

Table of contents

European Forward	9
Introduction	11
1 Scope	13
2 Normative references	14
3 Terms, definitions and abbreviated terms	15
3.1 Terms defined in other standards	15
3.2 Terms specific to the present standard	15
3.3 Abbreviated terms.....	18
3.4 Nomenclature	19
4 Overview	21
4.1 Plasma interaction effects.....	21
4.1.1 Presentation.....	21
4.1.2 Most common engineering concerns.....	21
4.1.3 Overview of physical mechanisms	22
4.2 Relationship with other standards	24
5 Protection programme	26
6 Surface material requirements	27
6.1 Overview	27
6.1.1 Description and applicability.....	27
6.1.2 Purpose common to all spacecraft	28
6.1.3 A special case: scientific spacecraft with plasma measurement instruments	28
6.2 General requirements	28
6.2.1 Maximum permitted voltage	28
6.2.2 Maximum resistivity.....	29
6.3 Electrical continuity, including surfaces and structural and mechanical parts.....	29
6.3.1 Grounding of surface metallic parts.....	29
6.3.2 Exceptions	30

6.3.3	Electrical continuity for surface materials	31
6.4	Surface charging analysis.....	35
6.5	Deliberate potentials	35
6.6	Testing of materials and assemblies.....	35
6.6.1	General.....	35
6.6.2	Material characterization tests.....	37
6.6.3	Material and assembly qualification.....	37
6.7	Scientific spacecraft with plasma measurement instruments	38
6.8	Verification.....	38
6.8.1	Grounding	38
6.8.2	Material selection	39
6.8.3	Environmental effects.....	39
6.8.4	Computer modelling	39
6.9	Triggering of ESD	40
7	Secondary arc requirements	41
7.1	Description and applicability	41
7.2	Solar arrays	42
7.2.1	Overview.....	42
7.2.2	General requirement	42
7.2.3	Testing of solar arrays.....	43
7.3	Other exposed parts of the power system including solar array drive mechanisms	47
8	High voltage system requirements	48
8.1	Description	48
8.2	Requirements	48
8.3	Validation.....	48
9	Internal parts and materials requirements	49
9.1	Description	49
9.2	General.....	49
9.2.1	Internal charging and discharge effects.....	49
9.2.2	Grounding and connectivity.....	49
9.2.3	Dielectric electric fields and voltages.....	50
9.3	Validation.....	51
10	Tether requirements	55
10.1	Description	55
10.2	General.....	55

10.2.1	Hazards arising on tethered spacecraft due to voltages generated by conductive tethers	55
10.2.2	Current collection and resulting problems	55
10.2.3	Hazards arising from high currents flowing through the tether and spacecraft structures	56
10.2.4	Continuity of insulation	56
10.2.5	Hazards from undesired conductive paths	56
10.2.6	Hazards from electro-dynamic tether oscillations	56
10.2.7	Other effects	56
10.3	Validation	57
11	Electric propulsion requirements	58
11.1	Overview	58
11.1.1	Description	58
11.1.2	Coverage of the requirements	58
11.2	General	60
11.2.1	Spacecraft neutralization	60
11.2.2	Beam neutralization	61
11.2.3	Contamination	62
11.2.4	Sputtering	62
11.2.5	Neutral gas effects	62
11.3	Validation	63
11.3.1	Ground testing	63
11.3.2	Computer modelling characteristics	63
11.3.3	In-flight monitoring	63
11.3.4	Sputtering	63
11.3.5	Neutral gas effects	64
Annex A	(normative) Electrical hazard mitigation plan - DRD	65
A.1	DRD identification	65
A.1.1	Requirement identification and source document	65
A.1.2	Purpose and objective	65
A.2	Expected response	65
A.2.1	Scope and content	65
A.2.2	Special remarks	66
Annex B	(informative) Tailoring guidelines	67
B.1	Overview	67
B.2	LEO	67
B.2.1	General	67

B.2.2	LEO orbits with high inclination	68
B.3	MEO and GEO orbits.....	68
B.4	Spacecraft with onboard plasma detectors	68
B.5	Tethered spacecraft.....	69
B.6	Active spacecraft	69
B.7	Solar Wind.....	69
B.8	Other planetary magnetospheres.....	69
Annex C (informative) Physical background to the requirements		70
C.1	Introduction.....	70
C.2	Definition of symbols.....	70
C.3	Electrostatic sheaths.....	70
C.3.1	Introduction	70
C.3.2	The electrostatic potential	71
C.3.3	The Debye length.....	71
C.3.4	Presheath	72
C.3.5	Models of current through the sheath.....	73
C.3.6	Thin sheath – space-charge-limited model.....	73
C.3.7	Thick sheath – orbit motion limited (OML) model	74
C.3.8	General case.....	75
C.3.9	Magnetic field modification of charging currents.....	75
C.4	Current collection and grounding to the plasma	75
C.5	External surface charging	76
C.5.1	Definition.....	76
C.5.2	Processes	76
C.5.3	Effects.....	77
C.5.4	Surface emission processes	77
C.5.5	Floating potential.....	78
C.5.6	Conductivity and resistivity	79
C.5.7	Time scales.....	81
C.6	Spacecraft motion effects	81
C.6.1	Wakes.....	81
C.6.2	Motion across the magnetic field	84
C.7	Induced plasmas	85
C.7.1	Definition.....	85
C.7.2	Electric propulsion thrusters.....	86
C.7.3	Induced plasma characteristics	86
C.7.4	Charge-exchange effects	87

C.7.5	Neutral particle effects	88
C.7.6	Effect on floating potential	88
C.8	Internal and deep-dielectric charging	88
C.8.1	Definition	88
C.8.2	Relationship to surface charging	89
C.8.3	Charge deposition	90
C.8.4	Material conductivity	90
C.8.5	Time dependence	93
C.8.6	Geometric considerations	93
C.8.7	Isolated internal conductors	94
C.8.8	Electric field sensitive systems	94
C.9	Discharges and transients	95
C.9.1	General definition	95
C.9.2	Review of the process	95
C.9.3	Dielectric material discharge	96
C.9.4	Metallic discharge	98
C.9.5	Internal dielectric discharge	99
C.9.6	Secondary powered discharge	100
C.9.7	Discharge thresholds	100
Annex D (informative)	Charging simulation	102
D.1	Surface charging codes	102
D.1.1	Introduction	102
D.2	Internal charging codes	104
D.2.1	DICTAT	104
D.2.2	ESADDC	104
D.2.3	GEANT-4	105
D.2.4	NOVICE	105
D.3	Environment model for internal charging	105
D.3.1	FLUMIC	105
D.3.2	Worst case GEO spectrum	105
Annex E (informative)	Testing and measurement.	106
E.1	Definition of symbols	106
E.2	Solar array testing	106
E.2.1	Solar cell sample	106
E.2.2	Pre-testing of the solar array simulator (SAS)	107
E.2.3	Solar array test procedure	109
E.2.4	Other elements	113

E.2.5	The solar panel simulation device	114
E.3	Measurement of conductivity and resistivity	116
E.3.1	Determination of intrinsic bulk conductivity by direct measurement	116
E.3.2	Determination of radiation-induced conductivity coefficients by direct measurement	117
E.3.3	Determination of conductivity and radiation-induced conductivity by electron irradiation.....	118
E.3.4	The ASTM method for measurement of surface resistivity and its adaptation for space used materials.....	118

References 120

Bibliography..... 124

Figures

Figure 6-1:	Applicability of electrical continuity requirements	32
Figure 7-1:	Solar array test set-up	45
Figure C-1 :	Schematic diagram of potential variation through sheath and pre-sheath.	72
Figure C-2 :	Example secondary yield curve	78
Figure C-3 :	Schematic diagram of wake structure around an object at relative motion with respect to a plasma.....	82
Figure C-4 :	Schematic diagram of void region	83
Figure C-5 :	Schematic diagram of internal charging in a planar dielectric.....	89
Figure C-6 :	Dielectric discharge mechanism.	97
Figure C-7 :	Shape of the current in relation to discharge starting point.....	97
Figure C-8 :	Example of discharge on pierced aluminized Teflon® irradiated by electrons with energies ranging from 0 to 220 keV.	98
Figure C-9 :	Schematic diagram of discharge at a triple point in the inverted voltage gradient configuration with potential contours indicated by colour scale.	99
Figure E-1 :	Photograph of solar cells sample – Front face & Rear face (Stentor Sample. Picture from Denis Payan - CNES®).....	107
Figure E-2 :	Schematic diagram of power supply test circuit.....	108
Figure E-3 :	Example of a measured power source switch response.....	108
Figure E-4 :	Example solar array simulator.....	109
Figure E-5 :	Absolute capacitance of the satellite	110
Figure E-6 :	Junction capacitance of a cell versus to voltage.....	112
Figure E-7 :	The shortened solar array sample and the missing capacitances	113
Figure E-8 :	Discharging circuit oscillations	114
Figure E-9 :	Effect of an added resistance in the discharging circuit (SAS + resistance)	114
Figure E-10 :	Setup simulating the satellite including flashover current	115

Figure E-11 : Basic arrangement of apparatus for measuring dielectric conductivity in planar samples.....	116
Figure E-12 : Arrangement for measuring cable dielectric conductivity and cross-section through co-axial cable.....	116
Figure E-13 : Arrangement for carrying out conductivity tests on planar samples under irradiation	118
Figure E-14 : Basic experimental set up for surface conductivity	119

Tables

Table 4-1: List of electrostatic and other plasma interaction effects on space systems.....	23
Table 7-1: Tested voltage-current combinations.....	42
Table 7-2: Typical inductance per unit length for cables	46
Table C-1 : Parameters in different regions in space	72
Table C-2 : Typical plasma parameters for LEO and GEO	83
Table C-3 : Plasma conditions on exit plane of several electric propulsion thrusters	87
Table C-4 : Emission versus backflow current magnitudes for several electric propulsion thrusters.....	87
Table C-5 : Value of E_a for several materials	91