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Process management for avionics – Atmospheric radiation effects –

Part 1: Accommodation of atmospheric radiation effects via single event effects within avionics electronic equipment

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROCESS MANAGEMENT FOR AVIONICS – ATMOSPHERIC RADIATION EFFECTS –

Part 1: Accommodation of atmospheric radiation effects via single event effects within avionics electronic equipment

FOREWORD

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- The subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

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

IEC 62396-1, which is a technical specification, has been prepared by IEC technical committee 107: Process management for avionics.

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

Enquiry draft	Report on voting
107/41/DTS	107/46/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.

IEC 62396, as currently conceived, consists of the following parts, under the general title *Process management for avionics – Atmospheric radiation effects:*

Part 1: Accommodation of atmospheric radiation effects via single event effects within avionics electronic equipment

Part 2: Guidelines for single event effects testing for avionics systems[1]

Part 3: Guidelines to optimize avionics system design to reduce single event effects rates[1]

Part 4: Guidelines for designing with high voltage aircraft electronics and potential single event effects[1]

Part 5: Guidelines for assessing thermal neutron fluxes and effects in avionics systems[1]

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,
- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

[1] Under consideration.

INTRODUCTION

This industry-wide technical specification informs avionics systems designers, electronic equipment, component manufacturers and their customers of the kind of ionising radiation environment that their devices will be subjected to in aircraft, the potential effects this radiation environment can have on those devices, and some general approaches for dealing with these effects.

The same atmospheric radiation (neutrons) that is responsible for the radiation exposure that crew and passengers acquire while flying is also responsible for causing the Single Event Effects (SEE) in the avionics electronic equipment. There has been much work carried out over the last few years related to the radiation exposure of aircraft passengers and crew. A standardised industry approach on the effect of the atmospheric neutrons on electronics should be viewed as consistent with and an extension of the on-going activities related to the radiation exposure of aircraft passengers and crew.

Atmospheric radiation effects are one factor that could contribute to equipment hard and soft fault rates. From a system safety perspective, using derived fault rate values, the existing methodology described in ARP4754 (accommodation of hard and soft fault rates in general) will also accommodate atmospheric radiation effect rates.

In addition, this technical specification is related to the JEDEC Standard JESD89, which relates to soft errors in electronics by atmospheric radiation at ground level (at altitudes less than 10 000 feet (3 040 m)).

PROCESS MANAGEMENT FOR AVIONICS – ATMOSPHERIC RADIATION EFFECTS –

Part 1: Accommodation of atmospheric radiation effects via single event effects within avionics electronic equipment

1 Scope and object

This Technical Specification is intended to provide guidance on Atmospheric Radiation effects on Avionics electronics used in aircraft operating at altitudes up to 60 000 feet (18,3 km). It defines the radiation environment, the effects of that environment on electronics and provides design considerations for the accommodation of those effects within avionics systems.

This Technical Specification is intended to help aerospace equipment manufacturers and designers to standardise their approach to Single Event Effects in Avionics by providing guidance, leading to a standard methodology.

Details of the radiation environment are provided together with identification of potential problems caused as a result of the atmospheric radiation received. Appropriate methods are given for quantifying Single Event Effect (SEE) rates in electronic components. The overall system safety methodology should be expanded to accommodate the Single Event Effects rates and to demonstrate the suitability of the electronics for the application at the component and system level.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62239, *Process management for avionics – Preparation of an electronic components management plan*

3 Terms and definitions

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

NOTE Users of this technical specification may use alternative definitions consistent with convention within their companies.

3.1
aerospace recommended practice
these documents relating to avionics are published by the Society of Automotive Engineers Inc

3.2
avionics equipment environment
is, for aeronautical equipment, the applicable environmental conditions (as described per the equipment specification) that the equipment shall be able to withstand without loss or degradation in equipment performance during all of its manufacturing cycle and maintenance life (the length of which is defined by the equipment manufacturer in conjunction with customers)

3.3
capable
term used to indicate that a component can be used successfully in the intended application

3.4
certified
indicates assessment and compliance to an applicable third party standard and maintenance of a certificate and registration (i.e. JAN, IECQ- CECC)

3.5
characterisation
process of testing a sample of components to determine the key electrical parameter values that can be expected of all produced components of the type tested

3.6
component application
process that assures that the component meets the design requirements of the equipment in which it is used

3.7
component manufacturer
organisation responsible for the component specification and its production

3.8
critical charge
smallest charge that will cause a SEE if injected or deposited in the sensitive volume

NOTE Units: picoCoulomb (pC). For many devices, this is now measured in femtoCoulombs (fC) rather than pC.

3.9
cross section (σ)
in radiation terms for proton and neutron interactions, this is combination of sensitive area and probability of an interaction depositing the critical charge for a SEE.

The cross section may be calculated using the following formula:

$$\sigma = number\ of\ errors/particle\ fluence$$

NOTE The units for cross section are cm^2 per device or per bit.

3.10
electron
elementary particle having a mass of approximately 1/1 840 atomic mass units, and negative charge of $1{,}602 \times 10^{-19}$ C

3.11
Electronic Components Management Plan
ECMP
equipment manufacturer's document that defines the processes and practices for applying components to an equipment or range of equipment. Generally, it addresses all relevant aspects of controlling components during system design, development, production, and post-production support

3.12
electronic components
electrical or electronic devices that are not subject to disassembly without destruction or impairment of design use. They are sometimes called electronic parts, or piece parts

NOTE Examples are resistors, capacitors, diodes, integrated circuits, hybrids, application specific integrated circuits, wound components and relays

3.13
electronic equipment
item produced by the equipment manufacturer, which incorporates electronic components

NOTE Examples are end items, sub-assemblies, line-replaceable units and shop-replaceable units.

3.14
Electronic Flight Instrumentation System
EFIS
example of an avionics electronic system requiring system development assurance level A type II and for which the pilot will be within the loop through pilot/system information exchange

3.15
expert
has demonstrated competence to apply knowledge and skill to the specific subject

3.16
firm fault
term used at the aircraft function level. It is a failure that cannot be reset other than by rebooting the system or by cycling the power to the relevant functional element. Such a fault could impact the value for the MTBF of the LRU and provide no fault found during subsequent test

3.17
Fly By Wire
FBW
example of avionics electronic system requiring system development assurance level A type I and for which the pilot will not be within the aircraft stability control loop

3.18
Functional Hazard Analysis
FHA
assessment of all hazards against a set of defined hazard classes

3.19
GeV
radiation particle energy giga electron volts (thousand million electron Volts)

NOTE The SI equivalent energy is 160,2 picoJoule.

3.20
gray
Gy
SI unit of ionising radiation dose and is the energy deposited as ionisation and excitation (J) per unit mass (kg)

NOTE Related units centigray (cGy) and rad. 1 cGy is equal to 1 rad.

3.21
hard error
permanent or semi-permanent damage of a cell by atmospheric radiation that is not recoverable even by cycling the power off and on

3.22
hard fault
term used at the aircraft function level. It refers to the permanent failure of a component within an LRU. A hard fault results in the removal of the LRU affected and the replacement of the permanently damaged component before a system/system architecture can be restored to full functionality. Such a fault could impact the value for the MTBF of the LRU repaired

3.23
heavy ions
positively charged nuclei of the elements other than hydrogen

3.24
in-the-loop
test methodology where an LRU is placed within a radiation beam that provides a simulation of the atmospheric neutron environment and where the inputs to the LRU would be from an electronic fixture external to the beam to enable a closed loop system

NOTE The electronic fixture would contain a host computer for the aircraft simulation model. The electronic fixture would also contain appropriate signal conditioning for compatibility with the LRU. In the case of an automatic control function, the outputs from the LRU could be, in turn, sent to an actuation means or directly to the host computer. The host computer would automatically close a stability loop (as in the case of a fly-by-wire control system). In the case of a navigation function, the outputs from the LRU could be sent to a display system where the pilot could then close the navigation loop.

3.25
Integrated Modular Avionics
IMA
implement aircraft functions in a multitask computing environment where the computations for each specific system implementing a particular function are confined to a partition that is executed by a common computing resource (a single digital electronic circuit)

3.26
latch-up
triggering of a parasitic pnpn circuit in bulk CMOS, resulting in a state where the parasitic latched current exceeds the holding current, this state is maintained while power is applied

3.27
Linear Energy Transfer
LET
energy deposited per unit path length in a semiconductor along the path of the radiation

NOTE Units: MeV·cm^2/mg.

3.28
Linear Energy Transfer threshold
LETth
for a given component is the minimum LET to cause an effect at a particle fluence of 1×10^7 ions/cm^2

3.29
Line Replaceable Unit
LRU
piece of avionics electronic equipment that may be replaced during the maintenance cycle of the system

3.30
may
indicates a course of action that is permissible within the limits of this document

3.31
MeV
radiation particle energy Mega electron volts (million electron Volts)

NOTE The SI equivalent energy is 160,2 femtojoule.

3.32
Mean Time Between Failure
MTBF
is a measure of reliability requirements and is the mean time between failure of equipment or a system in service

3.33
Mean Time Between Unscheduled Removals
MTBUR
is a measure of reliability requirements and is the mean time between unscheduled removal of equipment or a system in service

3.34
Multiple Bit Upset
MBU
occurs when the energy deposited in the silicon of an electronic component by a single ionising particle causes upset to more than one bit

3.35
neutron
elementary particle with atomic mass number of one and carries no charge. It is a constituent of every atomic nucleus except hydrogen

3.36
particle fluence
is for a unidirectional beam of particles the number crossing unit surface at right angles to beam. For isotropic flux, this is number entering sphere of unit cross-sectional area

NOTE Units: particles/cm^2.

3.37
particle flux
fluence rate per unit time

NOTE Units: particles/cm^2 s.

3.38
pion or pi-meson
sub atomic particle. The charge possibilities are (+1, –1, 0) and they are produced by energetic nuclear interactions

3.39
Preliminary System Safety Assessment
PSSA
evaluation of the planned architecture to determine the reasonableness of the architecture to meet the system safety requirements

3.40
proton
elementary particle with atomic mass number of one and positive electric charge. It is a constituent of all atomic nuclei

3.41
risk
measure of the potential inability to achieve overall program objectives within defined cost, schedule, and technical constraints

3.42
Single Event Burn Out
SEB
occurs when a powered electronic component or part thereof is burnt out as a result of the energy absorption triggered by an individual radiation event

3.43
Single Event Effect
SEE
response of a component caused by the impact of a single particle (for example galactic cosmic rays, solar energetic particles, energetic neutrons and protons)

NOTE The range of responses can include both non-destructive (for example upset) and destructive (for example latch-up or gate rupture) phenomena.

3.44
Single Event Functional Interrupt
SEFI
upset in a usually complex device, for example, a microprocessor, such that a control path is corrupted, leading the part to cease to function properly

NOTE This effect has sometimes been referred to as lockup, indicating that sometimes the part can be put into a "frozen" state (see 6.2.6).

3.45
Single Event Gate Rupture
SEGR
occurs in the gate of a powered insulated gate component when the radiation charge absorbed by the device is sufficient to cause gate rupture, which is destructive

3.46
Single Event Latch Up
SEL
occurs in a four layer semiconductor device when the radiation absorbed by the device is sufficient to cause a node within the powered semiconductor device to be held in a fixed state whatever input is applied until the device is de-powered, such latch up may be destructive or non-destructive

3.47
Single Event Transient
SET
spurious signal or voltage, induced by the deposition of charge by a single particle that can propagate through the circuit path during one clock cycle (see 6.2.4)

3.48
Single Event Upset
SEU
occurs in a semiconductor device when the radiation absorbed by the device is sufficient to change a cell's logic state

NOTE After a new write cycle, the original state can be recovered.

3.49
Single Hard Error
SHE
single event induced hard error
occurs when in a single event the radiation absorbed by the device is sufficient to cause permanent stuck-bit in the device, and a hard error within the equipment