EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space engineering

Electrical and electronic

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

Published by: ESA Publications Division
ESTEC, P.O. Box 299,
2200 AG Noordwijk,
The Netherlands

ISSN: 1028-396X

Price: EURO 20

Printed in The Netherlands

Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, National Space Agencies and European industry associations for the purpose of developing and maintaining common standards.

Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

The formulation of this Standard takes into account the existing ISO 9000 family of documents.

This Standard has been prepared by the ECSS Electrical and electronic Standards Working Group, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board.

(This page is intentionally left blank)

Contents list

Figures

Tables

(This page is intentionally left blank)

1
Scope

This Standard establishes the basic rules and general principles applicable to the electrical, electronic, electromagnetic, microwave and optical engineering processes. It specifies the tasks of these engineering processes and the basic performance and design requirements in each discipline.

It defines the terminology for the activities within these areas.

It defines the specific requirements for electrical subsystems and payloads, deriving from the system engineering requirements laid out in the Space System Engineering Standard ECSS-E-10.

When viewed from the perspective of a specific project context, the requirements defined in this Standard should be tailored to match the genuine requirements of a particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements or specifications, standards and related documents are evaluated and made applicable to a specific project. Application of the contract requirements may necessitate deletion, addition or modification of the requirements of this Standard.

(This page is intentionally left blank)

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 revisions 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 most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

ECSS-P-001	Glossary of terms
ECSS-E-00	Space engineering - Policy and principles
ECSS-E-10	Space engineering - System engineering
ECSS-E-30	Space engineering - Mechanical (to be published)
ECSS-E-50	Space engineering - Communication (to be published)
ECSS-M-40	Space project management - Configuration management
ECSS-Q-20	Space product assurance - Quality assurance
ECSS-Q-30	Space product assurance - Dependability
ECSS-Q-40	Space product assurance - Safety
ECSS-Q-60	Space product assurance - Electrical, electronic and electromechanical (EEE) components
ECSS-Q-60-11	Space product assurance - Derating and application rules (to be published)
ECSS-Q-70	Space product assurance - Materials, mechanical parts and processes
ECSS-Q-70-28	Space product assurance - The repair and modification of printed circuit board assemblies for space use (to be published)
IEC-60825	Safety of laser products
IEC-60479	Effects of current on human beings and livestock
IEEE 145-1993	Standard Definitions of Terms for Antennas
IEEE C95.1-1991	Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
IEEE 149-1979 (R 1990)	Test Procedures for Antennas

(This page is intentionally left blank)

3

Terms, definitions and abbreviated terms

3.1 Terms and definitions

The following terms and definitions are specific to this Standard in the sense that they are complementary or additional with respect to those contained in ECSS-P-001.

3.1.1 Centroid Error Function (CEF)

Difference between the position of the barycentre of the Point Spread Function (PSF), calculated by means of a suitable algorithm, and the theoretical position of the PSF centre, given by the intersection of the corresponding chief ray with the image plane. The centroid algorithm evaluates the position of the PSF energy barycentre and it is based on the energy measurement on a predetermined number of pixels in the image plane.

3.1.2 Encircled Energy Function (EEF)

The fraction of the PSF energy which lies within a circle, evaluated as a function of the circle radius.

3.1.3 Field Of View (FOV)

Angular extent of the object space which can be detected by an optical system or instrument. (The FOV is not be always symmetrical about the optical axis).

3.1.4 Instantaneous Field Of View (IFOV)

Angular extent of the object space which can be detected by an optical system or instrument, during a negligible time interval. (The IFOV is not be always symmetrical about the optical axis).

3.1.5 Line Spread Function (LSF)

One-dimensional transverse energy distribution in the image of a narrow slit object.

3.1.6 Modulation Transfer Function (MTF)

The modulation transfer function is the modulus of the optical transfer function. Considering a sine wave pattern object, the MTF is found to be the ratio of the modulation in the image to that in the object as a function of the spatial frequency of the sine wave pattern.

3.1.7 Noise Equivalent Power (NEP)

The Noise Equivalent Power is the value of the detector input power which produces a detector output equal to the r.m.s. noise output within a stated bandwidth at a stated frequency.

3.1.8 Optical Transfer Function (OTF)

It is the normalized Fourier transform of the point spread function

3.1.9 Point Spread Function (PSF)

Two dimensional energy distribution in the image of an object point.

3.1.10 Wavefront error (WFE)

Distribution of the distance between the wavefront exiting from an optical system and a reference wavefront or surface, measured on the normal to the reference wavefront and expressed in wavelength units.

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this Standard.

Abbreviation	Meaning
AC	Alternative Current
BOL	Beginning-of-Life
CEF	Centroid Error Function
CVCM	Collected Volatile Condensable Material
DC	Direct Current
DOD	Depth of Discharge
DRD	Document Requirements Definition
EED	Electroexplosive Device
EEF	Encircled Energy Function
EMEVP	Electromagnetic Effects Verification Plan
EMEVR	Electromagnetic Effects Verification Report
EMI	Electromagnetic Interference
EOL	End-of-Life
ESD	Electrostatic Discharge
FOV	Field of View
IFOV	Instantaneous Field of View
I-V	Current-Voltage
LSF	Line Spread Function
MLI	Multi-Layer Insulation
MTF	Modulation Transfer Function
NEP	Noise Equivalent Power
OTF	Optical Transfer Function
PCB	Printed Circuit Board
PSF	Point Spread Function
RF	Radio Frequency
r.m.s.	root-mean-square
TML	Total Mass Loss
WFE	Wavefront error
VSWR	Voltage Standing Wave Ratio

4
General requirements

4.1 Interface requirements

ECSS-E-10A requires that interfaces external or internal to a system are adequately specified (4.2.5) and verified (4.6). The following requirements address this issue and shall be processed in phase B, C and D of a project as requested in 5.5 of ECSS-E-10A.

4.1.1 Signals interfaces

a. Interface engineering shall ensure that the characteristics on both sides of each interface are compatible, including the effects of the interconnecting harness.

b. In order to minimize the number of interface types, standard interface circuitry shall be defined to be applied throughout a project according to ECSS-E-50.

c. Circuits receiving high level telecommands for direct execution of a major reconfiguration function or other critical function shall include noise discrimination filtering such that spurious commands of nominal peak-to-peak amplitude and of less than 10 % of the nominal command duration at a repetition period of 20 % of the nominal command duration are ignored. This requirement does not apply to direct commands on relay coils.

d. The application of signals to an unpowered unit shall not cause damage to that unit. An undefined status at the inputs of a powered unit shall not cause damage to this unit.

e. Signal interfaces shall withstand positive or negative voltages that are accessible on the same connector. Signal interfaces shall withstand maximum positive and negative fault voltages accessible on the same connector.

f. Provision shall be included to override any critical on-board autonomous function and to monitor its status, except where hazardous to the mission.

g. Any circuit intended to receive a signal shall include noise discrimination filtering compatible with the information content of the signal received.

4.1.2 Commands

a. Every command that is required by the spacecraft shall be evaluated for criticality. The criticality of a command is measured as its impact on the mission in case of inadvertent function (erroneous transmission), incorrect function (aborted transmission) or loss of function.

- Category 1 criticality: Loss of mission.
- Category 2 criticality: Temporary interruption of spacecraft performance, recoverable by ground command.
- Category 3 criticality: Causes no or minor degradation, recoverable by ground command.

The command criticality shall be assessed at equipment level and confirmed at subsystem/system level.

b. All executable commands shall be acknowledged by telemetry. The acknowledgment shall be explicit.

c. The function of an executable command shall not change throughout a mission and shall not depend on the history of previous commands.

d. Commands for which the criticality is category 1 shall require at least two separate commands for execution: an arm/safe or enable/disable followed by an execute command.

e. It shall be possible to repeat all executable commands numerous times without degradation of the function, or causing a change of status.

f. On-board processor commands:

- Processor and simple logic circuits shall not be able to issue category 1 critical commands without a ground commanded arm/safe or enable/disable command.
- Any on-board processing which issues commands to reconfigure subsystems or payloads shall be overridable and potentially inhibited by ground command.
- Configuration of a subsystem or equipment shall be possible from ground without intervention of the on-board processor.

4.1.3 Telemetry

a. Telemetry data shall permit unambiguous monitoring, throughout the mission of the spacecraft subsystems and payloads configuration up to all reconfigurable elements.

b. The precision, range and time resolution of any telemetry channel shall be consistent with requirements on tolerances on the parameter to be monitored.

c. All mainbus load currents shall be monitored by telemetry, to allow together with the bus voltage telemetry a complete monitoring of a mainbus power load.

4.2 Design requirements

4.2.1 Failure containment and redundancy

a. A single failure shall not propagate outside a single reconfigurable element.

b. Redundant functions shall be routed separately, preferably via redundant harness and physically separated connectors.

c. Redundant functions shall be physically separated and thermally decoupled, as a minimum, in a different package (e.g. PCB, Hybrid and Integrated Circuit), to avoid failure propagation.

d. For multi cavity hybrids, redundant/protection functions shall be located in a different cavity.

e. Any equipment dissipating more than 20 W in nominal or failure condition shall include a temperature monitoring capability.

f. In case of signal cross-strapping, no failure of either interface circuit shall propagate to the other one.

g. Essential functions are those functions without which:

- the satellite operator cannot recover the spacecraft, following any conceivable on-board or ground-based failure;
- the spacecraft cannot be commanded;
- the satellite permanently loses attitude and orbit control;
- the satellite consumables (e.g. fuel and energy) are depleted to such an extent that more than 10 % of the satellite lifetime is affected;
- the safety of crew is threatened.

Equipments providing essential functions shall not rely on other functions (e.g. synchronization and auxiliary supply) which are centrally generated: any such equipment shall be capable of operating independently of any external synchronization and auxiliary power supply.

h. All units that need to be powered during launch shall be designed for critical pressure and this shall be verified by test.

4.2.2 Data processing

All operational and scientific data require processing for acquisition, algorithm application, transmission and storage. Data processing includes the man machine interface, if any.

The data processing system shall include all hardware and software elements used for that purpose (e.g. microprocessor and its instruction set, interface means, data busses and remote terminals).

a. The architectural design shall be chosen in accordance with the recommendations of ECSS-E-50.

b. All elements shall conform to proven standards as defined in ECSS-E-50.

c. All processors shall have a minimum 50 % margin in memory size and load factor at PDR (Preliminary Design Review), taking into account the projected peak demand. This margin requirement does not apply to dedicated state machines where the bounds are precisely known.

The margin shall be periodically reviewed during project development.

d. System data busses and individual interfaces shall meet the peak demands with a margin of 50 %. This peak demand and the margin shall be periodically reviewed during the project development.

e. Reset or data corruption of functional chain at equipment level shall be kept to a rate of occurrence less or equal to 10^{-4} per day for worst case conditions of environment.

4.2.3 Electrical connectors

a. All connectors carrying source power shall be female type.

b. All test connectors on a unit shall be female type.

c. The use of a connector saver for ground testing shall in no way alter the performance of the equipment.

d. Connectors or routing of harness shall be designed to avoid inadvertent connection of wrong equipment. This should be done by using keyed connectors and adequate positioning of connectors. Where design considerations require connectors of similar configuration in close proximity, proper keying or marking shall prevent erroneous mating.

e. If the equipment has several connectors, visibility and clearance around each of them shall be such as to allow mating or demating without disturbing others already in place or necessitate special custom-made tooling. Possible insertion of a breakout box for trouble shooting should be considered.

f. Single wire and connector, externally or internally to a unit shall not be used to exchange mission-critical signals. Mission-critical assemblies shall use physically separated connectors and boards.

g. For pyrotechnics supplies and signals, specific requirements as per subclause 4.6 of this standard shall be applied. Otherwise, as a rule, different connectors shall be used for power and signals. When this is not feasible, as a minimum, power, and signals and telemetry shall be separated in the connector by a set of unused pins in order to avoid failure propagation.

h. Spare contacts or sockets shall be available on each connector and should be easily accessible.

i. At least one contact per connector shall be connected to the unit structure to connect shields via conducting backshells of connectors.

j. Each signal and its corresponding return shall, wherever feasible, be located on adjacent contacts.

4.2.4 Testing

a. Test/stimulus points shall be accessible without the need to modify the electrical configuration of an item of equipment and shall be suitably protected for flight operation.

b. Dedicated test connectors shall be used.

c. It shall be possible to test the redundant function of a closed unit.

d. Test points on equipment shall be protected against damage up to the maximum system voltage and unintentional connections of these points to ground should not influence the nominal operation of the equipment.

e. Unused stimulus points on equipment and payload shall not provoke unwanted operation.

f. Each protection circuit and each hot redundant function shall be testable on ground at system level.

4.2.5 Mechanical requirements

The mechanical design of electrical or optical equipment shall conform to ECSS-E-30.

4.2.6 Thermal requirements

The thermal design of electrical or optical equipment shall conform to ECSS-E-30.

4.2.7 Dependability requirements

a. Dependability analyses shall be performed according to ECSS-Q-30.

b. Electrical parts shall be derated according to ECSS-Q-60-11.

c. Each item shall be directly interchangeable in form, fit, and function with other equipment of the same part number and of the same qualification status. The performance characteristics and dimensions of the units shall be sufficiently uniform to permit equipment interchange without unforeseen adjustments and recalibration.

d. When components operating in a single event (e.g. fuses) are used, 4 times the needed quantity for flight units shall be procured as one lot: 25 % for the lot acceptance test, 25 % for flight use, 25 % for spares and the remaining 25 % for a confirmation test near to the launch date. For large quantities, the number of extra necessary components implied by this requirement may be reduced.

4.3 Safety

Equipment shall be designed to eliminate potential hazards to the maximum extent. Practical hazards which cannot be eliminated by design shall be controlled in accordance with the provisions in ECSS-Q-40.

4.4 Preparation for delivery

Packaging, marking and labelling shall conform to ECSS-Q-20.

4.5 Parts, materials and processes

a. The requirements of ECSS-Q-60 shall apply for EEE parts.

b. Printed circuit boards shall be repaired or modified according to ECSS-Q-70-28.

c. The requirements of ECSS-Q-70 shall apply for materials, mechanical parts and processes.

d. Radiation sensitivity of components shall be dealt with as defined in ECSS-Q-60.

e. Each equipment shall be marked or labelled according to requirement of ECSS-M-40.

4.6 Specific requirements on pyrotechnics

Specific electrical engineering requirements applying for pyrotechnics shall conform to ECSS-E-30 Part 2-6 “Pyrotechnics”.

4.7 Verification

The general requirements shall be verified and the verification method selected as per 4.6 of ECSS-E-10A. The corresponding verification tasks are specified in 5.6 of ECSS-E-10A.

a. Requirements of 4.1.1, 4.1.2 and 4.1.3 shall be verified by analysis and test.

b. Requirements of 4.2.1 shall be verified by analysis and also by test for 4.2.1 h.

c. Requirements of 4.2.2 shall be verified by analysis and test for c. and d.

d. Requirements of 4.2.3 and 4.2.4 shall be verified by analysis and by test for 4.2.4 c., d., e. and f.

e. Requirements of 4.2.5, 4.2.6, 4.2.7, 4.3, 4.4 and 4.5 shall be verified by analysis, or inspected as appropriate.

f. Requirements of 4.6 shall be verified by analysis and test.

(This page is intentionally left blank)

5

Electrical power

5.1 Functional description

Electrical power is used by all active spacecraft systems and equipment for their operation. Electrical power engineering includes power generation, energy storage, conditioning, line protection and distribution as well as high voltage engineering.

5.2 Power requirements and budgets

In conformity with ECSS-E-10A 4.2.8 and 4.5.1.3, budgets and margins shall be established and are requested by the following requirements.

Budgets shall be established as a task of phase B as requested in 5.5 of ECSS-E-10A and reviewed in all subsequent phases of the project.

a. The power subsystem of a spacecraft comprising the hardware and software used to generate, store, condition and distribute electrical power, as required by the satellite loads and quantified in the budgets, shall perform this function throughout all mission phases in the presence of all environments actually encountered.

b. The first engineering process required is an analysis of the power profile in the systems and the payload for all phases of the mission.

   The next engineering process required is an analysis of the energy demand in all phases of the missions, taking into account inrush and peak-power demands, eclipses, solar aspect angle or depointing.

   Resulting from the engineering processes described above, a power budget based on the peak power values and an energy budget based on the average power values shall be established, maintained and periodically reviewed during all project phases.

   These budgets shall take into account

   - spacecraft-sun distance,
   - sun and eclipse durations,
   - solar aspect angle,
   - pointing accuracy,
   - environmental temperature and degradation effects, and
   - reliability and safety aspects.

c. A system margin of no less than 5 % at launch on available power and energy shall be included in the budgets. As a minimum, these margins shall be available with one solar array string failed and one battery cell failed at the end of the designed life of the power system.

5.3 Failure containment and redundancy

a. Any protection feature supporting essential functions in converters or regulators shall not be implemented in the same hybrid package or integrated circuit nor utilize common references or auxiliary supply.

b. With the exception of protection features such as overvoltage, overcurrent and undefined start-up conditions which are usually backed-up by functional redundancy at equipment level, provision shall be made to override all other automatic protection features which can compromise the mission when failing.

c. Recovery of primary power shall be possible in any condition, even in case of loss of secondary power.

5.4 Energy generation

In the following, the notions of Beginning-of-Life (BOL) and End-of-Life (EOL) are used to define some requirements.

5.4.1 Solar cell requirements

a. The solar cell type shall be qualified according to an agreed specification. The specification test plan shall verify the solar cell performance requirements when submitted to the following environmental tests and measurements:

- visual inspection;
- dimensions and weight;
- electrical performance;
- temperature coefficients;
- spectral response;
- thermo-optical data;
- thermal cycling;
- humidity and temperature;
- anti-reflection coating and contacts adherence;
- interconnectors adherence;
- contact uniformity;
- electron or proton irradiation (EOL performance);
- photon irradiation;
- coverglass surface conductivity (if applicable);
- reverse I–V characteristics;
- active Germanium interface (if applicable).

5.4.2 Solar array

a. The solar array shall satisfy each average power demand (including battery recharge power) during operational life in sunlight with one string failed. In case of an unregulated bus, adequate provision shall be made for recovery from lock-up.

b. The solar array shall be divided into sections. Each solar array section shall be controlled by its own solar array regulator circuit.

c. Provision shall be made against possible failure propagation in case of failure of a solar array section and its connection to the power system.

d. The qualified derated current capability of slip ring contacts shall be greater than the best case BOL solar array section current in short circuit and take into account transient currents caused by the discharge of the solar array section capacitance.

e. The solar array design shall take into account charging phenomena and minimize or eliminate the energy storage due to differential charging. Charging phenomena shall not affect the performance or damage the solar array.

f. As a rule, solar array conductive structure shall not be bonded. Means shall be implemented to prevent electrostatic charging. If bleeding resistors are used to effect this, a value of no less than 10 kΩ shall be used.

5.4.3 Solar array power

The solar array power output evaluation shall take into account

- I-V characteristics at the beginning and the EOL;
- operating versus maximum power point;
- blocking diodes forward voltage at operating current and lowest temperature;
- BOL (i.e. calibration, seasonal effect, standard cell) and EOL (including life and radiation) loss factor;
- distribution resistance (including e.g. wiring, connectors and slip rings);
- shadowing and hot spot phenomena;
- no loss of power in case of a short between a string and the frame; and
- no loss of more than the equivalent power of two strings in case of two shorts on the same panel.

5.5 Energy storage

The depth of discharge (DOD) of a battery is defined as the ampere-hour removed from an initially fully charged battery expressed as a percentage of the nameplate capacity.

The recharge ratio or k factor (k) is defined as the ampere-hours charged divided by the ampere-hours previously discharged.

For the purpose of this subclause, a battery is defined as a number of cells in a common mechanical and thermal housing. Such a battery can be connected to other ones in parallel to increase ampere-hour capability or in series to increase battery voltage.

Subclauses 5.5.1 to 5.5.4 shall apply principally to rechargeable batteries but also to primary batteries where reference is not made to charge. Subclause 5.5.5 defines additional safety requirements for lithium primary batteries.

The requirements below are derived from the most demanding application of batteries (i.e. the main spacecraft power bus batteries) and may be tailored with proper justification for batteries supplying specific payload equipments.

5.5.1 Battery requirements

a. Batteries shall be designed to support the spacecraft through the launch sequence, including all anticipated contingencies and through all foreseen losses of solar energy during the mission, including those resulting from failures (e.g. depointing due to loss of pointing sensors, attitude control).

b. Where system requirements dictate that a battery shall tolerate a single fault, that battery shall be designed to operate with one cell either failed shorted or open circuit. With the exception of Ni-Cd batteries for which a cell open circuit failure may be considered non-credible, each cell shall be equipped with means to bypass it in case of failure. The probability of the bypass circuit untimely operation should be lower than the probability of an open circuit failure of the cell. If the bypass operation is not instantaneous, the power system design shall take into account the transient situation.

c. Cells making-up a battery shall be selected (matched) in accordance with the manufacturer's recommendations. When multiple batteries are connected in series or in parallel, matching requirements shall extend to these multiple batteries. Sufficient extra matched spare cells shall be procured to allow for replacement of any cells damaged during integration of batteries.

d. If batteries are connected or discharged in parallel, the current sharing shall be taken into account in the sizing of the batteries.

e. Battery inter-cell power connections shall be designed to minimize the series inductance and the magnetic moment.

f. Battery cells in a battery package having a metallic case shall be electrically isolated from each other and the battery structure by more than 1 MΩ (measured at 500 V DC). In such cases double isolation shall be applied between battery cells and battery structure.

g. The battery design shall include the following provisions for interfacing with the ground support equipment during pre-launch operations:

- signal lines for monitoring battery voltage, battery temperature and individual cell or cell group voltages;
- capability to charge or discharge the battery;
- capability to place a resistor or a shorting plug across each cell.

h. A logbook shall be maintained for each flight battery starting with the first activation after battery assembly up to launch. It shall detail chronologically all test sequences, summary of observations, identification of related computer-based records, malfunctions, names of responsible test personnel and references to test procedures.

The logbook shall be used for the following purposes:

- to ensure compliance with storage, handling and operational requirements before launch (e.g maximum time allowed at upper temperature limits, correct scheduling of maintenance activities);
- to allow verification of flight worthiness.

i. Battery thermal design shall take into account the following (including any single cell failure if single fault tolerance is required):

- maximum and minimum temperature of cell operation under intended cycling conditions;
- maximum allowed temperature gradients between different parts of the same cell and between two cells in a battery;
- instantaneous heat generated in cells and protection devices during all phases of the mission;
- recommendations from the manufacturer for the temperature and temperature gradients values to be applied shall be followed.

j. If batteries are connected in parallel or in series, the maximum temperature difference between all corresponding locations in the batteries shall be limited according to manufacturers recommendations. From experience, 3 °C has been used for NI-Cd batteries in parallel and 5 °C should be used for $Ni\text{-}H_2$ batteries in series.

k. In addition to the equipment level mechanical requirements imposed by the launch and other mission phases, the battery mechanical design shall take into account the following:

- maximum and minimum pressure values that can occur within cells under worst case conditions during ground operations and mission;

- manufacturer's recommendations for cell stress limits;
- possible fatigue due to stress cycles accompanying electrical cycling.

5.5.2 Battery charge and discharge management

a. The charging technique shall be designed to ensure that the batteries are adequately recharged without excessive overcharge under all mission phases. Effects of ageing on cell characteristics shall be accommodated (as well as the case of the single cell failure, if applicable).

When taper charging is employed, the voltage limit above which taper charging begins should be automatically adjusted to take into account cell temperature. In order to avoid excessive overcharge, either an additional recharge ratio limit shall be implemented or selectable multiple temperature-compensated voltage limits shall be available.

b. The charging technique shall be such as to ensure that the recharge ratio applied is appropriate for the particular cell technology, temperature of operation and cycle life requirements.

c. The charging technique shall ensure that the maximum allowed charge current recommended by the cell manufacturer is never exceeded and that any safety or lifetime related maximum cell voltage limit is respected.

d. The end of charge control shall be one fault tolerant.

e. Protection shall be provided at cell, battery or subsystem level to ensure that no cell violates any safety or lifetime related minimum voltage or maximum discharge current.

5.5.3 Battery cell requirements

a. The considerations leading to the choice of a battery technology to be used and the DOD to be applied shall include the following:

- cycle life requirement;
- availability of flight/test data;
- reliability requirements;
- battery mass constraints;
- launch and operational environment;
- possible magnetic cleanliness requirements;
- specific technology dependant characteristics such as the memory effect for Ni-Cd.

b. The ability of a cell to meet mission lifetime requirements, where not covered by qualification life testing or previous in flight experience, shall be justified by reference to relevant ground test data or by dedicated tests under representative conditions.

c. Any intended cell operation under acceleration greater than 1 G for prolonged periods (e.g. battery aboard a spin stabilized spacecraft) shall take into account possible effects upon both short term (e.g. capacity) performance and lifetime.

d. Safety requirements related to pressure vessels shall conform to ECSS-E-30 taking into account the appropriate safety requirements of ECSS-Q-40.

5.5.4 Battery use and storage

a. The design of the spacecraft shall allow for removal and replacement of batteries at any time prior to launch without affecting the acceptance status of the rest of the spacecraft.

b. After prolonged storage, cells and batteries shall be brought slowly to the ambient temperature. Low rate conditioning cycles according to manufacturer's specifications shall be performed to obtain nominal performance.

c. For the procurement of cells and batteries the procurer shall agree on precise storage and reactivation requirements as a minimum on:

   - maximum ground storage life (where applicable before and after activation);
   - maximum period of non-use without special "wake-up" cycling;
   - maximum battery temperatures and durations during pre-launch and operational phases;
   - battery maintenance during integration and pre-launch phases including case of launch delay;
   - storage procedure, storage temperature, cells discharge requirements,
   - humidity and packaging for storage;
   - reactivation procedure after storage;
   - storage procedure, storage temperature, state of charge, whether or not cells shall be individually shorted, details of any trickle charge or periodic maintenance.

   An agreement describing all these requirements shall be signed by both procurer and manufacturer.

d. Whenever possible, flight batteries shall not be used for ground operations to prevent any possible damage and subsequent degradation of life performance.

5.5.5 Battery safety requirements

Almost all battery technologies used aboard spacecraft can be hazardous if not properly managed. Most are capable of delivering very high currents when shorted. When abused, cells can develop excessive internal pressure and eventually vent their contents, in extreme cases explosively. The electrolyte, cell reactants, and/or reaction products expelled can be corrosive (e.g. alkaline cells, lithium-SO_2, Lithium $SOCl_2$), flammable (e.g. lithium cell organic electrolytes) or toxic endangering any nearby personnel as well as neighbouring equipment. The principal cell failure modes which can lead to these effects are listed below:

- overtemperature (from battery thermal dissipation or environmental heating);
- excessive currents (discharge or charge) including short-circuit (external or internal to the battery);
- overcharging (in the case of primary cells, attempting to charge);
- overdischarge (including cell reversal);
- cell leakage (gases or electrolyte).

Detailed descriptions of the hazards associated with different battery chemistry are given in reference document: NASA Aerospace Battery Safety Handbook, G. Halpert, S. Subbarao & J. Rowlette, JPL Publication 86-14.

The design rules in earlier sections which aim at maximizing battery performance and cycle life also reduce the possibility that cells and batteries will exhibit failure modes such as those listed above. However, in applying the safety rules of ECSS-Q-40, some battery failure modes can be found to be critical or catastrophic and further design or management provisions shall be implemented to achieve the required level of fault tolerance.

To avoid late discovery of battery safety issues the following shall be addressed at the battery selection and design phases:

a. All potential failure modes including those listed above and their possible consequences to personnel and equipment shall be specifically addressed.

b. The design of the battery and associated monitoring and control electronics shall, as far as is feasible, preclude the occurrence of any of the above. Where this is not feasible, the design shall mitigate the damaging effects of any such failure mode (e.g. containment of cell leakage at battery level).

c. The possibility of the failure of one or more cells within a battery due to imbalance in the state of charge, temperature or other parameter between cells shall be taken into account.

5.6 Power conditioning and control

The requirements in 5.6.1 and 5.6.2 apply to power subsystems and those in 5.6.3 and 5.6.4 apply both to power subsystems and payloads.

5.6.1 Spacecraft bus

a. No single point failure shall result in the loss of the power system capability to the extent that the minimum mission requirements, in any of its phases, cannot be fulfilled.

b. For manned missions, the above requirement is extended to two failures tolerance.

c. No single point failure in the spacecraft, including for instance failure of wiring and connectors, shall open or short a main electrical power bus or cause any overvoltage.

d. The design shall ensure that under all conditions during the required lifetime, including operation in eclipse with one battery cell open or shorted and one solar array string failed, that the main bus voltage shall remain within nominal tolerances.

In order to maximize the reuse of equipment, bus voltage types should be standardized.

For fully regulated buses, i.e. providing power day and night with a constant bus voltage, the following standard should be applied:

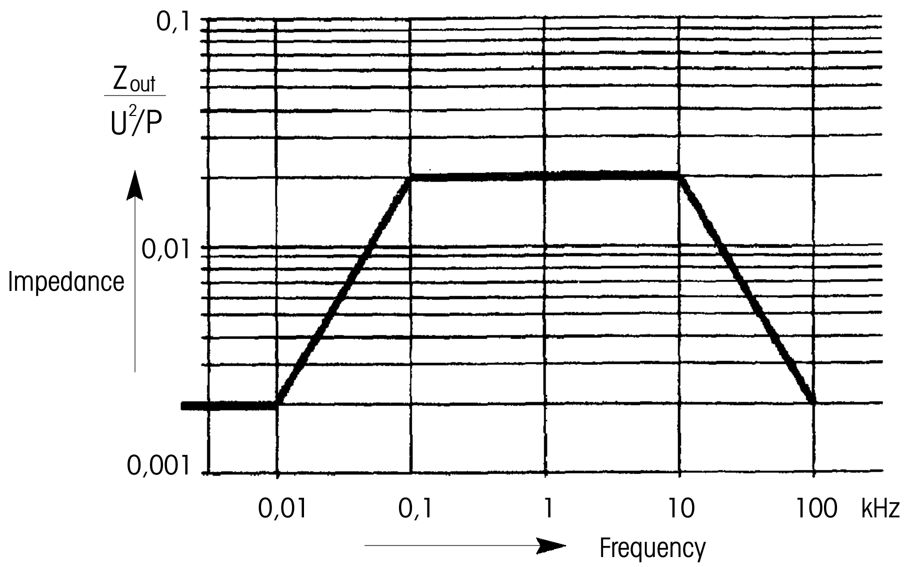
- 28 V for power up to 1,5 kW;
- 50 V for power up to 8 kW;
- 100 V and 120 V for higher power.

e. A fully regulated bus shall keep its nominal value in steady state of the main regulation point within ± 0,5 %. For load transients of up to 50 % of the nominal load, bus transients shall not exceed 1 % and the bus voltage shall remain within 5 % of its nominal value during all source transients and load transients in nominal operation. In case of fuse blowing, the recovery from the fuse clearance shall not produce an overshoot of more than 5 % above the nominal bus value.

f. A fully regulated bus shall have a nominal ripple voltage below 0,5 % peak-to-peak of the nominal bus voltage.

g. A fully regulated bus shall have commutation voltage spikes in the time domain of less than 2 % peak-to-peak of the nominal bus voltage. (Measured with an analog oscilloscope of 50 MHz minimum bandwidth or a digital oscilloscope offering equal or better performance).

h. At the point of regulation, the impedance mask of a fully regulated bus, operating with one source (e.g. battery, solar array) shall be below the impedance mask shown in Figure 1.



U = Nominal regulated output voltage (Volt)
P = Power capability (Watt)

Figure 1: Output impedance mask (Ohm)

i. For unregulated buses, the bus designer shall specify to the user the following parameters:

- maximum and minimum bus voltage guaranteed at payload level in all steady state and transients conditions;
- maximum ripple in time domain;
- maximum spikes in time domain around bus voltage current value (*);
- impedance mask.

(*) measured with an analog oscilloscope of 50 MHz minimum bandwidth or a digital oscilloscope offering equal or better performance)

5.6.2 Bus under/overvoltage

a. All non-essential loads shall be switched off automatically in the case of a bus or battery undervoltage of more than 10 % below minimal range value for a duration of more than 50 ms.

b. The spacecraft design shall be such that in the event of an undervoltage condition on the bus, no failure is induced in the power system or the loads during and when recovering from this undervoltage. After recovery, all essential loads shall be supplied nominally and all non-essential loads shall be in a known and safe configuration.

5.6.3 Power converters/regulators

a. The phase margin of converters and regulators shall be at least 50° and their gain margin 10 dB for worst case end-of-life conditions. This shall be verified by a stability analysis and test. For converters of the power system (solar array regulators, battery chargers and dischargers) the phase margin should be at least 60°.

b. The electrical zero-volt reference of isolated converters/regulators shall be isolated from the unit case by more than 1 kΩ. For satellites with stringent magnetic field requirements, this resistance shall be increased to 20 kΩ.

c. The capacitance between the zero-volt reference of isolated converters/regulators and the unit case shall be less than 50 nF.

d. If a switching converter is externally synchronized, it shall remain in nominal operation for any increase or decrease of synchronizing frequency, intermediate amplitude of synchronizing signal or phase jumps of this signal.

e. Under the occurrence of any single failure, the conducted emission shall not overpass the specified limit by more than 6 dB.

5.6.4 Payload interaction

a. All load requirements shall be verified by test.

b. No load shall generate a spurious response that can damage other equipment or otherwise be detrimental to the satellite operation during bus voltage variation, either up or down, at any ramp rate, and over the full range from zero to maximum bus voltage.

5.7 Power distribution and protection

5.7.1 General

a. The primary power source shall be grounded to the spacecraft structure at the star reference point with a low impedance able to sustain without degradation the worst case fault current.

b. All otherwise non-protected sections of a main bus distribution system shall be protected as a minimum by double isolation up to the first protection device (fuse, current breaker or current limiter). The double isolation assessment shall include harness, connector, wiring and PCB as relevant.

c. All load paths shall include protection circuitry as near as possible to source.

d. If fuses are used to protect main bus distribution lines, their rating shall be 4 times the maximum current in the load path, including transient (e.g. inrush) and it shall be verified by analysis that the power source can supply at least 4 times more current than the maximum fuse value.

e. If fuses are used to protect main bus distribution lines, they shall be accessible and replaceable up to and including the final integration of the spacecraft.

f. Power distribution from a regulated bus voltage shall ensure a minimum voltage at load level of nominal bus voltage minus 2 %, or 1 V, whichever is greater.

g. For a fully regulated bus, the integrated inrush surge current when switching a load shall be such that the bus voltage remains within $\pm$ 2 % of its nominal value.

h. If fuses are used to protect main bus distribution lines, the design shall ensure that the power generation system can fuse them in case of load short circuit within less than 50 ms.

i. Relays shall be protected such that the peak voltage across the contacts at switch-off does not exceed 1,1 $\times$ bus voltage.

j. Equipment connected to independent, redundant power buses shall ensure that no single failure causes the loss of more than one power bus. For manned missions a minimum of two fault tolerance designs shall be used.

k. All current limiting devices and automatic switch off circuits shall be monitored by telemetry. The failure of the monitoring function shall not cause the protection elements to fail.

l. All protection elements shall be designed such that they can be tested at equipment and subsystem level.

5.7.2 Harness

a. No piece of harness shall be used as a mechanical support.

b. For transmission of power, each line shall be twisted with its return to minimize current loop area and harness inductance. In case a return through structure is used, power cables shall be routed near ground plane to minimize current loop and loop inductance.

c. The power distribution shall be protected in such a way that no overcurrent in a distribution wire can provoke failure propagation to another wire.

d. The harness inductance for a fully regulated bus, from the distribution node of the regulated bus to the load, shall be such that the break frequency is at least 5 000 Hz, i.e.:

$$L < R/2\pi f$$

where:

L	harness inductance in H
R	harness resistance in Ω
f	break frequency in Hz

5.8 Safety

The design of electrical systems and payloads shall take into account safety aspects as documented in IEC 60479:1994 “Effects of current on human beings and livestock”.

5.9 High voltage engineering

A high voltage is defined as a voltage at which partial discharges or corona effects can occur.

In practice, this concerns voltages of the order of 200 V and above.

a. High voltage equipments shall be designed and manufactured taking into account the potential discharge phenomena according to Paschen curves in the environment encountered in flight.

b. The design of high voltage equipment shall be such that worst case DC and AC field strengths are less than half of the values for which breakdown can occur.

c. The field enhancement factors shall be controlled by the design. This applies in particular to the routing of high voltage cables.

d. For high voltage equipment design and testing, vacuum shall be understood as 10 Pa and below.

e. For potted circuits, the glass transition point of the potting material shall be outside the temperature range of qualification.

f. The minimum bend radius for high voltage cables shall respect the manufacturer’s recommendation.

5.10 Verification

The requirements on electrical power shall be verified and the verification method shall be selected as per 4.6 of ECSS-E-10A. The corresponding verification tasks are specified in 5.6 of ECSS-E-10A.

a. Requirement 5.2 c. shall be reviewed and verified by analysis at each stage of the project and by test in phase D.

b. Requirements of 5.3 shall be verified by analysis and test.

c. Requirements of 5.4 shall be verified by analysis, and for 5.4.1 a. according to required test plan.

d. Requirements of 5.5 shall be verified by analysis, and tests for 5.5.1 c., f., and logbook verification for 5.5.1 h.

e. Requirements of 5.5.2 shall be verified by analysis, and test for 5.5.2 c. and d.

f. Requirements of 5.5.3 shall be verified by analysis.

g. Requirements of 5.5.4 shall be verified by analysis, and verification of 5.5.4 c. procurer/supplier agreement.

h. Requirements of 5.5.5 shall be verified by analysis.

i. Requirements of 5.6 shall be verified by analysis or test, as appropriate.

j. Requirements of 5.7 shall be verified by analysis and test.

k. Requirement 5.8 shall be verified by analysis.

l. Requirements of 5.9 shall be verified by analysis.

(This page is intentionally left blank)

6
Electromagnetic Compatibility (EMC)

6.1 Policy

The spacecraft shall be designed to achieve electromagnetic compatibility (EMC) between all equipment and subsystems within the spacecraft and in the presence of its self-induced and external electromagnetic environment.

6.1.1 System level EMC Programme

The customer and supplier shall establish an overall EMC Programme. The purpose of the EMC Programme is to provide for spacecraft-level compatibility with minimum impact to programme cost, schedule and operational capabilities. The role of the customer in the EMC Programme shall be that of top-level oversight.

The EMC Programme shall accomplish the following goals:

a. Ensure that requirements of this standard are met.

b. Plan and verify that proper technical criteria, necessary design and management controls are in place to achieve EMC in an efficient manner. This shall be performed within the context of the EMC Control Plan (see DRD in annex A).

c. Plan and accomplish verification of spacecraft-level EMC. This shall be documented in the EMC Test and Verification Plan and Reports (see DRDs in annex B and C).

The EMC Programme shall be based on requirements of this standard, the statement of work, spacecraft specification, and other applicable contractual documents.

6.1.2 EMC Control Plan

The EMC Programme shall be documented in the EMC Control Plan. The Control Plan initial release documents procedures of the EMC Programme including basic design guidelines, while subsequent routine updates document programme progress. Contents of the EMC Control Plan shall be as defined in its DRD.

6.1.3 Electromagnetic Interference Safety Margin (EMISM)

Electromagnetic interference safety margins shall be mandatory and shall be determined for critical signals, pyrotechnics, and power circuits under all operating conditions. The minimum acceptable safety margins shall be 6 dB for power and signal circuits and 20 dB for pyrotechnic circuits. The susceptibility threshold shall be determined at the subsystem, equipment, or component level. A list of known and defined critical test points shall be submitted in the appropriate test plan.

6.2 General

6.2.1 Electromagnetic Interference (EMI) control

EMI characteristics (emission and susceptibility) shall be controlled to the extent necessary to ensure intra-system EMC, and compatibility with the predicted external electromagnetic environment.

6.2.2 Antenna-to-antenna (RF) compatibility

Spacecraft shall exhibit RF compatibility among all antenna-connected equipments/subsystems, subject to mission requirements. This requirement shall also be applicable on an inter-system basis, when an inter-system interface is required. The RF compatibility analysis, if used in lieu of test, shall include the effects of intermodulation products.

6.2.3 Electrical bonding

a. Electrical bonding measures shall be implemented for management of electrical current paths and control of voltage potentials to ensure required spacecraft performance and to protect both personnel and platform. Bonding provisions shall be compatible with other requirements imposed on the spacecraft for corrosion control.

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

c. All electronic and electrical items whose performance can be degraded or which can degrade the operation of the other electronic or electrical items due to the effects of electromagnetic energy shall be bonded to the ground subsystem with an overall bond DC resistance of 10 mΩ or less for metallic interfaces. Individual bond straps or connections shall have a DC resistance of less than 2,5 mΩ. For composite materials, bonding shall be accomplished at impedance levels consistent with the materials in use.

d. Isolated conducting items subject to energetic electrons and plasma or frictional charging shall be bonded to the spacecraft ground subsystem to prevent a differential build-up of charge that can result in an electrostatic discharge, unless it is shown that no hazard exists.

6.2.4 Grounding and wiring design

A controlled ground reference concept shall be defined for the spacecraft prior to initial release of the EMC control plan. Power, signal returns and references shall be considered. Impedance magnitudes over the affected signal spectrum shall be taken into account when determining which kinds of power and signals share common paths (wire or structure).

6.3 Spacecraft charging protection programme

6.3.1 General

The supplier's spacecraft charging protection programme shall include:

- the preparation and maintenance of an analysis plan, and
- the preparation and maintenance of a test plan.

The object of the programme shall ensure that the space vehicle is capable of operating in the specified space plasma charging environment and its energetic electron content without degradation of the specified space vehicle capability and reliability and without changes in operational modes, location, or orientation. The performance shall be accomplished without the benefit of external control such as commands from a ground station. The spacecraft charging protection programme, the analysis plan, and the test plan shall be subject to approval by the customer.

The spacecraft charging protection programme shall, in addition to surface electrostatic charging, explicitly treat the threat from internal electrostatic charging of dielectric materials and isolated conducting items due to the penetration of energetic electrons as defined in the environmental specification.

6.3.2 Performance

Space vehicle electrical subsystem and system outage shall be permissible during an arc discharge if operation and performance returns to specified levels within a telemetry main frame period after onset of the discharge or within some other period as defined by the customer. A command to the space vehicle from an external source such as a ground station shall not required to be executed if an arc discharge occurs during transmission of the command, provided that an unintended action does not result and that the space vehicle is capable of receiving and executing subsequent commands and meeting specified performance within the time period as defined by the customer. Space plasma-induced electrical transients shall not affect on-board digital data beyond the specified design limits.

6.3.3 Design

The following design requirements shall be implemented to protect against spacecraft charging hazards:

a. All conducting spacecraft vehicle elements shall be tied to an electrical grounding system such that the DC resistance between any two points is less than 0,1 Ω.

b. All thin (<10 μm) conducting surfaces on dielectric materials shall be electrically grounded to the common space vehicle structural ground such that the DC resistance between the surface and the structure is less than 10 Ω DC. The resistance levels of ground and bonds shall be verified by standard ohm meter and bondmeter measurements. The term "thin conducting surfaces" shall include all metallized surfaces of multi-layer insulation (MLI) thermal blankets, metallized dielectric materials in form of sheets, strips, tapes, or tiles, conductive coatings, conductive paints, conductive adhesives, and metallic grids or meshes.

c. All electronic cables shall be provided with EMI shielding to attenuate radiated fields from discharges (100 kHz to 1 GHz) by at least 40 dB. Attenuation levels of radiated fields shall be verified by standard measurement techniques or by analysis for representative locations internal to shielding enclosures. The method of verification shall be subject to approval by the customer. The shielding may be provided by the basic space vehicle structure designed as a "Faraday cage" with a minimum of openings or penetrations, by enclosures of electronics boxes, by separate cable shielding, or by combinations of the preceding shields. Electronics units and cables external to the basic space vehicle structure shall have individual shields providing 40 dB attenuation to EMI.

d. Materials used in the space vehicle design shall be selected to minimize absolute and differential surface and internal charging and their subsequent discharge effects in the specified environment while maintaining the specified performance capabilities. Materials used externally or internally should be tested or analysed to determine their charging and discharging characteristics in the specified environment. The method of test or analysis shall be subject to the approval of the customer.

6.4 Verification

6.4.1 General

a. The supplier shall be responsible for verifying that all requirements of this standard have been met. Verification methods shall be subject to customer's approval.

b. To complement the EMC control plan, the supplier shall prepare a system-level Electromagnetic Effects Verification Plan (EMEVP) which specifies in detail the methodology to be employed for verifying each electromagnetic effects requirement as well as success criteria for each subsystem and equipment. A demonstration of spacecraft level EMC shall be planned in this document. Customer approval of the EMEVP shall precede the start of qualification testing. The content of the EMEVP shall be as defined in its DRD in annex B.

c. The supplier shall prepare an Electromagnetic Effects Verification Report (EMEVR) as a complement to the EMC control plan. The EMEVR shall provide documentation demonstrating that each requirement of this standard has been met. The content of the EMEVR shall be as defined in its DRD in annex C.

6.4.2 Intra-system electromagnetic compatibility

A verification matrix shall be established within the EMEVP. This matrix shall show all combinations of individual equipment/subsystems which shall be tested in order to verify overall intra-system compatibility. Step-by-step test procedures for operation of all matrix equipment shall be included in the EMEVP to support test execution. Special support equipment shall be available to exercise culprits and victims, and detailed support equipment instructions shall be included. Each item of equipment and subsystem shall meet the requirements of its functional acceptance test procedure as installed on the platform, prior to system level EMC test.

6.4.3 Safety margin demonstration for critical or EED circuit

Safety margins shall be demonstrated at system-level. If done by test, the spacecraft suite of equipment and subsystems shall be operated in a manner simulating actual operations.

Monitored circuits shall either be instrumented for direct measurement of induced noise, or activating signal to noise ratio shall be reduced by the safety margin factor, whichever is technically correct and practical to implement.

Safety margin demonstration for a time domain circuit (includes EEDs and all non-tunable electronics) shall use time domain methods to verify safety margins

6.4.4 Electromagnetic Interference (EMI) control

The system level requirements, imposed in 6.2.1, shall be supported by prior verification of equipment and subsystem performance accordingly.

6.4.5 External electromagnetic environment

The spacecraft shall be exposed, in the best representative way, to those external electromagnetic environments identified in the system specification.

6.4.6 Antenna-to-antenna RF compatibility

An analysis shall be prepared as part of the EMC plan which shall identify risk frequencies. These shall be checked to demonstrate compatible operation. In general, each culprit and victim pair shall be operated in such a manner as to maximize likelihood of interference; subject, however, to the restriction that operating modes are simulations of mission operations. Demonstration that a victim receiver is compatible with the culprit shall consist of the ability to receive an intended signal at its low signal condition. Lack of intermodulation interference shall be verified by a combination of analysis and test.

6.4.7 Electrical bonding

Conformance to electrical bonding requirements shall be verified by test, analysis or inspection as appropriate for the particular bonding provision. Compatibility with corrosion control techniques shall be verified by demonstration that manufacturing processes which address corrosion control had been implemented.

6.4.8 Antenna counterpoise

Bonding of an antenna counterpoise to structure shall be verified through test, analysis, and inspection as appropriate for the particular application.

6.4.9 RF potentials

Verification of milliohm level bonds imposed for RF interference control purposes shall be by special low AC voltage output milliohmmeters. An AC meter shall be used in order to average out galvanic voltages, or if only a DC meter is available, then two measurements shall be made, with the second measurement having ohmmeter probes reversed from the first measurement, and both measurements averaged to determine true bond resistance. If the same bond path is used as a fault return path, it may be tested for that requirement using a high voltage, high current ohmmeter, but only after low voltage, low current measurements have been completed.

6.4.10 Static discharge

a. Bonding of discharge elements, thermal blankets, or metallic items removed from structure and requiring a bond for static potential equalisation shall be verified by test.

b. Immunity to electrostatic discharge shall be verified. Since ESD testing can cause catastrophic failure of the test article (and even more insidiously, latent failures) verification is only possible on engineering or prototype models, not on the flight article.

6.4.11 Spacecraft charging

Adequate control of static charging, plasma/payload induced differential charging/discharges and internal charging effects shall be verified by test, analysis or inspection as appropriate.

(This page is intentionally left blank)

7
Radio frequency systems

7.1 Functional description

Radio frequency (RF) systems include transmitters, receivers, antennas and their associated transmission lines (waveguides) including connectors, operating typically in the range from 30 MHz to 300 GHz. The transmitted or received signals can be narrowband or wideband, often with complex modulation and sometimes with multiple carriers. Transmitters and receivers require high mutual isolation and antennas can interact strongly with the spacecraft.

7.2 General

a. To achieve the RF performance requirements, the engineering processes shall consider the following parameters:
   - antenna field of view and polarization;
   - link or radiometric budget;
   - spatial and spectral resolution;
   - signal to noise ratio;
   - frequency plan.

b. To achieve the performances requirement, the RF design and development shall consider the following parameters:
   - transmitter power;
   - receiver sensitivity;
   - active and passive intermodulation products;
   - multipaction;
   - VSWR;
   - frequency stability;
   - spectral purity;
   - reflection and diffraction effects on antenna performance;
   - mutual coupling between antennas;
   - isolation between transmitter and receiver.

7.3 Antenna

a. Definition of the following antenna terms shall conform to IEEE Standard 145-1993:

- antenna;
- directivity;
- electrical boresight;
- gain;
- impedance mismatch factor;
- radiation pattern;
- radiation pattern cut;
- sense of polarization;
- side lobe;
- axial ratio;
- noise temperature.

b. Standard coordinate for antenna measurement is a right hand coordinate system in accordance with IEEE Standard 149-179.

7.4 Multipaction and gas discharge

a. RF systems shall operate without the presence of multipaction or gas discharge breakdown during all mission phases and ground integration. Equipment switched on during launch phase shall meet this requirement under reduced critical pressure environment.

b. RF systems shall be designed to provide a margin of at least 6 dB between the worst case operational power level and the power level at which multipaction or gas discharge breakdown is initiated.

c. A representative model shall be subjected to a design verification test during which a breakdown margin of at least 3 dB shall be established.

Electron seeding shall be used during the verification test.

If the breakdown margin exceeds 6 dB, the equipment shall be considered qualified in this respect and tests on production equipment shall not be required.

If the breakdown margin is between 3 dB and 6 dB, the design shall be considered satisfactory, but each production article shall be tested to ensure that a margin of at least 3 dB exists.

d. The design and test requirements stated in c. shall apply:

- with waveforms representative of operational use applied to or generated within the equipment;
- taking into account the venting characteristics of hollow structures where RF fields are present.

7.5 Passive intermodulation

a. Passive intermodulation products generated within the system shall conform to the mission specific requirements for acceptable interfering signal levels during all mission phases.

b. Analysis shall be carried out to:

- establish the predicted frequencies and levels of all passive intermodulation products; and
- identify all potential contributors to the system passive intermodulation and apportion requirements to them.

The analysis shall demonstrate a design margin of at least 30 dB between predicted system levels and the acceptable system interference levels.

c. Each production item of the system shall be subjected to a passive intermodulation test, during which a total stimulating power, 3 dB greater than the maximum operating power, shall be applied to the test article:

   - The temperature of the test article should be varied over its qualification temperature range at a representative rate during this test, and a margin of 10 dB shall be demonstrated between the maximum measured passive intermodulation level and the system requirement.
   - If the test can only be performed at a constant temperature, then a margin of at least 20 dB shall be demonstrated.
   - The passive intermodulation level(s) shall be continuously recorded during the test; the maximum passive intermodulation level shall include all short duration transients.
   - At least 10 temperature cycles should be carried out. Continuous monitoring of the first two cycles and of the last cycle should be made.

d. Sufficient inspections and tests shall be carried out on each production item of each contributor to the total system passive intermodulation, to ensure that a high level of confidence in satisfactory system level performance is obtained.

e. The design and test requirements in d. apply

   - in the presence of all specified RF signals, including those generated within and external to the system, and
   - with representative signal waveforms (number of carriers, modulation type).

   If tests are carried out with waveforms different to those specified for operation (e.g. a smaller number of carriers), an analysis, supported by test data, shall be prepared to establish the requirement and margin relationship between the test and the operational conditions.

7.6 Safety

Safety levels of electromagnetic radiation with respect to personnel are defined in IEEE C95.1‐1991.

7.7 Verification

The requirements on radio frequency and microwave shall be verified and the verification method selected as per 4.6 of ECSS‐E‐10A. The corresponding verification tasks are specified in 5.6 of ECSS‐E‐10A.

a. Requirements 7.2 and 7.3 shall be verified by analysis.

b. Requirements 7.4 and 7.5 shall be verified by test.

c. Requirement 7.6 shall be verified by analysis.

(This page is intentionally left blank)

8

Optical systems

8.1 Functional description

Optical systems are traditionally defined as corresponding to the domain of the electromagnetic spectrum visible to the human eye. However, with regard to the observation possibilities offered by the regions of the spectrum on either side of the visible region when operating outside the earth atmosphere, the domain of optics shall be enlarged to a frequency ranging from around $0{,}3 \times 10^{12}$ Hz (in vacuo wavelength of about 1 mm) to 3×10^{18} Hz (in vacuo wavelength of about 1 ångström.)

In the area of optical instrumentation, one can distinguish passive and active systems: passive systems are detection-oriented only whereas active systems include also radiation sources and operate as emitting and usually also receiving systems.

Emitting systems deliver a radiation flux, which can be directional, often with a limited spectrum, either to sound or irradiate a target (lidar) or to transmit a modulated signal (telecommunication).

Sensor instruments are either imaging systems or radiometers analysing the flux features (energy, spectrum, polarization). Sensor instruments can also include a scanning system to enlarge their field of view (FOV) beyond the instantaneous field of view (IFOV). The flux running through the instrument can be modified either by spatial filtering or spectral filtering, modulation or polarization.

Optical devices can also be used for communication (optic fiber) or energy transport.

Optical engineering includes optomechanical technology, electro-optical technology and lasers or a combination of these.

8.2 General requirements

8.2.1 Performance requirements

a. In assessing the imaging and projecting performances of an optical instrument the following parameters shall be taken into account:

- conformance of the paraxial parameters;
- image quality with regard to spatial resolution (expressed through for instance WFE, PSF, MTF, encircled energy)
- aperture imaging quality related to the radiant flux collection and field response;
- distortion, field curvature, depth of focus;
- chromatism;
- straylight;
- pointing and tracking performance;
- radiation damage and radiation induced transients.

b. In assessing the measuring and emitting performances of an optical instrument, the following parameters shall be taken into account:
- overall sensitivity;
- dynamic range and linearity;
- spectral response and out of band rejection;
- radiometric resolution (expressed through detectivity, NEP);
- spectral resolution (expressed through equivalent bandwidth);
- time resolution (e.g. acquisition time frame);
- polarization measurement accuracy and instrumental polarization;
- straylight rejection;
- preflight and In flight calibration;
- radiation damage and radiation induced transients.

8.2.2 Design requirements

a. The design shall take into account the environmental constraints with their potential effects as described in Table 1.

b. In addition to Table 1, the effect of environment on electro-optical components shall be taken into account (e.g. high energy particles on crystal impedance and humidity on high impedance transistors).

c. The design shall take into account the following parameters:
- power consumption;
- thermal regulation;
- use of approved and well characterized materials;
- electrostatic charging;
- structural stability;
- clearance (maximum amplitude of movement or shift of optics).

d. The criticality of the various components of the optical instrument with regard to contamination and cleanliness required shall be reviewed and the following parameters defined:
- CVCM;
- TML;
- need of space conditioning;
- class of clean room to be used.

Table 1: Environmental factors in the design of optical instruments

Load type	Influence on structural parts	Influence on optical elements	Influence on adhesives and optical cements
Thermal loads	• Microcracking • Stress and stress release • Permanent elongation • Thermal expansion • Change of thermal properties • Change of mechanical properties • Embrittlement	• Change of optical properties • Thermal expansion • Change of thermal properties • Change of mechanical properties • Induced birefringence	• Embrittlement • Stress and stress release • Thermal expansion • Change of thermal properties • Change of mechanical properties • Delamination
Mechanical loads	• Stress • Stress correlated cracking • Deformation • Rupture	• Stress • Cracks • Rupture • Induced birefringence	• Stress • Delamination
Radiation loads UV	• Embrittlement • Microcracking	• Solarization • Stress • Cracks • Fluorescence • Darkening	• Embrittlement • Darkening
High energy particles	• Embrittlement • Microcracking	• Solarization • Refractive index change • Dielectric breakdown • Stress • Radioluminescence • Scintillation • Darkening	• Embrittlement • Darkening
Vacuum condition	• Structure reorientation • Cold welding • Sublimation • Outgassing • Moisture release	• Contamination with outgassing products • Air and vacuum index change • Moisture release	• Outgassing • Embrittlement • Moisture release
Atomic oxygen	• Corrosion • Abrasion	• Corrosion • Abrasion	• Abrasion
Micrometeorites and space debris	• Mechanical damage	• Mechanical damage	• Mechanical damage
Spacecraft generated contamination	• Corrosion	• Contamination • Corrosion	• Contamination
Humidity (on-ground)	• Corrosion • Electrolytic corrosion • Moisture absorption	• Surface and coating degradation • Moisture absorption	• Moisture absorption

8.3 Safety

Safety of personnel using optical instruments shall be according to IEC 60825.

8.4 Verification

The requirements on optical systems shall be verified and the verification method selected as per 4.6 of ECSS-E-10A. The corresponding verification tasks are specified in 5.6 of ECSS-E-10A.

a. The performance requirements of 8.2.1 shall be verified by analysis and test.

b. The design requirements of 8.2.2 shall be verified by analysis.

c. The safety requirement of 8.3 shall be verified by analysis.

Annex A (normative)

EMC control plan - Document Requirements Definition (DRD)

A.1 Introduction

This document defines the approach, methods, procedures, resources and organization to design, produce and verify a product to operate within its specified electromagnetic environment and performance characteristics.

A.2 Scope and applicability

A.2.1 Scope

This Document Requirement Definition (DRD) establishes the data content requirements for the EMC control plan.

This DRD does not define format, presentation or delivery requirements for the EMC control plan.

A.2.2 Applicability

This DRD is applicable to all projects using the ECSS Standards.

A.3 References

A.3.1 Glossary and dictionary

This DRD uses terminology and definitions controlled by:

ECSS-P-001	Glossary of terms
ECSS-E-20	Space engineering - Electrical and electronic

A.3.2 Source document

This DRD defines the data requirements of an EMC control plan as controlled by ECSS-E-20.

A.4 Terms, definitions and abbreviated terms

A.4.1 Terms and definitions

For the purposes of this DRD the terms and definitions given in ECSS-P-001 and in ECSS-E-20 apply.

A.4.2 Abbreviated terms

The following abbreviations are used within this DRD.

Abbreviation	**Meaning**
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EED	Electro-Explosive Device
SRD	System Requirement Document

A.5 Description and purpose

The EMC control plan provides the instruction for conducting all activities related to the management, the design requirements and the verification of the electromagnetic compatibility of all items of equipment and subsystems of a project.

A.6 Application and interrelationship

The document shall be prepared for each project, based on the system requirement definition and the applicable electromagnetic specification.

It shall then apply to every item of equipment and subsystem in the project.

A.7 EMC control plan preliminary elements

A.7.1 Title

This document shall be titled "[insert a descriptive modifier, e.g. name of the project] EMC control plan".

A.7.2 Title page

The title page for this document shall identify the project document identification number, title of the document, date of release and release authority.

A.7.3 Contents list

The contents list shall identify the title and location of every clause and major subclause, figure, table and annex contained in the document.

A.7.4 Foreword

A foreword shall be included in the document which describes as many of the following items as are appropriate:

- identification of which organizational entity prepared the document;
- information regarding the approval of the document;
- identification of other organizations that contributed to the preparation of the document;
- a statement of effectivity identifying which other documents are cancelled and replaced in whole or in part;
- a statement of significant technical differences between this document and any previous document;
- the relationship of the document to other standards or documents.

A.7.5 Introduction

An introduction can be included to provide specific information or commentary about the technical content.

A.8 Content

A.8.1 Scope and applicability

This clause shall be numbered 1 and shall describe the scope, applicability and purpose of the EMC control plan

A.8.1.1 Scope

This subclause shall be numbered 1.1 and shall contain the following statements:

> "This EMC control plan defines the instructions for the [insert project identifier] project.
>
> This EMC control plan is based on the requirements of the [insert project SRD identifier]."

A.8.1.2 Purpose

This subclause shall be numbered 1.2 and shall contain the following statement:

> "This EMC control plan defines the EMC programme management, the system level performance and design requirements, the subsystem and equipment EMI performance requirements and verification requirements for electro-explosive devices design and verification, EMC analysis and spacecraft level verification."

A.8.2 References

This clause shall be numbered 2 and shall contain the following subclauses.

A.8.2.1 Normative references

This subclause shall be numbered 2.1 and shall contain the following statements:

> "This document incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at appropriate places in the text and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these apply to this document only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.
>
> [insert document identifier] [insert document title]."
> (Typically the SRD and some EMC standards can be quoted here.)

A.8.2.2 Informative references

This subclause shall be numbered 2.2 and shall contain the following statement:

> "The following documents, although not a part of this EMC control plan, amplify or clarify its contents:
>
> [insert document identifier] [insert document title]"

A.8.3 Terms, definitions and abbreviated terms

This clause shall be numbered 3 and shall contain the following subclauses.

A.8.3.1 Terms and definitions

This subclause shall be numbered 3.1 and shall list any applicable project dictionary or glossary, and all unusual terms or terms with a meaning specific to the EMC control plan, with the definition of each term.

If a project dictionary or glossary is applicable, insert the following sentence:

"The definitions of [insert title and identifier of applicable dictionaries or glossaries] apply to this document."

Insert the following sentence:

"The following terms and definitions are specific to this document:

[insert term] [insert definition]."

A.8.3.2 Abbreviated terms

This subclause shall be numbered 3.2 and shall list all abbreviations used in the EMC control plan with the full spelled-out meaning or phrase for each abbreviation.

A.8.4 Requirements to be verified

This clause shall be numbered 4 and shall list the requirements to be verified in the EMC control plan.

The following list includes areas for which requirements shall be generated in the EMC control plan. This list is not exhaustive.

a. EMC program management:
   - responsibilities of customer and supplier at all levels, lines and protocols of communication, control of design changes;
   - planning of the EMC control program: facilities and personnel required for successful implementation of the EMC control program; methods and procedures of accomplishing EMC design reviews and coordination;
   - program schedules: Integration of EMC program schedule and milestones within the program development master schedule.

b. System level performance and design requirements:
   - definition of electromagnetic and related environments;
   - definition of critical circuits;
   - allocation of design responses at system and subsystem and equipment levels;
   - antenna-to-antenna interference reduction analysis and technique;
   - establishment of a controlled grounding scheme;
   - wiring (including shielding and shield termination and categorization) practises;
   - electrical bonding;
   - material properties, effects of corrosion prevention and similar concerns on bonding and general EMC issues;
   - design criteria for alleviating effects of spacecraft charging and other electrification issues.

c. Subsystem and equipment EMI performance requirements and verification:
   - allocated EMI performance at the equipment level, including tailored equipment level requirements. The control plan shall be the vehicle for tailoring limits and test methods;
   - test results from subsystem and equipment level EMI tests shall be summarized. Any specification non-compliances judged to be acceptable shall be described in detail and the justifying rationale presented.

d. Electro-Explosive Devices (EED):
   - appropriate requirements (ISO 14304 – in preparation);
   - design techniques;
   - verification.

e. EMC analysis:

- predictions of intra-system EMI and EMC based on expected or actual equipment and subsystem EMI characteristics;
- design of solutions for predicted or actual interference situations;

f. Spacecraft level EMC verification:

Outline of system-level EMC test plan, including rationale for selection of critical circuits for safety margin demonstration and instrumentation techniques for both critical and EED circuit sensitization.

(This page is intentionally left blank)

Annex B (normative)

Electromagnetic effects verification plan - Document Requirements Definition (DRD)

B.1 Introduction

This document defines the approach, methods, procedures to verify electromagnetic effects.

B.2 Scope and Applicability

B.2.1 Scope

This Document Requirements Definition (DRD) establishes the data content requirements for the Electromagnetic Effects Verification Plan (EMEVP).

This DRD does not define format, presentation or delivery requirements for the Electromagnetic Effects Verification Plan.

B.2.2 Applicability

This DRD is applicable to all projects using the ECSS Standards.

B.3 References

B.3.1 Glossary and dictionary

This DRD uses terminology and definitions controlled by:

ECSS-P-001	Glossary of terms
ECSS-E-20	Space engineering - Electrical and electronic

B.3.2 Source document

This DRD defines the data requirements of an electromagnetic effects verification plan as controlled by ECSS-E-20.

B.4 Terms, definitions and abbreviated terms

B.4.1 Terms and definitions

For the purposes of this DRD the terms and definitions given in ECSS-P-001 and in ECSS-E-20 apply.

B.4.2 Abbreviated terms

The following abbreviations are used within this DRD.

Abbreviation	Meaning
EMEVP	Electromagnetic Effects Verification Plan
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EED	Electro-Explosive Device

B.5 Description and purpose

The electromagnetic effects verification plan provides the instruction for conducting all activities required to verify that the effects of the electromagnetic environment are compatible with the requirement of the project.

B.6 Application and interrelationship

The document is prepared for each project, based on the system requirement definition and the applicable electromagnetic specification.

It then applies to every item of equipment and subsystem in the project.

B.7 EMEVP preliminary elements

B.7.1 Title

This document shall be titled "[insert a descriptive modifier, e.g. name of the project] electromagnetic effects verification plan".

B.7.2 Title page

The title page for this document shall identify the project document identification number, title of the document, date of release and release authority.

B.7.3 Contents list

The contents list shall identify the title and location of every clause and major subclause, figure, table and annex contained in the document.

B.7.4 Foreword

A foreword shall be included in the document which describes as many of the following items as are appropriate:

- identification of which organizational entity prepared the document;
- information regarding the approval of the document;
- identification of other organizations that contributed to the preparation of the document;
- a statement of effectivity identifying which other documents are cancelled and replaced in whole or in part;
- a statement of significant technical differences between this document and any previous document;
- the relationship of the document to other standards or documents.

B.7.5 Introduction

An introduction can be included to provide specific information or commentary about the technical content.

B.8 Content

B.8.1 Scope and applicability

This clause shall be numbered 1 and shall describe the scope, applicability and purpose of the electromagnetic effects verification plan.

B.8.1.1 Scope

This subclause shall be numbered 1.1 and shall contain the following statements:

"This electromagnetic effects verification plan defines the instructions for the [insert project identifier] project.

This electromagnetic effects verification plan is based on the requirements of the [insert project EMC control plan identifier]."

B.8.1.2 Purpose

This subclause shall be numbered 1.2 and shall contain the following statement:

"This electromagnetic effects verification plan defines the plans to follow to select EMC criteria and limits, all tests conditions including test facilities, personnel, tests set-up, instruments range."

B.8.2 References

This clause shall be numbered 2 and shall contain the following subclauses.

B.8.2.1 Normative references

This subclause shall be numbered 2.1 and shall contain the following statements:

"This document incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at appropriate places in the text and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these apply to this document only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

[insert document identifier] [insert document title]."
(Typically the EMC control plan and some EMC standards can be quoted here.)

B.8.2.2 Informative references

This subclause shall be numbered 2.2 and shall contain the following statement:

"The following documents, although not a part of this electromagnetic effects verification plan, amplify or clarify its contents:

[insert document identifier] [insert document title]

B.8.3 Terms, definitions and abbreviated terms

This clause shall be numbered 3 and shall contain the following subclauses.

B.8.3.1 Terms and definitions

This subclause shall be numbered 3.1 and shall list any applicable project dictionary or glossary, and all unusual terms or terms with a meaning specific to the EMEVP, with the definition of each term.

If a project dictionary or glossary is applicable, insert the following sentence:

"The definitions of [insert title and identifier of applicable dictionaries or glossaries] apply to this document."

Insert the following sentence:

"The following terms and definitions are specific to this document:

[insert term] [insert definition]."

B.8.3.2 Abbreviated terms

This subclause shall be numbered 3.2 and shall list all abbreviations used in the electromagnetic effects verification plan with the full spelled-out meaning or phrase for each abbreviation.

B.8.4 Elements of the plan

This clause shall be numbered 4 and shall list the requirements of the plan. The following list is not exhaustive:

a. methods to be used to select critical circuits, used to monitor conformance to degradation criteria and safety margins, shall have the method of selection defined;

b. procedures used for developing failure criteria and limits;

c. test conditions and procedures for all electronic and electrical equipment installed in or associated with spacecraft and sequence for operations during tests, including switching. An intra-system compatibility culprit/victim test matrix shall be part of the test procedure;

d. implementation and application of test procedures which shall include modes of operation and monitoring points for each subsystem or equipment;

e. use of approved results from laboratory interference tests on subsystems and equipment;

f. methods and procedures for data readout and analysis;

g. means of verifying design adequacy of spacecraft electrification;

h. means of simulating and testing electro-explosive subsystems and devices (EEDs);

i. verifying electrical power quality, and methods for monitoring DC and AC (as applicable) power busses;

j. test locations and descriptions of arrangements for simulating operational performance in cases where actual operation is impractical;

k. configuration of equipment and subsystems modes of operation to ensure victim equipment and subsystems are tested in most sensitive modes, while culprit equipment and subsystems are tested in noisiest mode(s);

l. details concerning frequency ranges, channels, and combinations to be specifically tested such as image frequencies, intermediate frequencies, local oscillator, transmitter fundamental and harmonically related frequencies. Subsystem susceptibility frequencies identified during laboratory testing shall be included;

m. personnel required, including customer and supplier personnel at all levels, quality representatives;

n. list of all required test equipment, including a description of unique EMC instrumentation for stimulating and measuring electrical, electronic, and mechanical outputs of equipment and subsystems to be monitored during the test program.

Annex C (normative)

Electromagnetic effects verification report - Document Requirements Definition (DRD)

C.1 Introduction

This document defines the approach, methods, procedures to verify electromagnetic effects.

C.2 Scope and Applicability

C.2.1 Scope

This Document Requirements Definition (DRD) establishes the data content requirements for the Electromagnetic Effects Verification Report (EMEVR).

This DRD does not define format, presentation or delivery requirements for the Electromagnetic Effects Verification Report.

C.2.2 Applicability

This DRD is applicable to all projects using the ECSS Standards.

C.3 References

C.3.1 Glossary and dictionary

This DRD uses terminology and definitions controlled by:

ECSS-P-001	Glossary of terms
ECSS-E-20	Space engineering - Electrical and electronic

C.3.2 Source document

This DRD defines the data requirements of an electromagnetic effects verification report as controlled by ECSS-E-20.

C.4 Terms, definitions and abbreviated terms

C.4.1 Terms and definitions

For the purposes of this DRD the terms and definitions given in ECSS-P-001 and in ECSS-E-20 apply.

C.4.2 Abbreviated terms

The following abbreviations are used within this DRD.

Abbreviation	**Meaning**
EMEVP	Electromagnetic Effects Verification Plan
EMEVR	Electromagnetic Effects Verification Report
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EED	Electro-Explosive Device

C.5 Description and purpose

The electromagnetic effects verification report provides the instruction for reporting all activities in relation with the verification of the effects of the electromagnetic environment.

C.6 Application and interrelationship

The document is prepared for each project, based on the electromagnetic effects verification plan.

It then applies to every item of equipment and subsystem in the project.

C.7 EMEVR preliminary elements

C.7.1 Title

This document shall be titled "[insert a descriptive modifier, e.g. name of the project] electromagnetic effects verification report".

C.7.2 Title page

The title page for this document shall identify the project document identification number, title of the document, date of release and release authority.

C.7.3 Contents list

The contents list shall identify the title and location of every clause and major subclause, figure, table and annex contained in the document.

C.7.4 Foreword

A foreword shall be included in the document which describes as many of the following items as are appropriate:

- identification of which organizational entity prepared the document;
- information regarding the approval of the document;
- identification of other organizations that contributed to the preparation of the document;
- a statement of effectivity identifying which other documents are cancelled and replaced in whole or in part;
- a statement of significant technical differences between this document and any previous document;
- the relationship of the document to other standards or documents.

C.7.5 Introduction

An introduction can be included to provide specific information or commentary about the technical content.

C.8 Content

C.8.1 Scope and applicability

This clause shall be numbered 1 and shall describe the scope, applicability and purpose of the electromagnetic effects verification report.

C.8.1.1 Scope

This subclause shall be numbered 1.1 and shall contain the following statements:

> "This electromagnetic effects verification report defines the instructions for the [insert project identifier] project.
>
> This electromagnetic effects verification report is based on the requirements of the [insert project EMC control plan identifier and EMEVP]."

C.8.1.2 Purpose

This subclause shall be numbered 1.2 and shall contain the following statement:

> "This electromagnetic effects verification report reports on the results of the application of the electromagnetic effects verification procedure, as required by the EMC control plan."

C.8.2 References

This clause shall be numbered 2 and shall contain the following subclauses.

C.8.2.1 Normative references

This subclause shall be numbered 2.1 and shall contain the following statements:

> "This document incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at appropriate places in the text and publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these apply to this document only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.
>
> [insert document identifier] [insert document title]."
> (Typically the EMC control plan, the EMEVP and some EMC standards can be quoted here.)

C.8.2.2 Informative references

This subclause shall be numbered 2.2 and shall contain the following statement:

> "The following documents, although not a part of this electromagnetic effects verification report, amplify or clarify its contents:
>
> [insert document identifier] [insert document title]

C.8.3 Terms, definitions and abbreviated terms

This clause shall be numbered 3 and shall contain the following subclauses.

C.8.3.1 Terms and definitions

This subclause shall be numbered 3.1 and shall list any applicable project dictionary or glossary, and all unusual terms or terms with a meaning specific to the EMEVR, with the definition of each term.

If a project dictionary or glossary is applicable, insert the following sentence:

> "The definitions of [insert title and identifier of applicable dictionaries or glossaries] apply to this document."

Insert the following sentence:

"The following terms and definitions are specific to this document:

[insert term] [insert definition]."

C.8.3.2 Abbreviated terms

This subclause shall be numbered 3.2 and shall list all abbreviations used in the electromagnetic effects verification report with the full spelled-out meaning or phrase for each abbreviation.

C.8.4 Elements of the report

This clause shall be numbered 4 and shall include as a minimum:

a. identification of specific objectives, including applicable requirements and EMEVP references;

b. description of test article, including configuration and drawings and photographs as appropriate;

c. description of any fixes or configuration changes to article resulting from verification failures;

d. summary of results including an executive summary stating degree of conformance to requirements;

e. description of any deviations from test facilities, analysis techniques or tools, and inspection aids in EMEVP;

f. description of any deviations from step-by-step procedures in EMEVP;

g. test set-up diagrams/photographs as appropriate;

h. list of test equipment, including calibration information, as appropriate;

i. recorded data or logs, including instrument readings, correction factors, and reduced results; methods of data reduction shall be described. If value of data has been compromised due to test conditions, the reason and impact on results shall be stated;

j. identification of ambient and other test conditions.

Bibliography

ISO 14302	Electromagnetic Compatibility Requirements, Space Systems (in preparation)
ISO 14304	Criteria for explosive systems and devices used on space vehicle (in preparation)
MIL-STD-1541A	Electromagnetic compatibility requirements for space systems
MIL-STD-1512	Electroexplosive subsystems, electrically initiated, design requirements and test methods
JPL Publication 86-14	NASA Aerospace Battery Safety Handbook, G.Halpert, S.Subbarao & J.Rowlette
SPIE Vol. 2210	Optical design and technologies for space instrumentation, R.H Csichy

(This page is intentionally left blank)

ECSS Document Improvement Proposal		
1. Document I.D. ECSS-E-20A	**2. Document date** 4 October 1999	**3. Document title** Electrical and electronic
4. Recommended improvement (identify clauses, subclauses and include modified text or graphic, attach pages as necessary)		
5. Reason for recommendation		
6. Originator of recommendation		
Name:	Organization:	
Address:	Phone: Fax: E-mail:	**7. Date of submission:**
8. Send to ECSS Secretariat		
Name: W. Kriedte ESA-TOS/QR	Address: P.O. Box 299 2200 AG Noordwijk The Netherlands	Phone: +31-71-565-3952 Fax: +31-71-565-6839 E-mail: wkriedte@estec.esa.nl

Note: The originator of the submission should complete items 4, 5, 6 and 7.

This form is available as a Word and Wordperfect-Template on internet under http://www.estec.esa.nl/ecss/improve/

(This page is intentionally left blank)