IEC/TS 62500

Edition 1.0 2008-07

TECHNICAL SPECIFICATION

Process management for avionics – Defining and performing highly accelerated tests in aerospace systems – Application guide

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INTERNATIONAL
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COMMISSION

PRICE CODE **W**

ICS 03.100.50; 31.020; 49.060

ISBN 2-8318-9933-8

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PROCESS MANAGEMENT FOR AVIONICS – DEFINING AND PERFORMING HIGHLY ACCELERATED TESTS IN AEROSPACE SYSTEMS – APPLICATION GUIDE

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62500, which is a technical specification, has been prepared by IEC technical committee 107: Process management for avionics.

This technical specification cancels and replaces IEC/PAS 62500 published in 2006. This first edition constitutes a technical revision.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
107/79/DTS	107/90/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
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INTRODUCTION

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, it is on the contrary attempted 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 to 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.

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PROCESS MANAGEMENT FOR AVIONICS – DEFINING AND PERFORMING HIGHLY ACCELERATED TESTS IN AEROSPACE SYSTEMS – APPLICATION GUIDE

1 Scope

This technical specification specifies the targets assigned to highly accelerated tests, their basic principles, their scope of application and their implementation procedures. It is primarily intended for programme managers, designers, test managers, and RAMS experts to facilitate the draft of the specification and execution of highly accelerated tests. This guide is applicable to all programmes and is of primary interest to the industrial firms in charge of designing, developing and producing equipment built for these programmes, and also their customers who, in drafting contractual clauses, may require that their suppliers implement highly accelerated tests.

NOTE This technical specification 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 system level groups of equipment.

2 Terms and definitions

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

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NOTE Most of the terminology used in this technical specification 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
extrinsic 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 intrinsic limit imposed by the technologies used.

2.5
intrinsic defect
defect related to the component design, materials, processing, assembly or packaging and provoked under circumstances within the component's design specifications

2.6
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

2.7
patent defect
defect in a component which, after being precipitated, has become detectable by conventional performance checks

NOTE A patent defect thus stems from a latent defect which has evolved following application of appropriate stresses (e.g. temperature, vibrations, etc.) and which thus becomes detectable by a performance check.

2.8
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 extrinsic defects which, in all probability, would have appeared once utilisation had begun (early life failures)

2.9
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

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NOTE Contrary to highly accelerated testing, a "conventional" accelerated test (time/stress exchange) always relies on one or more analytical lifetime and damage models.

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2.10
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 technical specification.

2.11
reliability
ability of a product to perform a required function, in given conditions, for a given time interval

NOTE This characteristic is generally expressed by a probability.

2.12
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)

2.13
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)

2.14
fundamental limit
intrinsic 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 extrinsic defect

EXAMPLE: Melting temperature of a plastic, maximum junction temperature of a semiconductor, yield strength of a material, etc.

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

2.16
destruct margin
for a given stress, difference between the destruct limit and the specification

2.17
maturity
attainment of a product status for which its functional and operational performance can be considered stabilised with respect to the specifications

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

2.18
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precipitation
transformation, using appropriate stresses, of a latent defect (not yet detectable) into a patent defect (detectable)
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2.19
robustness
property of a product indicating reduced sensitivity of its performance to changes in the environmental stresses to which it is subjected, to component variation and to drifts in its manufacturing processes

NOTE 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.

2.20
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

2.21
failure modes and effects analysis
FMEA
qualitative method of reliability analysis which involves the study of the fault modes which can exist in every sub-item of the item and the determination of the effects of each fault mode on other sub-items of the item and on the required functions of the item

3 Acronyms

- **CDR:** Critical Design Review.
- **FMEA:** Failure Modes and Effects Analysis.
- **EMC:** Electromagnetic Compatibility.
- **ESS:** Environmental Stress Screening.

- **FRACAS:** Failure Reporting and Corrective Action System.
- **HAT:** Highly Accelerated Test
- **MTBF:** Mean Time Between Failures.
- **PCB:** Printed Circuit Board.
- **PDR:** Preliminary Design Review.
- **PRA:** Preliminary Risk Analysis.
- **RAMS:** Reliability, Availability, Maintainability, Safety.
- **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:

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– improving the robustness of the product, by eliminating the weaknesses inherent in the product design and/or processes, and in the technologies used;
– obtaining 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.

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Attaining these goals involves:

– detecting extrinsic 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 extrinsic 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, it is on the contrary attempted 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 extrinsic 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:** it is here understood that a highly accelerated test should 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 stage 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 to ensure that the product's performance is correct when it is subjected to the specific operating and environmental conditions.
– **A highly accelerated test should 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 should 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 cannot produce reliability measures:** 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.

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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 intrinsic 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 (extrinsic defects). An essential goal of the highly accelerated test is precisely to reveal the existence of these extrinsic 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 extrinsic defects, which only trigger malfunctions in out-of-specification product operating conditions, the following could be mentioned: