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Edition 1.0 2017-07

TECHNICAL REPORT

Process management for avionics – Atmospheric radiation effects –
Part 7: Management of single event effects (SEE) analysis process in avionics design

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IEC TR 62396-7, which is a technical report, has been prepared by IEC technical committee 107: Process management for avionics.

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

Enquiry draft	Report on voting
107/300/DTR	107/304/RVDTR

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

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

A list of all the parts in the IEC 62396 series, published under the general title *Process management for avionics – Atmospheric radiation effects*, can be found on the IEC website.

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

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- withdrawn,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

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

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PROCESS MANAGEMENT FOR AVIONICS – ATMOSPHERIC RADIATION EFFECTS –

Part 7: Management of single event effects (SEE) analysis process in avionics design

1 Scope

This part of IEC 62396, which is a technical report, describes a process to account for the effects of atmospheric radiation on electronic equipment. Single event effects (SEE) due to atmospheric radiation are one class of possible failure mechanisms that are addressed in the safety and reliability analyses of electronic equipment and associated functions.

This document focuses on electronic components, electronic equipment and associated electronic functions. System level analysis is not addressed in this document.

This document is intended to describe an approach to accounting for SEE in electronic equipment design, design review, and it can provide aid in the aerospace certification process. This document establishes an example process for assessing electronic components in the atmospheric radiation environment, evaluating for mitigations/protections/utilizations, and addressing the electronic equipment impacts of the SEE. The process is intended to support an SEE analysis for electronic equipment.

It does not describe, in detail, methods used to mitigate the effects of SEE in the electronic equipment design.

NOTE 1 IEC 62396-3 provides further details for this process.

NOTE 2 IEC 62396-2 provides further details for SEE testing.

This document, by itself, is not a program requirements document, i.e. it does not contain the word "shall." However it describes a process that can be used, for example, at the discretion and agreement of the users, to aid in the preparation and the maintenance of an electronic components management plan (see [1][1] and [7]). The output of the process described in this document provides data as an input into the product safety and reliability analyses.

Although developed for the avionics industry, this document can be used by other industrial sectors at their discretion.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 62396-1:2016, *Process management for avionics – Atmospheric radiation effects – Part 1: Accommodation of atmospheric radiation effects via single event effects within avionics electronic equipment*

1 Numbers in square brackets refer to the Bibliography.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62396-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE For the purposes of the document, the term "device" can be used in place of "electronic component".

3.2 Abbreviated terms

BIT built-in test

BoM bill of material

COTS commercial off the shelf

CRC cyclic redundancy check

E Energy

ECC error correction code

EDAC error detection and correction

FoM figure of merit

FPGA field-programmable gate array

IEEE Institute of Electrical and Electronics Engineers

I/O input/output

JEDEC JEDEC Solid State Technology Association

JESD JEDEC standard

L1/L2 level 1 / level 2 (related to microprocessor cache memories, "level 1" cache memory being usually built onto the microprocessor chip itself, "level 2" cache memory being usually on a separate chip or expansion card)

MBU multiple bit upset (in the same word)

MCU multiple cell upset

MTBF mean time between failure

P/SSA preliminary/system safety assessment

RAM random access memory

SDRAM synchronous dynamic random access memory

SEB single event burnout

SEE single event effect

SEFI single event functional interrupt

SEL single event latch-up

SET single event transient

SEU single event upset

SSA system safety assessment

TLB translation lookaside buffer

μP microprocessor

4 Radiation analysis process

4.1 General

Electronic components and integrated circuits have become increasingly susceptible to atmospheric radiation causing SEE. These phenomena are the result of interaction of high energy cosmic rays with silicon-based components. The resulting single event effects may cause various conditions; such as data corruption. Additional types of undesirable effects may include:

- damage to hardware;
- corrupted software residing in volatile memory;
- corrupted data in memory;
- microprocessor halts and interrupts;
- writing over critical data tables;
- unplanned events.

The industry trend is for continued decreases in electronic component feature size and operating voltages, while the number of gates on a given device continues to increase, which entails focusing attention on the radiation effects. As this trend continues to deep sub-micron feature sizes, electronic component designs are achieving higher densities and lower voltages, resulting in smaller active charge regions. In general, for decreasing feature size of silicon based cells, the expected critical charge decreases and the sensitivity to radiation may increase.

The radiation effects analysis example process described in this document assesses the radiation effects susceptibility of the electronic components and the effects at the electronic equipment level. This includes radiation effects assessment of the electronic components, mitigation analysis, and test of electronic components and electronic equipment if needed. This information may be utilized as input to a safety and reliability assessment of the electronic equipment.

An overview of the radiation analysis process is provided as example. The remainder of the document provides one way to perform a radiation analysis with 4.2 to 4.10 providing further details based on the radiation process shown in Figure 1.

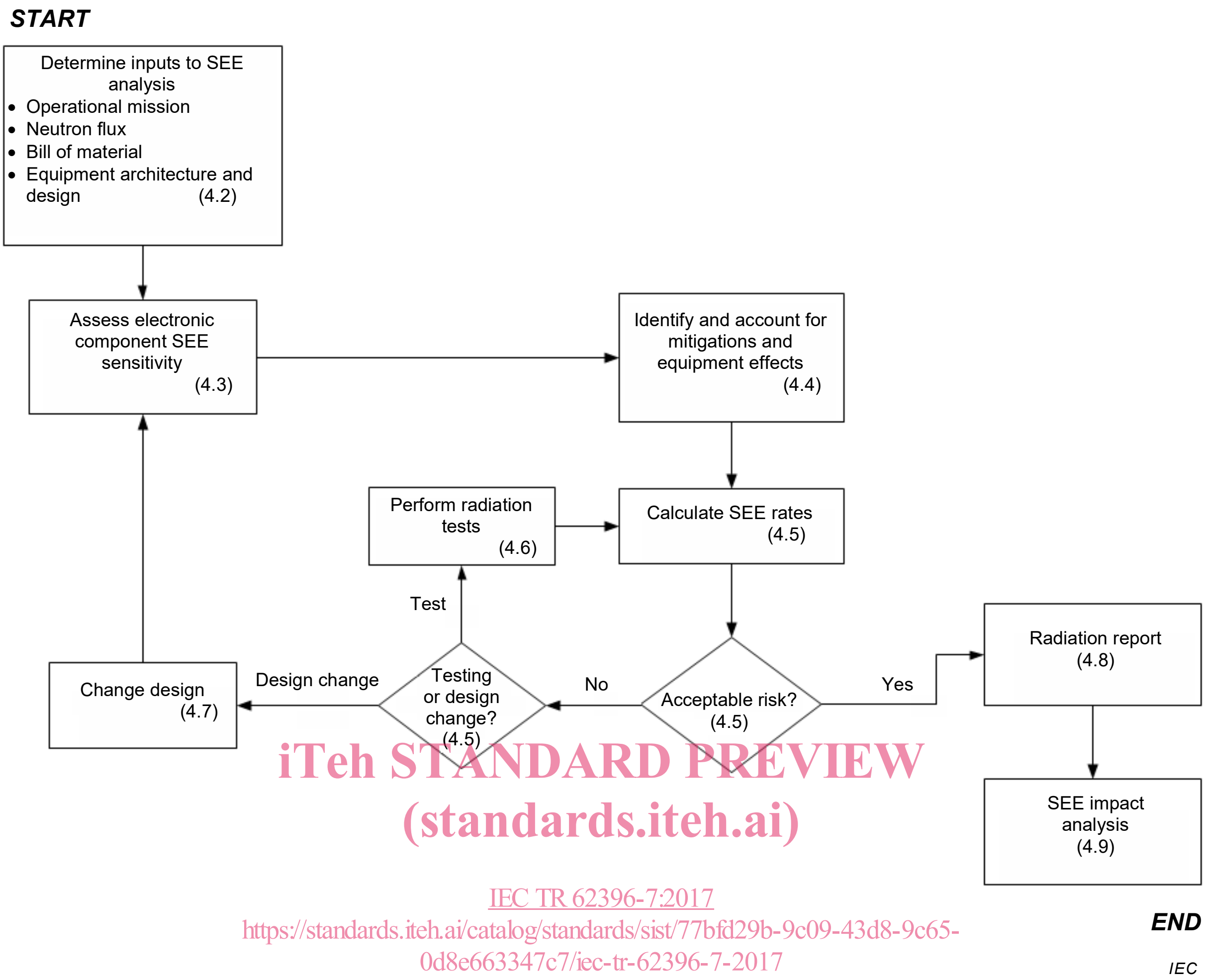

Figure 1 – Radiation analysis process overview

The process starts with the operational mission and data definition (e.g. atmospheric radiation environment, BoM…), and ends with a summary of the SEE effects data to be utilized as input for safety and reliability assessments. An atmospheric radiation analysis plan may be included in the planning for a new program. This analysis may be appropriate for new electronic equipment development, electronic equipment upgrades, and electronic component replacement programs.

Annex A provides, for information, a detailed radiation analysis process flowchart. This diagram expands on the steps defined in Figure 1. Additional detailed descriptions of the electronic component assessment, evaluation, electronic equipment impact analysis, and on-going electronic component management steps are provided,

4.2 Determine inputs to SEE analysis

Inputs to the SEE analysis may include various electronic equipment and operational mission definition, and detailed electronic equipment design information.

The atmospheric radiation definition may include the environment in which the electronic equipment operates and the flux densities under consideration based on operational missions. In the absence of such definition, the default levels of IEC 62396-1 are recommended.

The equipment design information may include the electronic equipment bill of materials (BoM), schematics and electronic equipment design material. In addition, existing and available SEE rates for known susceptible electronic components may be included.

4.3 Assess electronic component SEE sensitivity

Each electronic component on the electronic equipment BoM is assessed for its susceptibility to SEE, and classified according to its susceptibility to the various relevant SEE types (for example SEB, SEL, MCU, MBU, SEU, SEFI…; for more details see IEC 62396-1).

For all sensitive electronic components, cross-section data is obtained if possible. If no data is available, conservative estimates may be utilized for this initial step. Table B.1 provides a template for recording the components typically considered sensitive and which may result in a SEE analysis. Notes may be added to the table to indicate the source of the cross-section rates. This table may be used throughout the SEE analysis process, starting with the electronic component assessment, evaluation of mitigations/protections and SEE impact analysis.

Electronic components assessment process steps may include:

a) Classification of each electronic component as being either SEE-sensitive (identifying all applicable SEE types) or not SEE-sensitive.
b) For the sensitive electronic components, the column “Component SEE sensitivities” of Table B.1 is populated. Sources of data may include:
    1) test data (from a source such as high energy neutron beam; see list of facilities provided in IEC 62396-1 for example);
    2) industry data;
    3) in-service flight data;
    4) figure of merit (FoM) calculations based on test data from other sources (proton and heavy ion);
    5) conservative estimates.

    For more details related to these sources of data, one can refer to IEC 62396-1:2016, Annex G, and IEC 62396-2.
c) For each sensitive electronic component, describe the SEE sensitivity and provide all the SEE cross-section data for each applicable SEE type for the electronic component. Details on calculating the SEE rates in avionics are provided in IEC 62396-1.

The cross-section data, such as test data, vendor data or in-service data may be recorded into the template proposed in Table B.1, column “SEE cross-section data (cm^2/bit)” or column “SEE cross-section data (cm^2/device)”.

The SEE response of an electronic component is characterized as the SEE cross-section of that component. The SEE cross-section unit is cm^2/device or cm^2/bit. This cross-section, which is obtained through test, is the number of radiation events divided by the fluence of particles (particle/cm^2, particle flux integrated over the exposure time) to which the electronic component was exposed.

The SEE rate is calculated by multiplying the SEE cross-section and the integrated neutron flux rate. Generally, 6 000 neutron/cm^2h (E > 10 MeV) and 9 300 neutron/cm^2h (E > 1 MeV) are used for these calculations. The 1 MeV rate and greater is utilized for electronic components with feature sizes less than 150 nm.

This flux value represents the nominal high energy neutrons at 40 000 ft and 45° latitude, and is a recognized industry standard value. Details on calculating SEE rates in avionics are provided in IEC 62396-1. Thermal energy neutron background information is provided in IEC 62396-5.

The cross-sectional area is a figure of merit that establishes how sensitive the electronic component is to the effects of atmospheric radiation. The different types of effects, such as SEU, SEL or SEFI, have independent cross-sections. SEFI rates are often defined on a per-