



**SLOVENSKI STANDARD**  
**SIST-TP CEN/CLC/TR 17603-10-12:2021**

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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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RAPPORT TECHNIQUE  
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ICS 49.140

English version

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

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

Raumfahrttechnik - Handbuch zur Berechnung von  
Strahlung, Strahlungseffekten und Marginregeln

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

CEN and CENELEC members are the national standards bodies and national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

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## Table of contents

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<b>European Foreword</b> .....	<b>9</b>
<b>1 Scope</b> .....	<b>10</b>
<b>2 Terms, definitions and abbreviated terms</b> .....	<b>11</b>
2.1 Terms from other documents .....	11
2.2 Terms specific to the present handbook .....	11
2.3 Abbreviated terms.....	11
<b>3 Compendium of radiation effects</b> .....	<b>12</b>
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.....	17
3.6 Spacecraft charging.....	17
3.7 References .....	17
<b>4 Margin</b> .....	<b>19</b>
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 .....	25
4.7	Relationship with derating .....	25
4.8	Typical design margins .....	25
4.9	References .....	25
<b>5</b>	<b>Radiation shielding .....</b>	<b>26</b>
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 .....	32
5.3	Ionising dose enhancement .....	33
5.4	Material selection .....	33
5.5	Equipment design practice .....	33
5.5.1	Overview .....	33
5.5.2	The importance of layout .....	34
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 .....	36
5.7	Example detailed radiation transport and shielding codes .....	45
5.8	Uncertainties .....	45
5.9	References .....	46
<b>6</b>	<b>Total ionising dose .....</b>	<b>48</b>
6.1	Introduction .....	48
6.2	Definition .....	48
6.3	Technologies sensitive to total ionising dose .....	48
6.4	Total ionising dose calculation .....	50
6.5	Uncertainties .....	50

## CEN/CLC/TR 17603-10-12:2021 (E)

<b>7 Displacement damage</b> .....	<b>51</b>
7.1 Introduction.....	51
7.2 Definition .....	51
7.3 Physical processes and modelling .....	51
7.4 Technologies susceptible to displacement damage .....	55
7.4.1 Overview.....	55
7.4.2 Bipolar.....	56
7.4.3 Charge-coupled devices (CCD).....	57
7.4.4 Active pixel sensors (APS).....	57
7.4.5 Photodiodes.....	58
7.4.6 Laser diodes .....	58
7.4.7 Light emitting diode (LED).....	58
7.4.8 Optocouplers.....	58
7.4.9 Solar cells .....	59
7.4.10 Germanium detectors.....	59
7.4.11 Glasses and optical components.....	60
7.5 Radiation damage assessment.....	60
7.5.1 Equivalent fluence calculation .....	60
7.5.2 Calculation approach .....	60
7.5.3 3-D Monte Carlo analysis.....	60
7.5.4 Displacement damage testing .....	60
7.6 NIEL rates for different particles and materials .....	61
7.7 Uncertainties.....	68
7.8 References .....	68
<b>8 Single event effects</b> .....	<b>70</b>
8.1 Introduction.....	70
8.2 Modelling .....	71
8.2.1 Overview.....	71
8.2.2 Notion of LET (for heavy ions).....	71
8.2.3 Concept of cross section.....	71
8.2.4 Concept of sensitive volume, critical charge and effective LET .....	72
8.3 Technologies susceptible to single event effects .....	73
8.4 Test methods.....	73
8.4.1 Overview.....	73
8.4.2 Heavy ion beam testing.....	73

8.4.3	Proton and neutron beam testing .....	74
8.4.4	Experimental measurement of SEE sensitivity .....	74
8.4.5	Influence of testing conditions .....	75
8.5	Hardness assurance .....	77
8.5.1	Rate prediction .....	77
8.5.2	Prediction of SEE rates for ions .....	77
8.5.3	Improvements .....	79
8.5.4	Method synthesis .....	80
8.5.5	Prediction of SEE rates of protons and neutrons .....	80
8.5.6	Method synthesis .....	82
8.5.7	Calculation toolkit .....	82
8.5.8	Applicable derating and mitigating techniques .....	82
8.5.9	Analysis at system level .....	82
8.6	Destructive SEE .....	83
8.6.1	Single event latch-up (SEL) and single event snapback (SESB) .....	83
8.6.2	Single event gate rupture (SEGR) and single event dielectric rupture (SEDR) .....	85
8.6.3	Single event burnout (SEB) .....	86
8.7	Non-destructive SEE .....	87
8.7.1	Single event upset (SEU) .....	87
8.7.2	Multiple cell upset (MCU) and single word multiple bit upset (SMU) .....	87
8.7.3	Single event functional interrupt (SEFI) .....	89
8.7.4	Single event hard error (SEHE) .....	90
8.7.5	Single event transient (SET) and single event disturb (SED) .....	91
8.8	References .....	92
<b>9</b>	<b>Radiation-induced sensor backgrounds .....</b>	<b>96</b>
9.1	Introduction .....	96
9.2	Background in ultraviolet, optical and infrared imaging sensors .....	96
9.3	Background in charged particle detectors .....	100
9.4	Background in X-ray CCDs .....	100
9.5	Radiation background in gamma-ray instruments .....	101
9.6	Photomultiplier tubes and microchannel plates .....	104
9.7	Radiation-induced noise in gravity-wave detectors .....	105
9.8	Other problems common to detectors .....	105
9.9	References .....	106
<b>10</b>	<b>Effects in biological material .....</b>	<b>108</b>
10.1	Introduction .....	108

**CEN/CLC/TR 17603-10-12:2021 (E)**

10.2	Quantities used in radiation protection work.....	108
10.2.1	Overview.....	108
10.2.2	Protection quantities.....	109
10.2.3	Operational quantities .....	111
10.3	Radiation effects in biological systems.....	113
10.3.1	Overview.....	113
10.3.2	Source of data.....	114
10.3.3	Early effects .....	114
10.3.4	Late effects .....	115
10.4	Radiation protection limits in space.....	117
10.4.1	Overview.....	117
10.4.2	International agreements.....	117
10.4.3	Other considerations in calculating crew exposure.....	118
10.4.4	Radiation limits used by the space agencies of the partners of the International Space Station (ISS) .....	118
10.5	Uncertainties.....	122
10.5.1	Overview.....	122
10.5.2	Spacecraft shielding interactions.....	122
10.5.3	The unique effects of heavy ions.....	122
10.5.4	Extrapolation from high-dose effects to low-dose effects.....	123
10.5.5	Variability in composition, space and time.....	123
10.5.6	Effects of depth-dose distribution .....	123
10.5.7	Influence of spaceflight environment.....	123
10.5.8	Uncertainties summary .....	125
10.6	References .....	125

**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 .....	28
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.....	30
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.....	32



Figure 12: Five electric effects due to defects in the semiconductor band gap [RDE.4] .....	56
Figure 13: SEE initial mechanisms by direct ionisation (for heavy ions) and nuclear interactions (for protons and neutrons).....	70
Figure 22: ISOCAM images for quiet conditions (top) and during solar flare event of November 1997.....	98
Figure 23: Predicted and measured background spectra observed in OSSE instrument on Compton Gamma-Ray Observatory 419 days after launch [RDG.10].....	102
Figure 25: Relationship of quantities for radiological protection. ....	113

## 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. ....	44
Table 5: NIEL rates for electrons incident on Si (from Summers <i>et al</i> based on Si threshold of 21 eV [RDE.11]).....	61
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]. ....	62
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]. ....	63
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]. ....	64
Table 7: NIEL rates for neutrons incident on Si (part 2 of 3). These data are from Konobeyev <i>et al</i> [RDE.14]. ....	65
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]. ....	66
Table 8: NIEL rates for electrons in Si and GaAs (Akkerman <i>et al</i> [RDE.15]) .....	67
Table 9: NIEL rates for protons in Si.....	67
Table 10: NIEL rates for protons in GaAs. ....	68
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. ....	97
Table 12: Lifetime mortality in a population of all ages from specific cancer after exposure to low doses.....	116
Table 13: Estimates of the thresholds for deterministic effects in the adult human testes, ovaries, lens and bone marrow. ....	116

**CEN/CLC/TR 17603-10-12:2021 (E)**

Table 14: CSA career ionising radiation exposure limits.....	119
Table 15: ESA ionising radiation exposure limits.....	119
Table 16: NCRP-132 recommended RBEs.....	119
Table 17: NCRP-132 Deterministic dose limits for all ages and genders (Gy-Eq.).....	120
Table 18: NCRP-132 career ionising radiation exposure limits.....	120
Table 19: NCRP-132 career effective dose limits for age and gender specific ionising radiation exposure for 10-year careers.....	120
Table 20: JAXA short-term ionising exposure limits.....	120
Table 21: JAXA career ionising radiation exposure limits (Sv).....	121
Table 22: JAXA current career exposure limits by age and gender.....	121
Table 23: RSA short-term ionising exposure limits.....	121
Table 24: Russian career ionising radiation exposure limits.....	122

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[SIST-TP CEN/CLC/TR 17603-10-12:2021](https://standards.iteh.ai/catalog/standards/sist/77133421-b3b1-4811-8efe-0660f7060688/sist-tp-cen-clc-tr-17603-10-12-2021)

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## European Foreword

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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).

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# 1 Scope

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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

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### 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.

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### 2.3 Abbreviated terms **(standards.iteh.ai)**

The abbreviated terms 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 <sup>2</sup>	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 <sup>2</sup> versus MeV·cm <sup>2</sup> /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 <sup>2</sup> versus MeV	As above	Protons, neutrons, ions
Payload-specific radiation effects	Energy-loss spectra, charge-deposition spectra  charging	counts s <sup>-1</sup> MeV <sup>-1</sup>	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 <sup>a</sup>	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
	$\gamma$ -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
	$\gamma$ -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

<sup>a</sup> 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