SLOVENSKI STANDARD
SIST EN 16603-10-12:2014

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Vesoljska tehnika - Metoda za izračun prejetega sevanja in njegovih učinkov ter politika pri zasnovi mejnih vrednosti

Space engineering - Method for the calculation of radiation received and its effects, and a policy for design margins

Raumfahrttechnik - Methoden zur Berechnung von Strahlungsdosis, -wirkung und Leitfaden für Toleranzen im Entwurf

Ingéniérie spatiale - Procédé pour le calcul de rayonnement reçue et ses effets, et une politique de marges de conception

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Foreword

This document (EN 16603-10-12:2014) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN.

This standard (EN 16603-10-12:2014) originates from ECSS-E-ST-10-12C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2015, and conflicting national standards shall be withdrawn at the latest by January 2015.

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

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.”

1 Scope

This standard is a part of the System Engineering branch of the ECSS engineering standards 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 standard.

This standard applies to the evaluation of radiation effects on all space systems.

This standard applies to all product types which exist or operate in space, as well as to crews of manned space missions. The standard aims to implement a space system engineering process that ensures common understanding by participants in the development and operation process (including Agencies, customers, suppliers, and developers) and use of common methods in evaluation of radiation effects.

This standard is complemented by ECSS-E-HB-10-12 “Radiation received and its effects and margin policy handbook”.

This standard may be tailored for the specific characteristic and constrains of a space project in conformance with ECSS-S-ST-00.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply, However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
EN 16603-10-04	ECSS-E-ST-10-04	Space engineering – Space environment
EN 16603-10-09	ECSS-E-ST-10-09	Space engineering – Reference coordinate system
EN 16602-30	ECSS-Q-ST-30	Space product assurance – Dependability
EN 16602-60	ECSS-Q-ST-60	Space product assurance – Electrical, electronic and electromechanical (EEE) components

3 Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-ST-00-01 apply, in particular for the following terms:

derating

subsystem

3.2 Terms specific to the present standard

3.2.1 absorbed dose

energy absorbed locally per unit mass as a result of radiation exposure which is transferred through ionisation, displacement damage and excitation and is the sum of the ionising dose and non-ionising dose

NOTE 1 It is normally represented by D, and in accordance with the definition, it can be calculated as the quotient of the energy imparted due to radiation in the matter in a volume element and the mass of the matter in that volume element. It is measured in units of gray, Gy (1 Gy = 1 J kg^{-1} (= 100 rad)).

NOTE 2 The absorbed dose is the basic physical quantity that measures radiation exposure.

3.2.2 air kerma

energy of charged particles released by photons per unit mass of dry air

NOTE It is normally represented by K.

3.2.3 ambient dose equivalent, H*(d)

dose at a point equivalent to the one produced by the corresponding expanded and aligned radiation field in the ICRU sphere at a specific depth on the radius opposing the direction of the aligned field

NOTE 1 It is normally represented by H*(d), where d is the specific depth used in its definition, in mm.

NOTE 2 H*(d) is relevant to strongly penetrating radiation. The value normally used is 10 mm, but dose equivalent at other depths can be used when the dose equivalent at 10 mm provides an unacceptable underestimate of the effective dose.

3.2.4 bremsstrahlung

high energy electromagnetic radiation in the X-ray energy range emitted by charged particles slowing down by scattering off atomic nuclei

NOTE The primary particle is ultimately absorbed while the bremsstrahlung can be highly penetrating. In space the most common source of bremsstrahlung is electron scattering.

3.2.5 component

device that performs a function and consists of one or more elements joined together and which cannot be disassembled without destruction

3.2.6 continuous slowing down approximation range (CSDA)

integral pathlength travelled by charged particles in a material assuming no stochastic variations between different particles of the same energy, and no angular deflections of the particles

3.2.7 COTS

commercial electronic component readily available off-the-shelf, and not manufactured, inspected or tested in accordance with military or space standards

3.2.8 critical charge

minimum amount of charge collected at a sensitive node due to a charged particle strike that results in a SEE

3.2.9 cross-section

<single event phenomena> probability of a single event effect occurring per unit incident particle fluence

NOTE This is experimentally measured as the number of events recorded per unit fluence.

3.2.10 cross-section

<nuclear or electromagnetic physics> probability of a particle interaction per unit incident particle fluence

NOTE It is sometimes referred to as the *microscopic cross-section*. Other related definition is the macroscopic cross section, defines as the probability of an interaction per unit path-length of the particle in a material.

3.2.11 directional dose equivalent

dose at a point equivalent to the one produced by the corresponding expanded radiation field in the ICRU sphere at a specific depth d on a radius on a specified direction

NOTE 1 It is normally expressed as H′(d, Ω), where d is the specific depth used in its definition, in mm, and Ω is the direction.

NOTE 2 H′(d,Ω), is relevant to weakly-penetrating radiation where a reference depth of 0,07 mm is usually used and the quantity denoted H′(0,07, Ω).

3.2.12 displacement damage

crystal structure damage caused when particles lose energy by elastic or inelastic collisions in a material

3.2.13 dose

quantity of radiation delivered at a position

NOTE 1 In its broadest sense this can include the flux of particles, but in the context of space energetic particle radiation effects, it usually refers to the energy absorbed locally per unit mass as a result of radiation exposure.

NOTE 2 If "dose" is used unqualified, it refers to both ionising and non-ionising dose. Non-ionising dose can be quantified either through energy deposition via displacement damage or damage-equivalent fluence (see Clause 8).

3.2.14 dose equivalent

absorbed dose at a point in tissue which is weighted by quality factors which are related to the LET distribution of the radiation at that point

3.2.15 dose rate

rate at which radiation is delivered per unit time

3.2.16 effective dose

sum of the equivalent doses for all irradiated tissues or organs, each weighted by its own value of tissue weighting factor

NOTE 1 It is normally represented by E, and in accordance with the definition it is calculated with the equation below, and the w_T is specified in the ICRP-92 standard [RDH.22]:

$$E = \sum w_T \cdot H_T \qquad (1)$$

For further discussion on *E*, see ECSS-E-HB-10-12 Section 10.2.2.

NOTE 2 Effective dose, like organ equivalent dose, is measured in units of sievert, Sv. Occasionally this use of the same unit for different quantities can give rise to confusion.

3.2.17 energetic particle

particle which, in the context of space systems radiation effects, can penetrate outer surfaces of spacecraft

3.2.18 equivalent dose

See 3.2.41 (organ equivalent dose)

3.2.19 equivalent fluence

quantity which represents the damage at different energies and from different species by a fluence of monoenergetic particles of a single species

NOTE 1 These are usually derived through testing.

NOTE 2 Damage coefficients are used to scale the effect caused by particles to the damage caused by a standard particle and energy.

3.2.20 extrapolated range

range determined by extrapolating the line of maximum gradient in the intensity curve until it reaches zero intensity

3.2.21 Firsov scattering

the reflection of fast ions from a dense medium at glancing angles

NOTE See references [2].

3.2.22 fluence

time-integration of flux

NOTE It is normally represented by Φ.

3.2.23 flux

<unidirectional incident particles> number of particles crossing a surface at right angles to the particle direction, per unit area per unit time

3.2.24 flux

<arbitrary angular distributions> number of particles crossing a sphere of unit cross-sectional area (i.e. of radius $1/\sqrt{\pi}$) per unit time

NOTE 1 For arbitrary angular distributions, it is normally known as omnidirectional flux.

NOTE 2 Flux is often expressed in “integral form” as particles per unit time (e.g. electrons cm^{-2} s^{-1}) above a certain energy threshold.

NOTE 3 The directional flux is the differential with respect to solid angle (e.g. particles-$cm^{-2}steradian^{-1}s^{-1}$) while the “differential” flux is differential with respect to energy (e.g. particles-cm^{-2}MeV^{-1}s^{-1}). In some cases fluxes are treated as a differential with respect to linear energy transfer rather than energy.

3.2.25 ICRU sphere

sphere of 30 cm diameter made of ICRU soft tissue

NOTE This definition is provided by the International Commission of Radiation Units and Measurements Report 33 [12].

3.2.26 ICRU Soft Tissue

tissue equivalent material with a density of 1 g/cm^3 and a mass composition of 76,2 % oxygen, 11,1 % carbon, 10,1 % hydrogen and 2,6 % nitrogen.

NOTE This definition is provided in the ICRU Report 33 [12].

3.2.27 ionising dose

amount of energy per unit mass transferred by particles to a target material in the form of ionisation and excitation

3.2.28 ionising radiation

transfer of energy by means of particles where the particle has sufficient energy to remove electrons, or undergo elastic or inelastic interactions with nuclei (including displacement of atoms), and in the context of this standard includes photons in the X-ray energy band and above

3.2.29 isotropic

property of a distribution of particles where the flux is constant over all directions

3.2.30 L or L-shell

parameter of the geomagnetic field often used to describe positions in near-Earth space

NOTE L or L-shell has a complicated derivation based on an invariant of the motion of charged particles in the terrestrial magnetic field. However it is useful in defining plasma regimes within the magnetosphere because, for a dipole magnetic field, it is equal to the geocentric altitude in Earth-radii of the local magnetic field line where it crosses the equator.

3.2.31 linear energy transfer (LET)

rate of energy deposited through ionisation from a slowing energetic particle with distance travelled in matter, the energy being imparted to the material

NOTE 1 LET is normally used to describe the ionisation track caused due to the passage of an ion. LET