expected value (mean) of an item's preventive maintenance time.

Mean Time To Repair MTTR

MTTR is the expected Value (mean) of an item's repair time.

Mission Profile MP

The Mission Profile MP is a specific task which must be fulfilled by an item during a stated time under given conditions (The Mission Profile defines the required functions and the environmental conditions as a function of time).

Operational Availability; Point Availability

Probability that a product will perform its required function under given conditions at a stated instant of time.

Operational Effectiveness

Capability of an item to fulfil the specified functional requirements.

Packaging, Handling, Storage, and Transportation (PHS&T)

These activities includes resources and procedures to ensure that all equipment and support items are preserved, packaged, packed, marked, handled, transported, and stored properly for short- and long-term requirements. It includes material-handling equipment and packaging, handling and storage requirements, and pre-positioning of material and parts. It also includes preservation and packaging level requirements and storage requirements (for example, sensitive, proprietary, and controlled items). These activities include planning and programming the details associated with movement of the system/product in its shipping configuration to the ultimate destination via transportation modes and networks available. It further includes the determination of critical engineering design parameters and constraints that must be considered during system development (e.g., width, length, height, component and system rating, and weight).

Qualification

Process of demonstrating whether an entity is capable of fulfilling specified requirements.

Reliability

Probability that a product will perform is required function under given conditions for a stated time interval. This does not mean that redundant parts may not fail. Such parts can fail and be repaired. The relationship between reliability and other reliability measures is shown in Figure 5-1.

Safety

Ability of a product to cause neither injury to persons, nor significant material damage or other unacceptable consequences. Alternatively a state in which the risk of harm (to persons) or damage is limited to an acceptable level. The relationship between safety and reliability measures is shown in Figure 5-1.

Safety is subdivided into accident prevention (the product is safe working while it is operating correctly) and technical safety (the product has to remain safe even if a failure occurs). Safety is one of the aspects of Quality. The alternative definition is valid for the purposes of quality standards. the term "safety" is defined differently in ISO/IEC Guide 2.

Security

The capability of the Software product to protect information and data so that unauthorised person or systems cannot read or modify them and authorised persons or systems are not denied access to them.

System effectiveness

Characteristic of an item to fulfil the required functions with the best possible ratio between reliability and life cycle costs.

Supportability, Maintainability (for software)

The capability of the software product to be modified. Modifications may include corrections, improvements or adaptation of the software to change in environment, and requirements and functional specifications.

Time Between Preventive Maintenance TBPM

TBPM is a predetermined time interval between 2 preventive maintenance actions. An item may required several different TBPM. in this case, the shortest one is specified and normally the longer TBPMs are multiples of the shortest one.

Usability

The capability of a product to be understood, learned, used and efficient for the user, when used under specified conditions.

Useful Life

Total operating time of a product, ending for a non-repairable product when the failure probability becomes too high or the product functionality is obsolete, and for a repairable product when the intensity of failures becomes unacceptable or when after a failure the product is considered to be no longer repairable.

The term "Life Time" is only used for non-repairable products. It is the time span between initial operation and failure of a non-repairable item.

Validation

A process of confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled.

In design and development Validation concerns the process of examining a product to determine conformity with manufacture specifications. Validation is normally performed on the final product under defined operating conditions. It may be necessary in earlier stages. The term "validated" is used to designate the corresponding status. Multiples Validations may be carried out if there are different intended uses. Validation is done against the "Product Specification".

Referenced Documents

[1] A. Birolini, Quality and Reliability of Technical Systems Springer- Verlag

[2] ISO/IEC 9126-1, Software Engineering - Product Quality Part 1

[3] EN ISO 8402 Quality management and quality assurance - Vocabulary

[4] Reliability, Maintainability and Availability, October 1993

[5] BNAE RG Aéro 00040

[6] MIL-STD-961 Defence Specifications

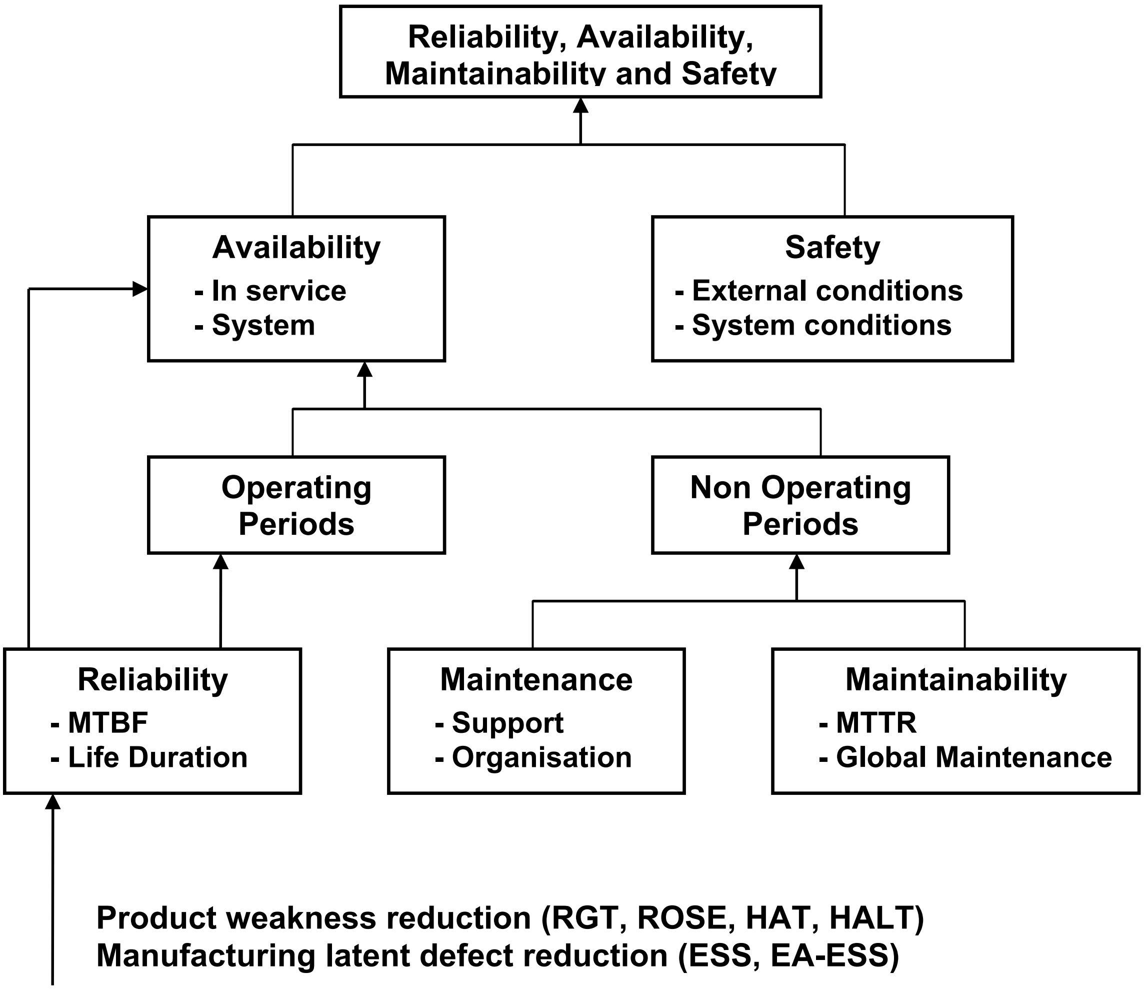

Figure 5-1 Hierarchy of terms

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