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Vesoljski inženiring - Ocena priročnika za polnjenje v najslabšem primeru v vesolju

Space engineering - Assessment of space worst case charging handbook

Raumfahrttechnik - Handbuch zur Bewertung von Weltraum-Worst-Case-Ladungen

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**Space engineering - Assessment of space worst case
charging handbook**

Ingénierie spatiale - Guide sur les techniques de
durcissement des ASICs et FPGAs vis-à-vis des effets
des radiations

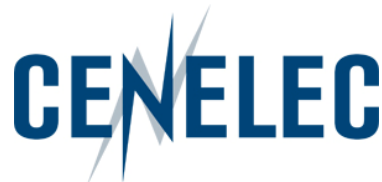
Raumfahrttechnik - Handbuch zur Bewertung von
Weltraum-Worst-Case-Ladungen

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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European Foreword

This document (FprCEN/TR 17603-20-06:2021) 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 16603-20.

This Technical report (FprCEN/TR 17603-20-06:2021) originates from ECSS-E-HB-20-06A.

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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Introduction

Spacecraft charging occurs due to the deposition of charge on spacecraft surfaces or in internal materials due to charged particles from the environment. Resulting high voltages and high electric fields cause electrostatic discharges which are a hazard to many spacecraft systems. Broadly speaking, spacecraft charging can be divided into surface charging, which is caused by plasma particles with energy up to several 10s of keV and internal charging which is caused by trapped radiation electrons with energy around 0,2 MeV and above.

Both surface and internal charging have been associated with malfunctions and damage to spacecraft systems over many years.

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Scope

Common engineering practices involve the assessment, through computer simulation (with software like NASCAP 0 or SPIS 0), of the levels of absolute and differential potentials reached by space systems in flight. This is usually made mandatory by customers and by standards for the orbits most at risk such as GEO or MEO and long transfers to GEO by, for example, electric propulsion.

The ECSS-E-ST-20-06 standard requires the assessment of spacecraft charging but it is not appropriate in a standard to explain how such an assessment is performed. It is the role of this document ECSS-E-HB-20-06, to explain in more detail important aspects of the charging process and to give guidance on how to carry out charging assessment by computer simulation.

The ECSS-E-ST-10-04 standard specifies many aspects of the space environment, including the plasma and radiation characteristics corresponding to worst cases for surface and internal charging. In this document the use of these environment descriptions in worst case simulations is described.

The emphasis in this document is on high level charging in natural environments. One aspect that is currently not addressed is the use of active sources e.g. for electric propulsion or spacecraft potential control. The tools to address this are still being developed and this area can be addressed in a later edition.

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References

EN Reference	Reference in text	#	Title
EN 16601-00-01	ECSS-S-ST-00-01	[RD.1]	ECSS-S-ST-00-01, ECSS system – Glossary of terms
EN 17603-10-04	ECSS-E-ST-10-04	[RD.2]	ECSS-E-ST-10-04, Space engineering, Space environment
EN 17603-20-06	ECSS-E-ST-20-06	[RD.3]	ECSS-E-ST-20-06, Space engineering, Spacecraft charging
		[RD.4]	Myron J. Mandell, Victoria A. Davis, David L. Cooke, Member, IEEE, Adrian T. Wheelock, and C. J. Roth, Nascap-2k Spacecraft Charging Code Overview, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 34, NO. 5, OCTOBER 2006
		[RD.5]	Benoit Thiébault, Benjamin Jeanty-Ruard, Pierre Souquet, Julien Forest, Jean-Charles Matéo-Vélez, Pierre Sarraïlh, David Rodgers, Alain Hilgers, Fabrice Cipriani, Denis Payan, and Nicolas Balcon, SPIS 5.1: An Innovative Approach for Spacecraft Plasma Modeling, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 43, NO. 9, SEPTEMBER 2015. [SPIS can be downloaded from http://dev.spis.org/projects/spine/home/spis]
		[RD.6]	D. Payan, V. Inguibert, and J.-M. Siguier, ESD and secondary arcing powered by the solar array – toward full arc free power lines, 14 th SCTC, ESTEC, 2016
		[RD.7]	M. Bodeau, Updated current and voltage thresholds for sustained arcs in power systems, IEEE Trans. on Plasma Science, Vol. 42, No. 7, 2014
		[RD.8]	C. Imhof, H. Mank, and J. Lange, Charging simulations for a low earth orbit satellite with SPIS using different environmental inputs, 14 th SCTC, ESTEC, 2016
		[RD.9]	Yeh and Gussenhoven, The statistical electron environment for Defense Meteorological Satellite Program eclipse charging, JGR, vo.92, no.A7, pp.7705-7715, 1987

FprCEN/TR 17603-20-06:2021 (E)

EN Reference	Reference in text	#	Title
		[RD.10]	F. Lei, P. R. Truscott, C. S. Dyer, B. Quaghebeur, D. Heynderickx, P. Nieminen, H. Evans, and E. Daly, MULASSIS: A Geant4-Based Multilayered Shielding Simulation Tool, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 49, NO. 6, DECEMBER 2002
		[RD.11]	Adamec, V. and J. Calderwood, J Phys. D: Appl. Phys., 8, 551-560, 1975.
		[RD.12]	D.J.Rodgers, K. Ryden G.L. Wrenn, P.M. Latham, J. Sorensen, & L. Levy (1998). An Engineering Tool for the Prediction of Internal Dielectric Charging, Proc. 6th Spacecraft Charging Technology Conference, Hanscom, USA
		[RD.13]	R. Hanna, T. Paulmier, P. Molinie, M. Belhaj, B. Dirassen, D. Payan and N. Balcon, J. Appl. Phys. 115, 033713 (2014)]
		[RD.14]	Insoo Jun, Henry B. Garrett, Wousik Kim, and Joseph I. Minow, Review of an Internal Charging Code, NUMIT, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 36, NO. 5, OCTOBER 2008
		[RD.15]	F. Lei, D. Rodgers and P. Truscott, MCICT MONTE-CARLO INTERNAL CHARGING TOOL, Proc. 14 th Spacecraft Charging Technology Conference, ESA/ESTEC, Noordwijk, NL, 08 APRIL 2016
		[RD.16]	Alex Hands, Keith Ryden, Craig Underwood, David Rodgers and Hugh Evans, A New Model of Outer Belt Electrons for Dielectric Internal Charging (MOBE-DIC) IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 62, NO. 6, DECEMBER 2015
		[RD.17]	G. P. Ginet, P. O'Brien, S. L. Huston W. R. Johnston, T. B. Guild, R. Friedel, C. D. Lindstrom, C. J. Roth, P. Whelan, R. A. Quinn, D. Madden, S. Morley, Yi-Jiun Su, AE9, AP9 and SPM: New Models for Specifying the Trapped Energetic Particle and Space Plasma Environment, Space Science Reviews November 2013, Volume 179, Issue 1-4, pp 579-615
		[RD.18]	B. Jeanty-Ruard, A. Trouche, P. Sarrailh, J. Forest. Advanced CAD tool and experimental integration of GRAS/GEANT-4 for internal charging analysis in SPIS. Spacecraft Charging Technology Conference SCTC 2016, Apr 2016, NOORDWIJK, Netherlands.

EN Reference	Reference in text	#	Title
		[RD.19]	D. Payan, A. Sicard-Piet, J.C. Mateo-Velez, D.Lazaro, S. Bourdarie, et al.. Worst case of Geostationary charging environment spectrum based on LANL flight data. Spacecraft Charging Technology Conference 2014 (13 th SCTC), Jun 2014, PASADENA, United States.
		[RD.20]	Gussenhoven, M.S. and E. G. Mullen (1983), Geosynchronous environment for severe spacecraft charging, J. Spacecraft and Rockets 20, N°1, p. 26.
		[RD.21]	Matéo-Vélez, J.-C., Sicard, A., Payan, D., Ganushkina, N., Meredith, N. P., & Sillanpää, I. (2018). Spacecraft surface charging induced by severe environments at geosynchronous orbit. Space Weather, 16.
		[RD.22]	NASA-HDBK-4002A, Mitigating in space charging effects – a guideline, 03-03-2011
		[RD.23]	Inguibert, V., Siguier, J. M., Sarrailh, P., Matéo-Vélez, J. C., Payan, D., Murat, G., & Baur, C. Influence of Different Parameters on Flashover Propagation on a Solar Panel. IEEE Transactions on Plasma Science (2017)
		[RD.24]	E. Amorim, D. Payan, R. Reulet, and D. Sarrail, "Electrostatic discharges on a 1 m2 solar array coupon – Influence of the energy stored on coverglass on flashover current," in Proc. 9th Spacecraft Charging Technol. Conf., Tsukuba, Japan, Apr. 2005
		[RD.25]	R. Briet,, "Scaling laws for pulse waveforms from surface discharges," in Proc. 9th SCTC, Tsukuba, Japan, Apr. 2005.,
		[RD.26]	D. C. Ferguson and B. V. Vayner, "Flashover current pulse formation and the perimeter theory," IEEE Trans. Plasma Sci., vol. 41, no. 12, pp. 3393–3401, Dec. 2013
		[RD.27]	J.-F. Roussel et al., "SPIS multiscale and Multiphysics capabilities: Development and application to GEO charging and flashover modelling," IEEE Trans. Plasma Sci., vol. 40, no. 2, pp. 183–191, Feb. 2012.
		[RD.28]	J. A. Young and M. W. Crofton, "The effects of material at arc site on ESD propagation," in Proc. 14th SCTC, Noordwijk, The Netherlands, Apr., pp. 1–7, 2016
		[RD.29]	P. Sarrailh et al., "Plasma bubble expansion model of the flash-over current collection on a solar array-comparison to EMAGS3 results," IEEE Trans. Plasma Sci., vol. 41, no. 12, pp. 3429–3437, Dec. 2013

FprCEN/TR 17603-20-06:2021 (E)

EN Reference	Reference in text	#	Title
		[RD.30]	V. Inguibert et al., "Measurements of the flashover expansion on a real-solar panel—Preliminary results of EMAGS3 project," IEEE Trans. Plasma Sci., vol. 41, no. 12, pp. 3370–3379, Dec. 2013.
		[RD.31]	A. Gerhard et al., "Analysis of solar array performance degradation during simulated flashover discharge experiments on a full panel and using a simulator circuit," IEEE Trans. Plasma Sci., vol. 43, no. 11, pp. 3933–3938, Nov. 2015
		[RD.32]	Sarno-Smith, Lois K., Larsen, Brian A., Skoug, Ruth M., Liemohn, Michael W., Breneman, Aaron, Wygant, John R., Thomsen, Michelle F., Spacecraft surface charging within geosynchronous orbit observed by the Van Allen Probes, Space Weather, Volume 14, Issue 2, Pages 151–164, February 2016
		[RD.33]	Ganushkina, N. Yu., Amariutei, O. A., Welling, D., Heynderickx, D., Nowcast model for low-energy electrons in the inner magnetosphere, Space Weather, Volume 13, issue 1, pp. 16-34, 2015
		[RD.34]	NASA Technical paper 2361, 1984 Design guidelines for assessing and controlling spacecraft charging effects
		[RD.35]	Matéo-Vélez, J.-C., Sicard, A., Payan, D., Ganushkina, N., Meredith, N. P., & Sillanpää, I. (2018). Spacecraft surface charging induced by severe environments at geosynchronous orbit. Space Weather, 16. https://doi.org/10.1002/2017SW001689

Terms, definitions and abbreviated terms

3.1 Terms from other documents

- a. For the purpose of this document, the terms and definitions from ECSS-S-ST-00-01 apply, in particular the following terms:
1. environment

3.2 Abbreviated terms

For the purpose of this document, the abbreviated terms from ECSS-S-ST-00-01 apply and in particular the following:

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Abbreviation	Meaning
AU	astronomical unit
BOL	beginning-of-life
CAD	computer-aided design
CSDA	continuous slowing down approximation (relating to range of radiation in matter)
EMC	electromagnetic compatibility
ESD	electrostatic discharge
EOL	end-of-life
GDML	Geometry Definition Markup Language
GUI	graphical user interface
GEO	geostationary orbit
GTO	geostationary transfer orbit
MEO	medium Earth orbit
MLI	multi-layer insulation
LANL	Los Alamos National Laboratory
LEO	low Earth orbit
SEE	secondary electron emission