

This is a preview of "IEC 62396-1 Ed. 1.0 ...". Click here to purchase the full version from the ANSI store.



Edition 1.0 2012-05

# INTERNATIONAL STANDARD



---

**Process management for avionics – Atmospheric radiation effects –  
Part 1: Accommodation of atmospheric radiation effects via single event effects  
within avionics electronic equipment**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

PRICE CODE **XD**

ICS 03.100.50; 31.020; 49.060

ISBN 978-2-83220-099-5

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references .....	8
3 Terms and definitions .....	9
4 Abbreviations and acronyms.....	16
5 Radiation environment of the atmosphere.....	18
5.1 Radiation generation .....	18
5.2 Effect of secondary particles on avionics .....	18
5.3 Atmospheric neutrons.....	18
5.3.1 General .....	18
5.3.2 Energy spectrum of atmospheric neutrons .....	19
5.3.3 Altitude variation of atmospheric neutrons .....	20
5.3.4 Latitude variation of atmospheric neutrons .....	21
5.3.5 Thermal neutrons within aircraft.....	23
5.4 Secondary protons .....	23
5.5 Other particles.....	24
5.6 Solar enhancements.....	25
5.7 High altitudes greater than 60 000 feet (18 290 m) .....	25
6 Effects of atmospheric radiation on avionics .....	26
6.1 Types of radiation effects .....	26
6.2 Single event effects (SEE).....	26
6.2.1 General .....	26
6.2.2 Single event upset (SEU) .....	27
6.2.3 Multiple bit upset (MBU) and multiple cell upset (MCU) .....	27
6.2.4 Single effect transients (SET).....	29
6.2.5 Single event latch-up (SEL).....	29
6.2.6 Single event functional interrupt (SEFI) .....	30
6.2.7 Single event burnout (SEB) .....	30
6.2.8 Single event gate rupture (SEGR) .....	30
6.2.9 Single event induced hard error (SHE) .....	31
6.2.10 SEE potential risks based on future technology .....	31
6.3 Total ionising dose (TID) .....	31
6.4 Displacement damage .....	32
7 Guidance for system designs.....	33
7.1 Overview .....	33
7.2 System design.....	36
7.3 Hardware considerations .....	37
7.4 Parts characterisation and control .....	38
7.4.1 Rigour and discipline .....	38
7.4.2 Level A systems .....	38
7.4.3 Level B.....	39
7.4.4 Level C.....	39
7.4.5 Levels D and E .....	40
8 Determination of avionics single event effects rates .....	40

8.1	Main single event effects .....	40
8.2	Single event effects with lower event rates .....	40
8.2.1	Single event burnout (SEB) and single event gate rupture (SEGR) .....	40
8.2.2	Single event transient (SET) .....	41
8.2.3	Single event hard error (SHE) .....	41
8.2.4	Single event latch-up (SEL) .....	41
8.3	Single event effects with higher event rates – Single event upset data .....	42
8.3.1	General .....	42
8.3.2	SEU cross-section .....	42
8.3.3	Proton and neutron beams for measuring SEU cross-sections .....	42
8.3.4	SEU per bit cross-section trends in SRAMs .....	46
8.3.5	SEU per bit cross-section trends and other SEE in DRAMs .....	47
8.4	Calculating SEE rates in avionics .....	49
8.5	Calculation of availability of full redundancy .....	50
8.5.1	General .....	50
8.5.2	SEU with mitigation and SET .....	50
8.5.3	Firm errors and faults .....	51
9	Considerations for SEE compliance .....	51
9.1	Compliance .....	51
9.2	Confirm the radiation environment for the avionics application .....	51
9.3	Identify system development assurance level .....	51
9.4	Assess preliminary electronic equipment design for SEE .....	51
9.4.1	Identify SEE-sensitive electronic components .....	51
9.4.2	Quantify SEE rates .....	51
9.5	Verify that the system development assurance level requirements are met for SEE .....	51
9.5.1	Combine SEE rates for entire system .....	51
9.5.2	Management of parts control and dependability .....	52
9.6	Corrective actions .....	52
Annex A (informative)	Thermal neutron assessment .....	53
Annex B (informative)	Methods of calculating SEE rates in avionics electronics .....	54
Annex C (informative)	Review of test facility availability .....	60
Annex D (informative)	Tabular description of variation of atmospheric neutron flux with altitude and latitude .....	68
Annex E (informative)	Consideration of effects at higher altitudes .....	69
Annex F (informative)	Prediction of SEE rates for ions .....	74
Annex G (informative)	Late news as of 2011 on SEE cross-sections applicable to the atmospheric neutron environment .....	77
Bibliography	.....	88
Figure 1	– Energy spectrum of atmospheric neutrons at 40 000 feet (12 160 m), latitude 45 degrees .....	19
Figure 2	– Model of the atmospheric neutron flux variation with altitude (see Annex D) .....	21
Figure 3	– Distribution of vertical rigidity cut-offs around the world .....	22
Figure 4	– Model of atmospheric neutron flux variation with latitude .....	22
Figure 5	– Energy spectrum of protons within the atmosphere .....	24
Figure 6	– System safety assessment process .....	34
Figure 7	– SEE in relation to system and LRU effect .....	36

Figure 8 – Variation of RAM SEU cross-section as function of neutron/proton energy .....	44
Figure 9 – Neutron and proton SEU bit cross-section data .....	45
Figure 10 – SEU cross-section in SRAMs as function of manufacture date .....	47
Figure 11 – SEU cross-section in DRAMs as function of manufacture date .....	48
Figure E.1 – Integral linear energy transfer spectra in silicon at 100 000 feet (30 480 m) for cut-off rigidities ( $R$ ) from 0 GV to 17 GV .....	70
Figure E.2 – Integral linear energy transfer spectra in silicon at 75 000 feet (22 860 m) for cut-off rigidities ( $R$ ) from 0 to 17 GV .....	70
Figure E.3 – Integral linear energy transfer spectra in silicon at 55 000 feet (16 760 m) for cut-off rigidities ( $R$ ) from 0 GV to 17 GV .....	71
Figure E.4 – The influence of solar modulation on integral linear energy transfer spectra in silicon at 150 000 feet (45 720 m) for cut-off rigidities ( $R$ ) of 0 GV and 8 GV .....	71
Figure E.5 – The influence of solar modulation on integral linear energy transfer spectra in silicon at 55 000 feet (16 760 m) for cut-off rigidities ( $R$ ) of 0 GV and 8 GV .....	72
Figure E.6 – Calculated contributions from neutrons, protons and heavy ions to the SEU rates of the Hitachi-A 4Mbit SRAM as a function of altitude at a cut-off rigidity ( $R$ ) of 0 GV .....	73
Figure E.7 – Calculated contributions from neutrons, protons and heavy ions to the SEU rates of the Hitachi-A 4Mbit SRAM as a function of altitude at a cut-off rigidity ( $R$ ) of 8 GV .....	73
Figure F.1 – Example differential LET spectrum .....	75
Figure F.2 – Example integral chord length distribution for isotropic particle environment .....	75
Figure G.1 – Variation of the high energy neutron SEU cross-section per bit as a function of device feature size for SRAMs and SRAM arrays in microprocessors and FPGAs .....	79
Figure G.2 – Variation of the high energy neutron SEU cross-section per bit as a function of device feature size for DRAMs .....	80
Figure G.3 – Variation of the high energy neutron SEU cross-section per device as a function of device feature size for NOR and NAND type flash memories .....	81
Figure G.4 – Variation of the MCU/SBU percentage as a function of feature size based on data from many researchers in SRAMs [43, 45] .....	82
Figure G.5 – Variation of the high energy neutron SEFI cross-section in DRAMs as a function of device feature size .....	83
Figure G.6 – Variation of the high energy neutron SEFI cross-section in microprocessors and FPGAs as a function of device feature size .....	84
Figure G.7 – Variation of the high energy neutron single event latch-up (SEL) cross-section in CMOS devices (SRAMs, processors) as a function of device feature size .....	85
Figure G.8 – Single event burnout (SEB) cross-section in power devices (400 V – 1 200 V) as a function of drain-source voltage ( $V_{DS}$ ) .....	86
Table 1 – Nomenclature cross reference .....	35
Table B.1 – Sources of high energy proton or neutron SEU cross-section data .....	55
Table B.2 – Some models for the use of heavy ion SEE data to calculate proton SEE data .....	56
Table D.1 – Variation of 1 MeV to 10 MeV neutron flux in the atmosphere with altitude .....	68
Table D.2 – Variation of 1 MeV to 10 MeV neutron flux in the atmosphere with latitude .....	68
Table G.1 – Information relevant to neutron-induced SET .....	86

## 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

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62396-1 has been prepared by IEC technical committee 107: Process management for avionics.

IEC 62396-1 cancels and replaces IEC/TS 62396-1 published in 2006.

This International Standard includes the following technical changes with respect to the Technical Specification:

- a) Guidance has been provided on the environment for altitudes above 60 000 feet (18,3 km) and the effects on electronics are documented in Annex E and F;
- b) Annex G has been added to provide late news as of 2011 on SEE cross-sections applicable to the atmospheric neutron environment.

This is a preview of "IEC 62396-1 Ed. 1.0 ...". [Click here to purchase the full version from the ANSI store.](#)

The text of this international standard is based on the following documents:

FDIS	Report on voting
107/176/FDIS	107/182/RVD

Full information on the voting for the approval of this international standard 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.

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 publication will remain unchanged until the stability 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

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

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

**IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.**

## 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 and protons) 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 International Standard refers to the JEDEC Standard JESD89A, 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**

This part of IEC 62396 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 International Standard 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC/TS 62239:2008, *Process management for avionics – Preparation of an electronic components management plan*

NOTE IEC/TS 62239-1, *Process management for avionics – Management plan – Part 1: Preparation and maintenance of an electronic components management plan* is under study and will supersede IEC/TS 62239.

IEC/TS 62396-2:2008, *Process management for avionics – Atmospheric radiation effects – Part 2: Guidelines for single event effects testing for avionics systems*

IEC/TS 62396-3, *Process management for avionics – Atmospheric radiation effects – Part 3: Optimising system design to accommodate the single event effects (SEE) of atmospheric radiation*

IEC/TS 62396-4:2008, *Process management for avionics – Atmospheric radiation effects – Part 4: Guidelines for designing with high voltage aircraft electronics and potential single event effects*

IEC/TS 62396-5, *Process management for avionics – Atmospheric radiation effects – Part 5: Guidelines for assessing thermal neutron fluxes and effects in avionics systems*