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Vesoljska tehnika - Priročnik za izračun sevanja in njegovih učinkov ter za politiko pri načrtovanju mejnih vrednosti

Space engineering - Calculation of radiation and its effects and margin policy handbook

Raumfahrttechnik - Handbuch zur Berechnung von Strahlung, Strahlungseffekten und Marginregeln

Ingénierie spatiale - Manuel de calcul du transport des radiations et de leurs effets, et politique des marges

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This Technical Report was approved by CEN on 19 March 2021. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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European Foreword

This document (CEN/CLC/TR 17603-10-12:2021) has been prepared by Technical Committee CEN/CLC/JTC 5 “Space”, the secretariat of which is held by DIN.

It is highlighted that this technical report does not contain any requirement but only collection of data or descriptions and guidelines about how to organize and perform the work in support of EN 16603-10-12.

This Technical report (CEN/CLC/TR 17603-10-12:2021) originates from ECSS-E-HB-10-12A.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any TR covering the same scope but with a wider domain of applicability (e.g.: aerospace).

1 Scope

This handbook is a part of the System Engineering branch and covers the methods for the calculation of radiation received and its effects, and a policy for design margins. Both natural and man-made sources of radiation (*e.g.* radioisotope thermoelectric generators, or RTGs) are considered in the handbook.

This handbook can be applied to the evaluation of radiation effects on all space systems.

This handbook can be applied to all product types which exist or operate in space, as well as to crews of on manned space missions.

This handbook complements to EN 16603-10-12 “Methods for the calculation of radiation received and its effects and a policy for the design margin”.

2 Terms, definitions and abbreviated terms

2.1 Terms from other documents

For the purpose of this document, the terms and definitions from ECSS-S-ST-00-01 and ECSS-E-ST-10-12C apply.

2.2 Terms specific to the present handbook

None.

2.3 Abbreviated terms

The abbreviated specified in ECSS-E-ST-10-12C apply to this handbook.

3
Compendium of radiation effects

3.1 Purpose

This clause provides a brief summary of the various mechanisms for radiation damage and effects, and is summarised in the context in Table 1, which identifies important parameters to quantify effects, and gives units and examples. Table 2 can be used by the reader to cross-reference component/instrument technology to radiation effects discussed in detail elsewhere in this document.

Table 1: Summary of radiation effects parameters, units and examples.

Effect	Parameter	Typical units	Examples	Particles
Total ionising dose (TID)	Ionising dose in material	grays (material) (Gy(material)) or rad(material) 1 Gy = 100 rad	Threshold voltage shift and leakage currents in CMOS, linear bipolar (note dose-rate sensitivity)	Electrons, protons, bremsstrahlung
Displacement damage	Displacement damage equivalent dose (total non-ionising dose) Equivalent fluence of 10 MeV protons or 1 MeV electrons	MeV/g cm^{-2}	All photonics, e.g. CCD transfer efficiency, optocoupler transfer ratio Reduction in solar cell efficiency	Protons, electrons, neutrons, ions
Single event effects from direct ionisation	Events per unit fluence from linear energy transfer (LET) spectra & cross-section versus LET	cm^2 versus MeV·cm^2/mg	Memories, microprocessors. Soft errors, latch-up, burn-out, gate rupture, transients in op-amps, comparators.	Ions Z>1
Single event effects from nuclear reactions	Events per unit fluence from energy spectra & cross-section versus particle energy	cm^2 versus MeV	As above	Protons, neutrons, ions
Payload-specific radiation effects	Energy-loss spectra, charge-deposition spectra charging	counts s^{-1} MeV^{-1}	False count rates in detectors, false images in CCDs Gravity proof-masses	Protons, electrons, neutrons, ions, induced radioactivity (α, β±, γ)
Biological damage	Dose equivalent = Dose(tissue) x Quality Factor; equivalent dose = Dose(tissue) x radiation weighting factor; Effective dose	sieverts (Sv) or rems 1 Sv = 100 rem	DNA rupture, mutation, cell death	Ions, neutrons, protons, electrons, γ-rays, X-rays
Charging	Charge	coulombs (C)	Phantom commands from ESD	Electrons

Table 2: Summary of radiation effects and cross-references to other chapters (part 1 of 2)

Sub-system or component	Technology	Effect	ECSS-E-ST-10-12C Cross-reference	ECSS-E-HB-10-12A Cross-reference
Integrated circuits	Power MOS	TID SEGR SEB	Clause 7 Clause 9.4.1.6 Clause 9.4.1.6	Clause 6 Clause 8.6.2 Clause 8.6.3
	CMOS	TID SEE (generally)	Clause 7 Clause 9	Clause 6 Clause 8
	Bipolar	TNID SEU SET TID	Clause 8 Clauses 9.4.1.2, 9.4.1.3 Clause 9.4.1.7 Clause 7	Clause 7.4.2 Clause 8.7.1 Clause 8.7.5 Clause 6
	BiCMOS	TID TNID SEE (generally)	Clause 7 Clause 8 Clause 9	Clause 6 Clause 7.4.2 Clause 8
	SOI	TID SEE (generally exc. SEL)	Clause 7 Clause 9	Clause 6 Clause 8
Optoelectronics and sensors (1)	MEMS [a]	TID	Clause 7	Clause 6
	CCD	TNID TID Enhanced background (SEE)	Clause 8 Clause 7 Clauses 10.4.2, 10.4.3, 10.4.5	Clause 7.4.3 Clause 6 Clauses 9.2, 9.4
	CMOS APS	TNID TID SEE (generally) Enhanced background	Clause 8 Clause 7 Clause 9 Clauses 10.4.2, 10.4.3, 10.4.5	Clause 7.4.4 Clause 6 Clause 8 Clauses 9.2, 9.4,
	Photodiodes	TNID TID SET	Clause 8 Clause 7 Clause 9.4.1.7	Clause 7.4.5 Clause 6 Clause 8.7.5
	LEDs	TNID	Clause 8	Clause 7.4.7
	laser LEDs	TNID	Clause 8	Clause 7.4.6
	Opto-couplers	TNID SET	Clause 8 Clause 9.4.1.7	Clause 7.4.8 Clause 8.7.5
	γ-ray or X-ray scintillator	TNID (alkali halides) Enhanced background	Clause 8 Clauses 10.4.2, 10.4.3, 10.4.4	Clause 7.4.11 Clause 9.5
	γ-ray semiconductor	TNID Enhanced background	Clause 8 Clauses 10.4.2, 10.4.3, 10.4.4	Clause 7.4.10 Clause 9.5
	charge particle detectors	TNID (scintillator & semiconductor) Enhanced background TID (scintillator & semiconductors)	Clause 8 Clause 10.4.2, 10.4.3 Clause 7	Clause 9.5 Clause 9.3 Clause 6
	microchannel plates	Enhanced background	Clause 10.4.6	Clause 9.6
	photomultiplier tubes	Enhanced background	Clause 10.4.6	Clause 9.6

[a] MEMS refers to the effects on the microelectromechanical structure only. Any surrounding microelectronics are also subject to other radiation effects identified in “Integrated circuits” row