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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 - Berechnung der Strahlung und ihrer Auswirkungen sowie Handbuch zur Margenpolitik

Ingénierie spatiale - Manuel de calcul du rayonnement et de ses effets, et politique de marge

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TECHNICAL REPORT
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FINAL DRAFT
**FprCEN/CLC/TR 17603-
10-12**

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ICS

English version

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

Ingénierie spatiale - Manuel de calcul du rayonnement
et de ses effets, et politique de marge

Raumfahrttechnik - Berechnung der Strahlung und
ihrer Auswirkungen sowie Handbuch zur
Margenpolitik

This draft Technical Report is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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Table of contents

European Foreword	9
1 Scope	10
2 Terms, definitions and abbreviated terms	11
2.1 Terms from other documents	11
2.2 Terms specific to the present handbook	11
2.3 Abbreviated terms.....	11
3 Compendium of radiation effects	12
3.1 Purpose	12
3.2 Effects on electronic and electrical systems.....	14
3.2.1 Total ionising dose	14
3.2.2 Displacement damage	14
3.2.3 Single event effects.....	15
3.3 Effects on materials	16
3.4 Payload-specific radiation effects.....	16
3.5 Biological effects.....	16
3.6 Spacecraft charging.....	17
3.7 References	17
4 Margin	19
4.1 Introduction.....	19
4.1.1 Application of margins.....	19
4.2 Environment uncertainty	20
4.3 Effects parameters' uncertainty.....	21
4.3.1 Overview	21
4.3.2 Shielding	21
4.3.3 Ionising dose calculation	22
4.3.4 Non-ionising dose (NIEL, displacement damage).....	22
4.3.5 Single event effects.....	22
4.3.6 Effects on sensors.....	23
4.4 Testing-related uncertainties.....	23
4.4.1 Overview	23
4.4.2 Beam characteristics.....	23

4.4.3	Radioactive sources	23
4.4.4	Packaging	24
4.4.5	Penetration	24
4.4.6	Representativeness	24
4.5	Procurement processes and device reproducibility	24
4.6	Project management decisions	24
4.7	Relationship with derating	25
4.8	Typical design margins	25
4.9	References	25
5	Radiation shielding	26
5.1	Introduction	26
5.2	Radiation transport processes	26
5.2.1	Overview	26
5.2.2	Electrons	26
5.2.3	Protons and other heavy particles	28
5.2.4	Electromagnetic radiation – bremsstrahlung	31
5.3	Ionising dose enhancement	32
5.4	Material selection	32
5.5	Equipment design practice	33
5.5.1	Overview	33
5.5.2	The importance of layout	33
5.5.3	Add-on shielding	34
5.6	Shielding calculation methods and tools – Decision on using deterministic radiation calculations, detailed Monte Carlo simulations, or sector shielding analysis	35
5.7	Example detailed radiation transport and shielding codes	44
5.8	Uncertainties	44
5.9	References	44
6	Total ionising dose	47
6.1	Introduction	47
6.2	Definition	47
6.3	Technologies sensitive to total ionising dose	47
6.4	Total ionising dose calculation	48
6.5	Uncertainties	49
7	Displacement damage	50
7.1	Introduction	50
7.2	Definition	50

FprCEN/CLC/TR 17603-10-12:2020 (E)

7.3	Physical processes and modelling	50
7.4	Technologies susceptible to displacement damage	54
7.4.1	Overview	54
7.4.2	Bipolar	55
7.4.3	Charge-coupled devices (CCD)	55
7.4.4	Active pixel sensors (APS)	56
7.4.5	Photodiodes	56
7.4.6	Laser diodes	57
7.4.7	Light emitting diode (LED)	57
7.4.8	Optocouplers	57
7.4.9	Solar cells	57
7.4.10	Germanium detectors	58
7.4.11	Glasses and optical components	58
7.5	Radiation damage assessment	58
7.5.1	Equivalent fluence calculation	58
7.5.2	Calculation approach	59
7.5.3	3-D Monte Carlo analysis	59
7.5.4	Displacement damage testing	59
7.6	NIEL rates for different particles and materials	59
7.7	Uncertainties	67
7.8	References	67
8	Single event effects	69
8.1	Introduction	69
8.2	Modelling	70
8.2.1	Overview	70
8.2.2	Notion of LET (for heavy ions)	70
8.2.3	Concept of cross section	70
8.2.4	Concept of sensitive volume, critical charge and effective LET	71
8.3	Technologies susceptible to single event effects	71
8.4	Test methods	72
8.4.1	Overview	72
8.4.2	Heavy ion beam testing	72
8.4.3	Proton and neutron beam testing	73
8.4.4	Experimental measurement of SEE sensitivity	73
8.4.5	Influence of testing conditions	74
8.5	Hardness assurance	75
8.5.1	Rate prediction	75

8.5.2	Prediction of SEE rates for ions.....	75
8.5.3	Improvements	78
8.5.4	Method synthesis	79
8.5.5	Prediction of SEE rates of protons and neutrons.....	79
8.5.6	Method synthesis	80
8.5.7	Calculation toolkit.....	81
8.5.8	Applicable derating and mitigating techniques.....	81
8.5.9	Analysis at system level	81
8.6	Destructive SEE	82
8.6.1	Single event latch-up (SEL) and single event snapback (SESB).....	82
8.6.2	Single event gate rupture (SEGR) and single event dielectric rupture (SEDR)	84
8.6.3	Single event burnout (SEB).....	85
8.7	Non-destructive SEE	85
8.7.1	Single event upset (SEU).....	85
8.7.2	Multiple-cell upset (MCU) and single word multiple-bit upset (SMU).....	86
8.7.3	Single event functional interrupt (SEFI).....	88
8.7.4	Single event hard error (SEHE).....	88
8.7.5	Single event transient (SET) and single event disturb (SED).....	89
8.8	References	91
9	Radiation-induced sensor backgrounds	95
9.1	Introduction.....	95
9.2	Background in ultraviolet, optical and infrared imaging sensors.....	95
9.3	Background in charged particle detectors	99
9.4	Background in X-ray CCDs.....	99
9.5	Radiation background in gamma-ray instruments	100
9.6	Photomultiplier tubes and microchannel plates	103
9.7	Radiation-induced noise in gravity-wave detectors	104
9.8	Other problems common to detectors	104
9.9	References	104
10	Effects in biological material	106
10.1	Introduction.....	106
10.2	Quantities used in radiation protection work.....	106
10.2.1	Overview.....	106
10.2.2	Protection quantities.....	107
10.2.3	Operational quantities	109
10.3	Radiation effects in biological systems.....	111

FprCEN/CLC/TR 17603-10-12:2020 (E)

10.3.1	Overview.....	111
10.3.2	Source of data.....	112
10.3.3	Early effects	112
10.3.4	Late effects	112
10.4	Radiation protection limits in space.....	114
10.4.1	Overview.....	114
10.4.2	International agreements.....	115
10.4.3	Other considerations in calculating crew exposure.....	115
10.4.4	Radiation limits used by the space agencies of the partners of the International Space Station (ISS)	116
10.5	Uncertainties.....	119
10.5.1	Overview.....	119
10.5.2	Spacecraft shielding interactions.....	119
10.5.3	The unique effects of heavy ions.....	119
10.5.4	Extrapolation from high-dose effects to low-dose effects.....	120
10.5.5	Variability in composition, space and time.....	120
10.5.6	Effects of depth-dose distribution	120
10.5.7	Influence of spaceflight environment.....	121
10.5.8	Uncertainties summary	122
10.6	References	122

<https://standards.iteh.ai/catalog/standards/sist/77133421-b3b1-4811-8efe-0660f7060688/ksist-tp-fprcen-clc-tr-17603-10-12-2021>

Figures

Figure 1: CSDA range of electrons in example low- and high-Z materials as a function of electron energy	27
Figure 2: Total stopping powers for electrons in example low- and high-Z materials ...	27
Figure 3: Intensity of mono-energetic protons in a beam as a function of integral pathlength,	29
Figure 4: Projected range of protons in example low- and high-Z materials as a function of proton energy	29
Figure 5: Total stopping powers for protons in example low- and high-Z materials.	30
Figure 6: Stopping power for electrons from collisions with atomic electrons and bremsstrahlung production, and from bremsstrahlung production alone....	31
Figure 12: Five electric effects due to defects in the semiconductor band gap [RDE.4]	55
Figure 13: SEE initial mechanisms by direct ionisation (for heavy ions) and nuclear interactions (for protons and neutrons).	69
Figure 22: ISOCAM images for quiet conditions (top) and during solar flare event of November 1997.....	97
Figure 23: Predicted and measured background spectra observed in OSSE instrument on Compton Gamma-Ray Observatory 419 days after launch [RDG.10].	101

Figure 25: Relationship of quantities for radiological protection.	111
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Tables

Table 1: Summary of radiation effects parameters, units and examples.	12
Table 2: Summary of radiation effects and cross-references to other chapters (part 1 of 2)	13
Table 2: Summary of radiation effects and cross-references to other chapters (part 2 of 2)	14
Table 3: Description of physics models (part 1 of 4)	37
Table 3: Description of physics models (part 2 of 4)	38
Table 3: Description of physics models (part 3 of 4)	39
Table 3: Description of physics models (part 4 of 4)	40
Table 4: Example radiation transport simulation programs which are applicable to shielding and effects analysis.	43
Table 5: NIEL rates for electrons incident on Si (from Summers <i>et al</i> based on Si threshold of 21 eV [RDE.11]).	60
Table 6: NIEL rates for protons incident on Si (part 1 of 2). This is a subset of NIEL data from Huhtinen and Aarnio [RDE.12].	61
Table 6: NIEL rates for protons incident on Si (part 2 of 2). This is a subset of NIEL data from Huhtinen and Aarnio [RDE.12].	62
Table 7: NIEL rates for neutrons incident on Si (part 1 of 2). This is a subset of NIEL from Griffin <i>et al</i> [RDE.13].	63
Table 7: NIEL rates for neutrons incident on Si (part 2 of 3). These data are from Konobeyev <i>et al</i> [RDE.14].	64
Table 7: NIEL rates for neutrons incident on Si (part 3 of 3). This is a subset of NIEL from Huhtinen and Aarnio [RDE.12].	65
Table 8: NIEL rates for electrons in Si and GaAs (Akkerman <i>et al</i> [RDE.15])	66
Table 9: NIEL rates for protons in Si.	66
Table 10: NIEL rates for protons in GaAs.	67
Table 11: Typical materials for UV, visible and IR sensors, with band-gap and electron-hole production energies (e-h production energy for MCT is based on Klein semi-empirical formula.	96
Table 12: Lifetime mortality in a population of all ages from specific cancer after exposure to low doses.	113
Table 13: Estimates of the thresholds for deterministic effects in the adult human testes, ovaries, lens and bone marrow.	114
Table 14: CSA career ionising radiation exposure limits.	116
Table 15: ESA ionising radiation exposure limits.	116
Table 16: NCRP-132 recommended RBEs.	117
Table 17: NCRP-132 Deterministic dose limits for all ages and genders (Gy-Eq.).	117
Table 18: NCRP-132 career ionising radiation exposure limits.	117

FprCEN/CLC/TR 17603-10-12:2020 (E)

Table 19: NCRP-132 career effective dose limits for age and gender specific ionising radiation exposure for 10-year careers	117
Table 20: JAXA short-term ionising exposure limits	118
Table 21: JAXA career ionising radiation exposure limits (Sv)	118
Table 22: JAXA current career exposure limits by age and gender	118
Table 23: RSA short-term ionising exposure limits.	119
Table 24: Russian career ionising radiation exposure limits	119

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[kSIST-TP FprCEN/CLC/TR 17603-10-12:2021](https://standards.iteh.ai/catalog/standards/sist/77133421-b3b1-4811-8efe-0660f7060688/ksist-tp-fprcen-clc-tr-17603-10-12-2021)
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European Foreword

This document (FprCEN/CLC/TR 17603-10-12:2020) has been prepared by Technical Committee CEN/CLC/JTC 5 “Space”, the secretariat of which is held by DIN.

This document is currently submitted to the Vote on TR.

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 (FprCEN/CLC/TR 17603-10-12:2020) 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).

This document is currently submitted to the CEN CONSULTATION.

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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”.

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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

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