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Process management for avionics –

Guide for defining and performing highly accelerated tests in avionic systems

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:
Draft PAS	**Report on voting**
107/54/NP	107/61/RVN

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from 2006-11. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

PROCESS MANAGEMENT FOR AVIONICS –

Guide for defining and performing highly accelerated tests in avionic systems

1 Scope and object

In an increasingly harsh economic context (tighter performance requirements, shorter development cycles, reduced cost of ownership, etc.), it is essential to ensure product maturity rapidly and, in any case, by the time of commissioning.

It is with a view to remedying shortcomings in traditional development methods that "highly accelerated" tests have been developed. The main underlying principle behind this new type of test strategy is as follows: rather than reasoning in terms of conformity with a specification and simply performing conventional tests, we on the contrary attempt to push the product to its limits by applying environmental stresses and/or stimuli of levels higher than the specification. The aim is thus to take full advantage of current technologies, by eliminating defects which generate potential failures, as of the first prototypes.

A well-conducted accelerated test process should, in a relatively short time, lead to a significant increase in the robustness of a product, as early as the initial prototypes stage at the beginning of the development phase, thus accelerating early maturity of this product. Furthermore, identification of the margins available on a "mature" product helps design and size its future environmental stress screening profile more accurately, by increasing the severity of the loadings applied to just what is needed, leading to a particularly significant boost in the efficiency of this environmental stress screening process.

The object of this PAS [1)] is to specify the targets assigned to the highly accelerated tests, their basic principle, their scope of application and their implementation procedures.

This guide is thus a methodological document aimed at facilitating drafting of the specification and then performance of highly accelerated tests by the programme managers.

It is primarily intended for programme managers, designers, test managers, and RAMS experts.

This guide concerns all programmes, in particular aeronautical, space and armaments programmes. It primarily concerns the industrial firms in charge of designing, developing and producing components built for these programmes, but also their customers who, in drafting contractual clauses, may require that their suppliers implement highly accelerated tests.

The recommendation applies to all types of equipment used in systems developed in these programmes, whatever their nature (electronic, electromechanical, mechanical, electro-hydraulic, electro-pneumatic, etc.) and whatever their size, from "low-level" subassemblies (PCBs, mechanical assemblies, connectors, etc.), up to components or component groups.

NOTE Presently, there are no documentary standards for highly accelerated tests. This recommendation thus relies on a number of documents which are not standards, which are of various origins and which are usually very recent, as well as on other more standard documents, but not specifically dedicated to highly accelerated tests.

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1) Proposed by a working group comprising representatives of the aeronautical, space and armaments industries (customers and suppliers), as well as representatives of laboratories specialising in testing.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE Most of the terminology used in this recommendation conforms to that used in Recommendation RG.Aéro 000 27. For the other terms, it relies on those used in other documents, such as ET 99.04 (see Bibliography).

2.1
step stressing
gradual step-wise increase in the level of stress applied to a product

2.2
hard failure
failure which does not disappear on returning to a lower stress level and which can only be eliminated by repair

2.3
soft failure
failure appearing after a certain given stress level, which disappears when the stress falls back below this level

2.4
chargeable defect
fault or weakness inherent in the design of a product or its manufacturing processes and the elimination of which, presumed to be economically feasible, leads to an improvement in its operating and/or destruction margins

NOTE This type of defect, which is always the result of a deviation from standard best practices, is not by definition related to the resistance limit imposed by the technologies used.

2.5
latent defect
defect which originally exists in the equipment but has not yet been precipitated and is thus as yet undetectable by conventional performance checks on this equipment

2.6
patent defect
defect in a component which, after being precipitated, has become detectable by conventional performance checks. A patent defect thus stems from a latent defect which has evolved following application of appropriate stresses (for example, temperature, vibrations, etc.) and which thus becomes detectable by a performance check.

2.7
environmental stress screening (ESS)
set of production process tasks consisting in applying to the equipment concerned, within the limits permitted by its design, particular environmental stresses in order – during manufacturing – to reveal and eliminate the largest possible number of defects which, in all probability, would have appeared once utilization had begun (teething troubles)

2.8
accelerated test
test, the aim of which is to predict the behaviour and/or lifetime of a product in its operational conditions of use, by subjecting it to stresses harsher than the values expected during its lifespan profile. Contrary to highly accelerated testing, a "conventional" accelerated test (time/stress exchange) always relies on one or more analytical lifetime and damage models

2.9
highly accelerated test
test during which the product or some of its component parts are subjected to environmental and/or operating stresses that are increased progressively to values far in excess of the specified values, up to the operating and/or destruction limits of the product

NOTE The rise in exposure time or number of cycles, whether or not associated with a combination of certain stresses raised to values close to, or equal to, the specification (or stresses whose nature is not specified) may meet the same targets as those of the highly accelerated tests, as defined in this PAS.

2.10
reliability
ability of a product to perform a required function, in given conditions, for a given time interval, generally expressed by a probability

2.11
destruction limit
level of stress above which the product will suffer irreversible damage and will no longer be in conformity with nominal performance once the stress level is returned to below the specified value (notion of irreversibility)

2.12
operating limit
stress level above which the product no longer functions nominally. When the stress is returned to below this level, product performance returns to nominal (notion of reversibility)

2.13
fundamental limit
resistance limit determined by the technology of a product or particular component, with respect to a given stress (temperature, vibration, electrical voltage, etc.). This limit, whether or not destructive, is an absolute barrier and cannot therefore be attributed to a chargeable defect

NOTE Examples are the melting temperature of a plastic, the maximum junction temperature of a semiconductor, the yield strength of a material, etc.

2.14
operating margin
for a given stress, difference between the operating limit and the specification

2.15
destruct margin
for a given stress, difference between the destruct limit and the specification

2.16
maturity
attainment of a product status for which its functional and operational performance can be considered stabilized with respect to the specifications

NOTE Maturity is the result of a gradual process of eliminating chargeable defects still present in the product and the associated processes. This process is called maturing.

2.17
precipitation
transformation, using appropriate stresses, of a latent defect (not yet detectable) into a patent defect (detectable)

2.18
robustness
property of a product indicating reduced sensitivity of its performance to changes in the environmental stresses to which it is subjected, to dispersions of its components and to drifts of its manufacturing processes. Robustness to a large extent is the result of action taken to obtain sufficient operating margins while at the same time reducing all forms of variability

2.19
reliability, availability, maintainability, safety/RAMS
range of capabilities of a product enabling it to achieve specified functional performance, at the required time, for the required duration, without damage to itself or its environment

3 Acronyms

- CDR Critical Design Review.
- EMC Electromagnetic Compatibility.
- ESS Environmental Stress Screening.
- FMECA Failure Mode Effects and Criticality Analysis.
- FRACAS Failure Reporting and Corrective Action System.
- MTBF Mean Time Between Failures.
- PCB: Printed Circuit Board.
- PDR: Preliminary Design Review.
- PRA Preliminary Risk Analysis.
- RS Requirements Specification.
- RTV Rapid Temperature Variation.
- TTM Time To Market.

4 Highly accelerated test goals and principles

4.1 General characteristics

A highly accelerated test is a test in which the product or some of its component parts are subjected to environmental and/or operating stresses which are gradually raised to values in excess of the specified values, until the product operating and/or destruction limits are reached.

The primary purpose of highly accelerated tests is to contribute to

– improving the robustness of the product, by eliminating the weaknesses inherent in the product design and/or processes, and in the technologies used;
– products that are mature as of the first production article;
– improving the reliability and lifespan of the product in service;
– reducing development times and costs;
– specifying optimal environmental stress screening.

Attaining these goals involves

– detecting chargeable defects as early as possible (so that they can be corrected), as these defects are inherent in design errors or insufficient control of the manufacturing processes;

– exploration of the operating limits, once chargeable defects have been eliminated so that, whenever applicable, they can be pushed back through new design choices, when the margins in relation to the specified operating range appear inadequate.

Instead of reasoning in terms of conformity with the specification, which is a poor way of reflecting the product's real lifespan profile, we will on the contrary look to push the product to breaking point (often up to failure), using environmental stresses or various stimuli at levels far in excess of the specifications, in order to reveal, identify, then correct the chargeable defects still present. This implies, on the one hand, exploration of the available margins and, on the other, improving these margins through appropriate action on the design of the product itself or its manufacturing processes (see Annex D).

Owing to the adopted definition for the highly accelerated test, the following characteristics of this type of highly accelerated test can be identified:

– A highly accelerated test is a proactive type of test: we here understand that a highly accelerated test shall be considered as a tool to support the design of the product and its processes and that it normally leads to engineering activities aimed at understanding the failure mechanisms observed, in order to provide the corrections felt to be economically feasible and which will enable them to be eliminated or at least delay their evolution. The highly accelerated test is "proactive" in that it encourages these engineering actions at the earliest in development.

– A highly accelerated test is not a conformity test: through the desire to explore the margins and expand them, if necessary, the highly accelerated test looks above all to reveal the product defects which generate failures when working beyond the specifications. It is therefore the opposite of a conformity test, which simply aims at ensuring that the product's performance is correct when it is subjected to the specific operating and environmental conditions.

– A highly accelerated test must not be confused with an ordinary margins verification test: a margins verification test in fact simply aims to ensure that product performance remains correct when the stress values are raised to predetermined values above the specified values, whatever the initially adopted margin. Consequently, the margins verification test consists in practice in applying an extra coefficient to certain specified stresses (referred to as the "regulation coefficient" in certain mechanical professions). It is similar to a conformity test, even if it deals with performance conformity in operating conditions which are outside the specified range. The highly accelerated test, for its part, establishes operating and/or destruction margins for the product.

– A highly accelerated test must not be confused with a "conventional" accelerated lifespan test: the purpose of an accelerated lifespan test is, in fact, to predict the evolution of the behaviour of a product in its operational conditions of use, by subjecting it to stresses that are harsher than the values expected during its lifespan profile. To do this, the accelerated test relies on analytical product failure mode acceleration models, which is not the case with the highly accelerated test.

– A highly accelerated test has no predictive goal: as the highly accelerated test works outside the specified domains, the analytical acceleration models can no longer apply to the domains explored. Furthermore, it is very hard to involve the "time" factor given the very short duration of the test. The result is that, as things currently stand, the highly accelerated test cannot be used to estimate product reliability or lifetime characteristics in the specified conditions of use.

Annex A specifies the characteristics of a highly accelerated test versus a growth, validation and reliability qualification test.

4.2 General principles of highly accelerated tests

As a design tool, the highly accelerated test aims – through application of stresses going beyond the specification or simply not specified – to stimulate all the weak points in the product design during development and in its manufacturing processes. Revealing these weak points is thus an opportunity to improve the product or processes, more quickly than with a traditional approach, leading to an expansion of the operating margins and thus greater reliability.

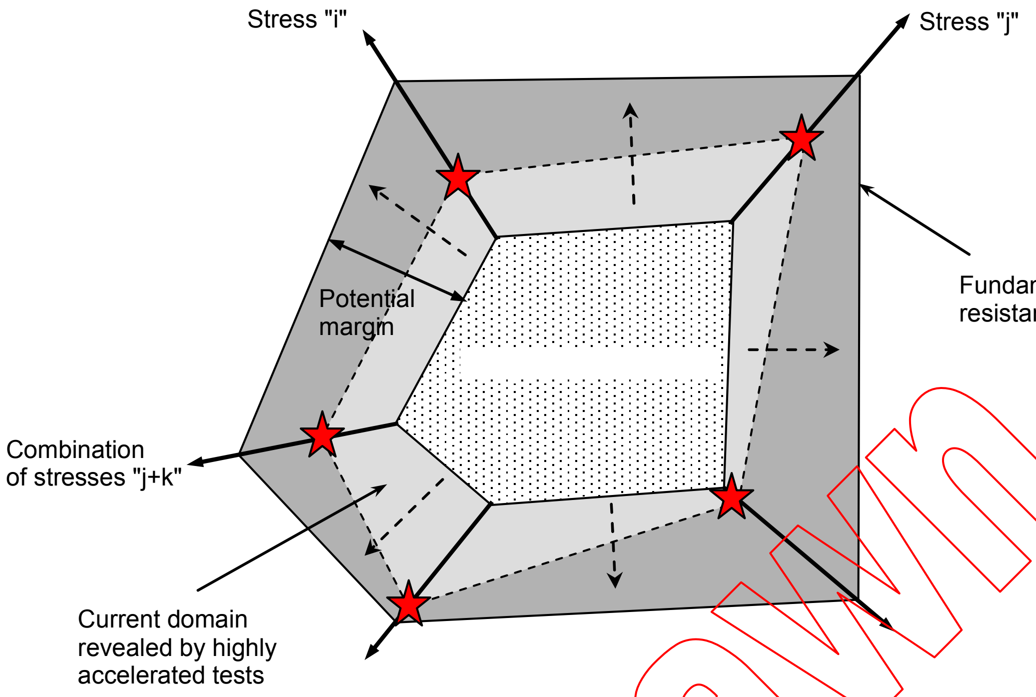
It is important to understand that in a highly accelerated test, the stresses applied are chosen so as to actively stimulate the defects and weak points of the product and its processes, and are not therefore designed to simulate the conditions of use of the product during its lifespan profile. These stresses are applied either alone or combined, well past the values expected during the lifespan of the product, until they reach the fundamental resistance limit set by the technology. This implies gradually eliminating the various barriers preventing this limit from being reached and which are due to the existence of any weak points still present (chargeable defects). An essential goal of the highly accelerated test is precisely to reveal the existence of these chargeable defects, even when they lead to a malfunction of the product used beyond its qualification conditions.

Among the reasons which justify the desire to correct chargeable defects which only trigger malfunctions in out-of-specification product operating conditions, we could mention the following.

– The experience built up by companies that use highly accelerated tests shows that most malfunctions detected during these tests end up being detected in the field, if the chargeable defects revealed by these tests are not eliminated.
– There is often a considerable gap between the specification conditions and the actual conditions of use of a product, in particular if there is a wide variety of a product usage. Consequently, certain lifespan profile situations, sometimes very short, require the product to operate in severity conditions far beyond the specified coverage.
– Experience shows that chargeable defects can often be easily located and can be eliminated or attenuated both easily and economically (for example, insufficient component size, inadequately tightened screw, components mounted on vibrating parts of a PCB, PCB inadequately secured in a unit subject to vibration, weakness of a mechanical link, etc.).

Owing to its damaging nature, the principle of the highly accelerated test is thus a cultural sea-change in relation to the traditional approach, the main aim of which is to ensure the conformity of product performance in the specified conditions. As shown in Figure 1, the aim is now no longer simply to show that the product is in conformity, but to prove that exploration has been conducted beyond the specified frontier, in order to clean the product of obstacles limiting its potential robustness, that correspond to the resistance limit set by the technology.

NOTE It is important to note that performing a highly accelerated test should not lead to over-sizing. The ultimate purpose of the highly accelerated test is to track down and eliminate chargeable defects, those which by their very principle are the result of non-compliance with, or ignorance of the state of the art rules of, good practice (in design and manufacture). These actions are therefore dedicated to eliminating chargeable defects, contributing to improving the operating margins and obtaining potential margins. Generally speaking, one does not attempt to push back the fundamental limits of the components and/or materials, which would call into question the design choices (product and/or processes), entailing significant additional investment and time.



Specified domain: described in the product specification.

Domain revealed by the highly accelerated tests: this corresponds to the real limits of the product, as revealed by the highly accelerated tests. The stars bordering this domain correspond to chargeable defects detected, causing the product to cease to function at this stress level.

Technological domain: this corresponds to the ideal product, designed and produced without error, but which represents the fundamental limit, and defines the potential margin with respect to the specification.

Growth in margin by gradually increasing the stresses and correcting the chargeable defects revealed

Chargeable defect (to be detected and eliminated)

Figure 1 – Exploration of margins using a highly accelerated test

4.3 Example of the limitations of highly accelerated tests

Despite its efficiency and speed, the highly accelerated test method does, nevertheless, have its limitations, and these may, in certain cases, require it to be supplemented by prior specific testing or security checking of product components.

In practice, and independently of the parameters that highly accelerated tests do not address by their very nature (such as ESDs, sealing, etc.), they provide relatively little information about the robustness of products that change over time as a result of internal physico-chemical reactions.

Take, for example, the issue of electromigration in ceramic condensers.

This effect causes condensers ultimately to fail as a result of short-circuiting, which may take two weeks or two years to occur, depending on the design of the product, the manufacturing process and the conditions under which it is used.