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Space systems — Electromagnetic compatibility requirements

Systèmes spatiaux — Exigences relatives à la compatibilité électromagnétique

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO 14302:2002), which has been technically revised.

The main changes are as follows:

— updating related standard documents such as AIAA, ECSS, MIL-STD and etc., considering with new work has been accomplished over the past 10 years in this field within the US AIAA and ECSS. Particularly in space - there are many more orbiting transmitters and receivers exploiting the EM spectrum for earth observation, communications etc.;

— the inclusion of EMC flow chart to clarify timeline for EMC plan, design, analysis and test/evaluation phase of project;

— the inclusion of technical requirements for multipaction, intermodulation and electrostatic discharge with consideration of changes of electronic equipment with higher speed digital devices, data bus & clock frequencies, and switch mode Power supplies by PWM signalling;

— updating of technical requirements, taking into account that equipment is still being qualified or qualified by similarity to heritage specifications from the 80's.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document addresses the equipment-level requirements, verification and rationale of system-level compatibility concerns used in the development and procurement of complete space systems.

This document includes requirements at all the following levels:

— general system requirements;

— specific system requirements;

— equipment-level electromagnetic interference requirements.

The equipment-level requirements are summarized in Tables 1 and 2.

This document does not include detailed design requirements. Instead, engineering issues to be addressed during execution of the electromagnetic compatibility (EMC) control programme are presented. Requirements in this document may be tailored based on contractual agreements.

This document references civilian equipment-level electromagnetic interference (EMI) test methods to minimize cost and allow the use of standard test methods. This document does not contain EMI test limits. Test limits should be developed based on the environment, power quality definition and operational requirements.

Annex A presents the rationale behind each requirement/test technique, guidance for meeting requirements and test procedures where an acceptable reference is not available. Use of Annex A is advised in order to allow for optimal tailoring of this document for individual programmes.

Space systems — Electromagnetic compatibility requirements

1 Scope

This document contains a process to establish performance requirements for the purpose of ensuring space systems electromagnetic compatibility (EMC). The engineering issues to be addressed in order to achieve system-level EMC are identified herein, with guidance and rationale towards achieving specification conformance. The method for the derivation of typical equipment-level requirements from a space-system-level requirement is illustrated. This document also aids in the selection of tailored requirements for a specific mission (see Annex A).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7137:1995, *Aircraft — Environmental conditions and test procedures for airborne equipment*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques — Electrostatic discharge immunity test*

ISO 24637, *Space systems — Electromagnetic interference (EMI) test reporting requirements*

ECSS-E-20-01A, *Multipaction Design and Test*

Aerospace Report No. TOR-2014-02198, *Standard/Handbook for Multipactor Breakdown Prevention in Spacecraft Components*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
break-out box
non-flight piece of test support equipment that is connected in-line with a cable that accommodates external connection (usually binding posts) of instrumentation or series/parallel test networks to the wiring in that cable

3.1.2
complete space system
suite of equipment, subsystems, skills, and techniques capable of performing or supporting an operational role

Note 1 to entry: A complete space system includes related facilities, equipment, subsystems, materials, services, and personnel required for its operation to the degree that it can be considered self-sufficient within its operational or support environment.

Note 2 to entry: The complete space system normally refers to the spacecraft or launch vehicle itself.

3.1.3
dead-facing
removal of power from a circuit prior to mating/de-mating of the circuit interface (usually to prevent arcing or inadvertent short circuits)

3.1.4
electromagnetic compatibility
EMC
ability of a space equipment or system to function satisfactorily in its intended electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

3.1.5
electromagnetic interference
EMI
degradation of the performance of a space *equipment* (3.1.6), transmission, channel, or system caused by an electromagnetic disturbance

3.1.6
equipment
integrated set of parts, and components

Note 1 to entry: An equipment accomplishes a specific function.

Note 2 to entry: An equipment is self-contained and classified as such for the purposes of separate manufacture, procurement, drawings, specification, storage, issue, maintenance, or use.

SOURCE: ISO 10795 3.93

3.1.7
faying surface
prepared conductive surface of sufficient area and conductivity that, when joined under pressure contact, ensures a low electrical bond impedance for the required life of the connection

3.1.8
floating
status of a circuit isolated from another one, which is characterized by a resistance of strong value in parallel with a capacity.

Note 1 to entry: In low frequency, the circuit is actually high impedance; it is not the case in HF considering the parasitic capacitor. “Floating” is therefore to use for a frequency domain that it is then necessary to specify.

3.1.9
immunity
ability of a device, *equipment* (3.1.6), or system to perform without degradation in the presence of an electromagnetic disturbance

3.1.10
internal charging
phenomenon caused by penetration of high-energy electrons through spacecraft structures and/or component walls so that these particles are incident on ungrounded metallic or dielectric internal surfaces

3.1.11
line impedance stabilization network
LISN
network inserted in the supply mains lead of an apparatus to be tested which provides, in a given frequency range, specified source or load impedance for the measurement of disturbance currents and voltages and which may isolate the apparatus from the supply mains in that frequency range

3.1.12
power quality requirement
requirement developed for the space system that defines the conducted voltage and current noise (from load regulation, spikes, sags, etc.) the power user can expect

3.1.13
procuring authority
agency or organization funding or administering a contract for the development of the space system

3.1.14
radio frequency interference
RFI
degradation of the reception of a wanted signal caused by a radio frequency disturbance

3.1.15
safety margin
ratio of circuit threshold of *susceptibility* (3.1.18) to induced circuit noise under worse-case expected environmental conditions (intrasystem and intersystem)

3.1.16
subsystem
set of interdependent elements constituted to achieve a given objective by performing a specified function, but that does not, on its own, satisfy the customer's requirement

Note 1 to entry: Generally, a piece of equipment is housed within a single enclosure, while a subsystem may consist of several interconnected units.

Note 2 to entry: ISO 10795 3.231, modified — Note 1 to entry added.

3.1.17
susceptibility
correct operation of electrical *equipment* (3.1.6), referred to as the victim, in the presence of unplanned electromagnetic disturbances

Note 1 to entry: A victim is a component/subsystem that is susceptible to interference.

3.1.18
suppression
act of eliminating electromagnetic noise through the process of filtering, shielding, or other methods that reduce the impact of noise on a system

3.2 Abbreviated terms

ACS attitude control system

BCI bulk current injection

CDR	critical design review
CE	conducted emissions
CISPR	International Special Committee on Radio Interference
COTS	commercial off-the-shelf
CS	conducted susceptibility
DSO	digital storage oscilloscope
EED	electro-explosive device
EGSE	electrical ground support equipment
EMCAB	electromagnetic compatibility advisory board
EME	electromagnetic environment
EMEVP	electromagnetic effects verification plan
EMEVR	electromagnetic effects verification report
EMISM	electromagnetic interference safety margin
ESD	electrostatic discharge
EUT	equipment under test
FMEA	failure mode effects analysis
GEO	geosynchronous Earth orbit
HF	high frequency
ICD	interface control document
LEO	low Earth orbit
Mil-Std	military standard
NASA	National Aeronautics and Space Administration
PDR	preliminary design review
RDR	requirements definition review
RE	radiated emissions
RF	radio frequency
RFP	request for proposal
r.m.s.	root-mean-square
RS	radiated susceptibility
r.s.s.	root-sum-square
SAE	Society of Automotive Engineers

SMPS	switched mode power supply
TTL	transistor-to-transistor logic
UHF	ultrahigh frequency
VHF	very high frequency
VLF	very low frequency

4 Requirements

4.1 General system requirements

4.1.1 General

The space system shall be electromagnetically compatible among all equipment/subsystems within the space system and with the self-induced and defined external electromagnetic environment during all phases of its mission.

4.1.2 System-level EMC programme

4.1.2.1 General

The procuring authority and prime contractor shall establish an overall EMC programme based on requirements of this document, the statement of work, space system specification, and other applicable contractual documents. The purpose of the EMC programme is to ensure space-system-level compatibility with minimum impact to programme, cost, schedule, and operational capabilities. An EMC programme shall include EMC control documentation and an EMC advisory board (EMCAB). The EMC staff responsible for these functions should be appropriate to the size and complexity of the programme. Typical programme milestones and their corresponding EMC data/deliverables are provided in Annex A (see Table A.1). Commercial space programmes having historically successful EMC control and management programmes in place may submit documentation to the procuring authority for an alternate means of equipment-level conformance, providing that the system-level interface requirements of this document are met.

When viewed from the perspective of a specific program or project context, the requirements defined in this document may be tailored to match the actual requirements of the particular program or project. Tailoring of requirements shall be undertaken in consultation with the procuring agency where applicable.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some exceptional cases, modification and addition of requirements in the standards.

4.1.2.2 Electromagnetic compatibility advisory board

The EMCAB shall be responsible for timely and effective execution of the EMC programme under the general project manager. The prime contractor or developer shall chair the EMCAB, with procuring authority oversight. Other EMCAB members may invite associate contractors or developers and an independent expert of a space engineering certification body. Procuring activities may waive this requirement for systems that do not involve sufficient levels of integration to justify such a board; then the prime contractor shall execute EMCAB functions. The EMCAB shall accomplish its duties and document its activities mainly through the use of the system-level EMC documentation. It is also the responsibility of the EMCAB to solve problems related to EMC as they arise.

4.1.2.3 EMC programme

Details of the EMC programme shall be documented in the EMC control plan or other EMC contract documentation. Initial releases shall document the mechanics of the EMC programme, including basic design guidelines, while subsequent routine updates shall document programme progress. The requirements and approach established by the prime contractor shall be in a contractual document. An overall programmatic EMC program is shown in Figure 1. The contents of the EMC control plan or other EMC contract documentation shall include, but not be limited to, the following:

a) EMC programme management is defined by:

   1) responsibilities of procuring authority, prime and associate contractors, lines and protocols of communication, and control of design changes;

   2) planning the EMC programme, consisting of:

      i) facilities and personnel required for successful implementation of the EMC programme;

      ii) methods and procedures of accomplishing EMC design reviews and coordination (within the EMCAB, if applicable);

      iii) proposed charter;

      iv) details of the operation of the EMCAB, if needed;

   3) programme schedules, including integration of the EMC programme schedule and milestones within th e programme development master schedule;

b) system-level performance and design requirements, consisting of:

   1) definition of electromagnetic and related environments; including considerations related to hazards of electromagnetic radiation to fuels, humans, and explosive systems, such as electro-explosive devices (EED's) (see 4.2.9), launch vehicles, interfacing vehicles, and launch site environment, including electronic equipment at the launch site area;

   2) definition of critical circuits;

c) electro-explosive devices, consisting of:

   1) appropriate EED EMC requirements;

   2) design techniques;

   3) verification techniques;

d) subsystem/equipment EMI performance requirements and verification, consisting of:

   1) allocation of design responses at system and subsystem/equipment levels as defined in this document;

   2) allocated EMI performance at the equipment level, including tailored equipment-level requirement of which the control plan is the vehicle for tailoring limits and test methods;

   3) test results from subsystem/equipment level EMI tests shall be summarized:

      i) any specification non-conformances judged to be acceptable shall be described in detail; and analysis of the non-compliant conditions on overall EMC performance shall be provided as a part of the justifying rationale;

ii) cost, mass, schedule, reliability, system operability, and other factors should also be addressed;

e) EMC analysis:

1) by making predictions of intrasystem EMI/EMC based on expected or actual equipment/subsystem EMI characteristics;

2) by designing solutions for predicted or actual interference situations using equipment-level data as input, impedance coupling (conducted emissions), wire-to-wire, field-to-wire:

i) all coupling modes should be considered to determine or predict EMI safety margin (EMISM) of intra-system EMI/EMC based on specified interface control document (ICD) values or actual (waiver/deviation request) values of equipment/subsystem EMI characteristics;

ii) design solutions should address what filtering, shielding, and grounding need to be applied to achieve these predicted EMISM's;

f) spacecraft charging/discharging analysis;

g) space-system-level EMC verification consisting of an outline of system-level EMC verification plan, including rationale for selection of critical circuits for safety margin demonstration, and instrumentation techniques for both critical and EED circuit and sensitization;

h) method of disposing waivers initial release and subsequent updates of the EMC control plan shall be prepared and submitted in accordance with contractual terms.

i)

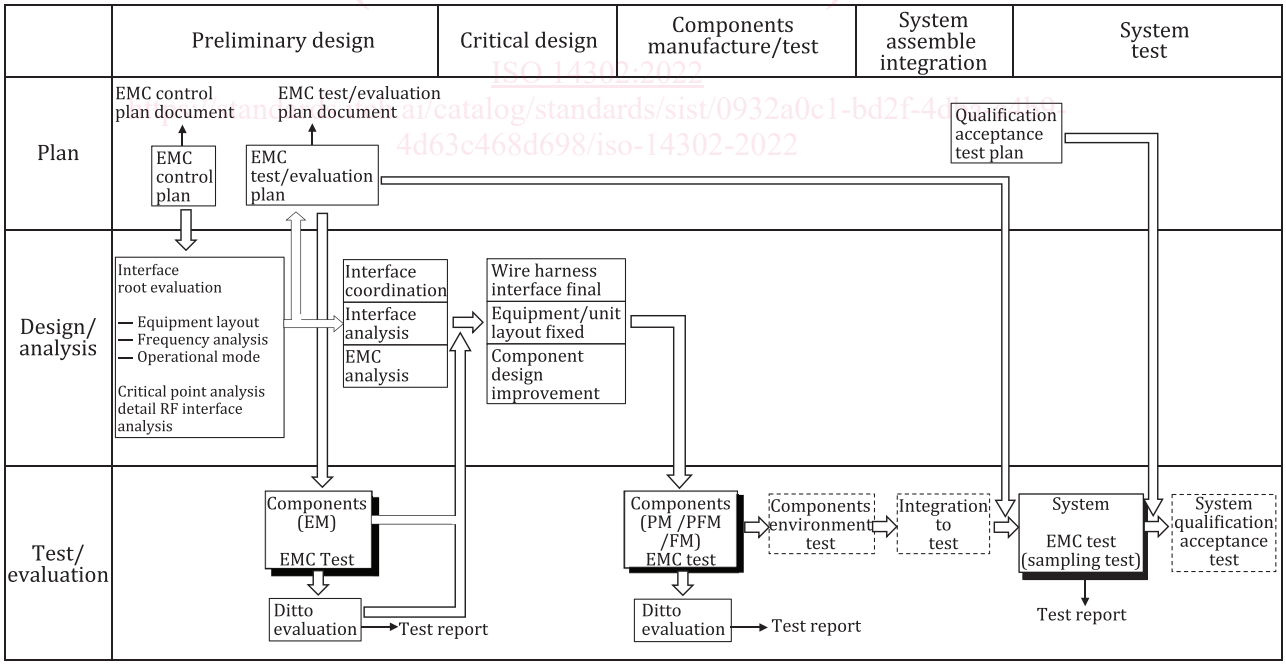

Figure 1 — Overall programmatic EMC program

4.1.3 Equipment/subsystem criticality categories

The EMCAB shall identify functional criticality for all equipment/subsystems. Functional criticality categories include the following:

a) category I, safety critical:

   EMI problems can result in loss of life and/or loss of space platform;

b) category II, mission critical:

   EMI problems can result in injury, damage to space platform, mission abort or delay, or performance degradation which unacceptably reduces mission effectiveness;

c) category III, non-critical:

   EMI problems can result only in annoyance, minor discomfort, or loss of performance which does not reduce desired spacecraft effectiveness.

4.1.4 Safety margins

Design safety margins shall be established by the EMCAB for both critical functions and EED circuits. Design margins shall consider likely degradation modes of circuits and circuit protection methods over projected spacecraft lifetime.

4.2 Specific system requirements

4.2.1 External electromagnetic environment

The space system shall operate without performance degradation in the electromagnetic environment, not only self-induced but that due to external sources (intersystem EMI) such as other radio frequency sources, high-energy charged particles of space environment or plasma effects. The EMCAB shall determine the electromagnetic environment based on mission requirements.

4.2.2 Intrasystem EMC

The space system shall not interfere with key requirements of a subsystem. Each equipment/subsystem shall operate without performance degradation during concurrent operation of any combination of the remaining equipment/subsystems, subject to mission requirements.

4.2.3 EMI control

The prime contractor shall be responsible for translating system-level EMC goals into equipment/subsystem-level EMI performance requirements. Test limits and test methods may be tailored if required, with procuring authority approval, to meet programme needs. EMI characteristics (emissions and susceptibility) shall be controlled to the extent necessary to ensure intrasystem EMC and compatibility with the predicted external electromagnetic environment. Equipment/subsystem-level EMI performance requirements and test methods shall be in accordance with 4.3 and 5.3.

4.2.4 Grounding and wiring design

4.2.4.1 Grounding

A controlled ground reference concept shall be established for the space system prior to initial release of the EMC control plan or other EMC contract documentation. Both power and signal returns and references shall be considered. Impedance magnitudes of these connections over the affected signal spectrum shall be considered in determining which kinds of power and signals may share common paths (wire or structure). Resistance and inductance values for each element of the ground return circuit architecture may be assigned; the common-mode voltages that develop at circuit reference

points can then be computed. These computed values may be compared to conducted susceptibility requirements for equipment.

For one architecture assumption, and knowing the noisy signals and EM environments, the computation of the reported energies from sources to receivers should be performed at the system scale. The architecture definition includes materials nature, grounding choices and harnesses locations. Then the EMC objectives can be defined with the margins for all equipment under sources of the same level that the ones considered with their shields in the computation.

4.2.4.2 Wiring

Wiring, cable separation, shielding, and signal category design guidelines for the space system shall be established. Pigtail shield connections shall not be used.

4.2.5 Electrical bonding

4.2.5.1 General

Electrical bonding measures shall be implemented for management of intentional electrical current paths and control of voltage potentials to ensure required space system performance and protection of personnel. Bonding provisions shall be compatible with other requirements imposed on the space system for corrosion control.

4.2.5.2 Power current feeder and return paths

If the structure is used as the current return path, bonding provisions shall be provided so that current paths of electrical power sources are such that the total direct current (d.c.) voltage drops between the power subsystem point of regulation and the electrical loads are within applicable power quality standard tolerances.

4.2.5.3 Shock and safety hazard

To prevent shock hazards to personnel, all exposed conductive items subject to fault condition charging shall be bonded as necessary to limit potentials to prevent shock to personnel. In order to clear faults or provide against accidental discharge of fault current to ground through a conductor, all exposed conductive items, which can become charged due to an electrical fault condition, shall be bonded to the ground subsystem. Bonding impedance shall be sufficiently low to ensure enough current to clear the fault by tripping a circuit protection device.

4.2.5.4 Antenna counterpoise

Antenna structures relying on a counterpoise connected to (or implemented on) the spacecraft skin shall have an RF bond to structure such that RF currents flowing on the skin have a low impedance path to and through the counterpoise.

4.2.5.5 RF potentials

All electronic and electrical items, which can experience degraded operation or can degrade the operation of other electronic or electrical items in response to external electromagnetic energy, shall be bonded to the ground subsystem with a faying surface bond to present a low impedance at the frequencies of interest. For composite materials, bonding shall be alternating current (a.c.) accomplished at impedance levels consistent with the materials in use. Where vibration or thermal isolation is required, bond straps may be used. The bond straps shall be as short as possible and maintain a low inductance path. Bond straps should only be used as a last resort.