ESA PSS-02-10 Vol 1 Issue 1
November 1992

Power Standard

Prepared by:
Power & Energy Conversion Division
European Space Research and Technology Centre
Noordwijk, The Netherlands

Approved by:
The Inspector General, ESA

european space agency / agence spatiale européenne
8-10, rue Mario-Nikis, 75738 PARIS 15, France

Published by ESA Publications Division,
ESTEC, Noordwijk, The Netherlands

Printed in The Netherlands

ESA price code: E1

ISSN 0379-4059

ABSTRACT

The **Power standard** defines the requirements on electrical power systems (EPS) to be applied by contractors and subcontractors to ESA spacecraft and associated equipment or payloads.

The **Power Standard, ESA PSS-02-10,** consists of two volumes, which support two guideline specifications.

Volume 1, the standard itself, is called the power standard **PS**.

Volume 2, a reference document, is called the power standard rationale **PR**; it gives the **rationale** behind the requirements specified in volume 1.

ESA PSS-02-101 gives the guidelines for the establishment of a power-supply subsystem specification, while **ESA PSS-02-102** gives the guidelines for the establishment of an electrical unit specification.

The applicable document **ESA PSS-02-11**: Test methods for the ESA power standard, which is not yet available, will define the relevant test methods to be followed.

DOCUMENT CHANGE RECORD

ISSUE NUMBER AND DATE	SECTIONS AFFECTED	REMARKS

TABLE OF CONTENTS

PAGE

1. INTRODUCTION 1
   - 1.1 SCOPE 1
   - 1.2 ESA STANDARDISATION POLICY 1
   - 1.3 APPLICABILITY 2

2. APPLICABLE AND REFERENCE DOCUMENTS 3
   - 2.1 APPLICABLE DOCUMENTS 3
   - 2.2 REFERENCE DOCUMENTS 7

3. TERMS, DEFINITIONS, ABBREVIATIONS, SYMBOLS AND UNITS 9

4. ELECTRICAL REQUIREMENTS 11
   - 4.1 GENERAL REQUIREMENTS 11
   - 4.2 SOURCE REQUIREMENTS 15
   - SOLAR ARRAY 19
   - BATTERY 21
   - CONVERTER OR REGULATOR 28

5. DISTRIBUTION AND PROTECTION REQUIREMENTS 31
   - 5.1 GENERAL REQUIREMENTS 31
   - 5.2 RELAYS AND FUSES 33
   - 5.3 SSPCs 35

6. REQUIREMENTS ON EQUIPMENT AND PAYLOADS 37
   - 6.1 GENERAL REQUIREMENTS 37
   - 6.2 CONVERTER TYPE LOADS 41

7. THERMAL AND MECHANICAL REQUIREMENTS 43

8. RELIABILITY REQUIREMENTS 47

9. SAFETY REQUIREMENTS 49
   - 9.1 PRESSURE VESSELS 49
   - 9.2 PYROTECHNICS 49

10. PARTS, MATERIALS AND PROCESSES 51

11. MAINTAINABILITY AND AVAILABILITY REQUIREMENTS 53

12. OPERABILITY REQUIREMENTS 55

13. QUALITY ASSURANCE REQUIREMENTS 57

14. QUALIFICATION AND TESTING REQUIREMENTS 59

KEY WORD / REQUIREMENT CROSS REFERENCE 61

1. INTRODUCTION

1.1 SCOPE

This specification (**ESA PSS-02-10, VOL 1**) defines the requirements on electrical power systems (EPS) that are applicable to all ESA programmes for spacecraft and associated equipment or payloads.

The specification is limited to the definition of the requirements for voltage regulated power buses. Due to their mission- and technology-specific nature, partially regulated power buses are considered to be project specific and will require the definition of requirements agreed between the ESA project and the prime contractor concerned.

A rationale for all the power-system-specific requirements set out in this standard is provided in reference document **ESA PSS-02-10 Vol 2**.

The document **ESA PSS-02-101** contains guidelines for the establishment of a power-supply-subsystem specification, while **ESA PSS-02-102** contains guidelines for the establishment of an electrical-unit specification. The Agency strongly recommends the use of these guidelines for the establishment of such specifications, because they address all the items that need to be specified in such documents.

Test methods to be followed are defined in applicable document **ESA PSS-02-11**.

1.2 ESA STANDARDISATION POLICY

The objectives of ESA standardisation policy are:

- to set minimum acceptable requirements for design, performance, construction, test and operation in critical areas, such as those involving human safety or high investment risk;
- to avoid unnecessary repetitive effort by applying the past experience of the Agency and industry to new projects and programmes;
- to provide interoperability between different space system elements;

- to provide cost reduction or avoidance of duplication of tasks through commonality at design, development, manufacture, test and operational phases.

1.3 APPLICABILITY

This power standard applies to all ESA spacecraft and payload programmes. In the case of conflict with the applicable documents listed in Section 2, this standard takes precedence when it defines a higher-level requirement, specifically to electrical power applications.

Nevertheless the EMC requirements defined in the EMC standard, ESA PSS-02-20, can be more stringent than those necessary for a correct operation of the power subsystem and power distribution and, when relevant, these shall apply.

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The latest issue of the following documents is applicable to the extent specified in Sections 1.2 and 1.3 (documents marked with a "*" are in preparation or still TBD):

ESA PSS-01-0	Basic requirements for product assurance of ESA spacecraft and associated equipment.
ESA PSS-01-10	Product assurance management and audit systems for ESA spacecraft and associated equipment.
ESA PSS-01-11	Configuration management and control for ESA space systems.
ESA PSS-01-20	Quality assurance requirements for ESA space systems.
ESA PSS-01-201	Contamination and cleanliness control.
ESA PSS-01-202	Preservation, storage, handling and transportation of ESA spacecraft hardware.
ESA PSS-01-203	Quality assurance of test houses for ESA spacecraft and associated equipment.
ESA PSS-01-30	Reliability assurance of ESA space systems.
ESA PSS-01-301	Derating requirements and application rules for electronic components.
ESA PSS-01-302*	Failure rates for ESA space systems.
ESA PSS-01-303*	Requirements for failure mode, effects and criticality analysis and associated activities on ESA space systems.
ESA PSS-01-40	System safety requirements for ESA space systems.

ESA PSS-01-401	ESA fracture control requirements.
ESA PSS-01-402*	Design safety requirements for ESA space systems.
ESA PSS-01-403*	Hazard analysis requirements and methods for ESA space systems.
ESA PSS-01-404*	Risk assessment requirements and methods for ESA space systems.
ESA PSS-01-50	Maintainability requirements for ESA space systems.
ESA PSS-01-60	Component selection, procurement and control for ESA space systems.
ESA PSS-01-603	ESA preferred parts list.
ESA PSS-01-604	Generic specification for silicon solar cells.
ESA PSS-01-608	Generic specification for hybrid microcircuits.
ESA PSS-01-609*	Radiation design handbook.
ESA PSS-01-610	Design guidelines for capability approval of film hybrid microcircuits and microwave hybrid integrated circuits (MHIC's).
ESA PSS-01-70	Material and process selection and quality control for ESA space systems and associated equipment.
ESA PSS-01-701	Data for selection of space materials.
ESA PSS-01-702	A thermal vacuum test for the screening of space materials.
ESA PSS-01-704	A thermal cycling test for the screening of space materials and processes.
ESA PSS-01-707	The evaluation and approval of automatic machine wave soldering for ESA spacecraft hardware.

ESA PSS-01-708	The manual soldering of high reliability electrical connections.
ESA PSS-01-710	The qualification and procurement of two-sided printed circuit boards (fused tin-lead or gold-plated finish).
ESA PSS-01-721	Flammability testing for the screening of space materials.
ESA PSS-01-722	The control of limited-life materials.
ESA PSS-01-726	The crimping of high-reliability electrical connections.
ESA PSS-01-728	The repair and modification of printed - circuit boards and solder joints for space use.
ESA PSS-01-738	High-reliability soldering for surface - mount and mixed - technology printed circuit - boards.
ESA PSS-01-802	Environment requirements specification for space equipment: unit-level environmental test specification.
ESA PSS-02-101*	Guidelines for the establishment of a power supply subsystem specification.
ESA PSS-02-102*	Guidelines for the establishment of an electrical unit specification.
ESA PSS-02-11*	Test methods for the ESA power standard.
ESA PSS-02-12*	Power and signal cabling standard.
ESA PSS-02-13*	Ni-H_2 cell, battery standard.
ESA PSS-02-14*	Ni-Cd cell, battery standard.
ESA PSS-02-20*	ESA standard on EMC requirements for space systems.
ESA PSS-02-303*	Requirements for HV transformers and components used in electronic power conditioners.

ESA PSS-03-10*	Thermal control design and testing - standard for general requirements.
ESA PSS-03-108	Spacecraft thermal-control design data handbook.
ESA PSS-04-106	Packet telemetry standard.
ESA PSS-04-107	Packet telecommand standard.
ESA PSS-08-10*	Natural environment.
MIL-HDBK 217	Failure rates.

2.2 REFERENCE DOCUMENTS

The following documents are mentioned as a reference only. It is, however, strongly advisable to take their recommendations into account.

1. Satellite power system topologies (ESA Journal 1989, vol. 13, pp 77-88).
2. Pulse-width-modulation (PWM) conductance control (ESA Journal 1989, vol. 13, pp 33-46).
3. Simple pole/zero modelling of conductance controllers (ESA SP-294, pp 415-423).
4. PWM converter topologies (ESA SP-294, pp 297-305).
5. The sequential switching shunt regulator S^3R (ESA SP-126, pp 123-136).
6. Temperature derivative battery charge control (ESA SP-230, pp 107-122).
7. Nickel Hydrogen cell specification for GEO spacecraft (ESA-NH-GEO).
8. Nickel Hydrogen cell performance, design and qualification test requirements for Columbus (Issue 8).
9. Solar Array Design Handbook
   Rauschenbach, Hans S
   Van Nostrand Reinhold Company, 1980
10. Solar Cell Radiation Handbook
    Third edition
    JPL Publication 82-69, November 1982
11. Procedure for the measurement of spacecraft solar arrays electrical performance (ESTEC working paper nr 1700, January 1993)
    ESTEC XP division

3. TERMS, DEFINITIONS, ABBREVIATIONS, SYMBOLS AND UNITS

AC	alternating current
ADC	DC current
Ag-Cd	silver-cadmium
Aol	open loop gain
App	ampere peak to peak
BCR	battery charge regulator
BDR	battery discharge regulator
BOL	beginning of life
BW	bandwidth
C_{bus}	main bus capacitor
CGP	common ground point
dB	decibel
DC	direct current
disch	discharge
DOD	depth of discharge
EGSE	electrical ground support equipment
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EOL	end of life
EPS	electrical power system
ESA	European Space Agency
ESD	electrostatic discharge
FMECA	failure mode effects and criticality analysis
GEO	geostationary orbit
HDBK	handbook
Hrs	hours
IC	integrated circuit
I_{nom}	nominal current
LEO	low earth orbit
LEV	level
max	maximum
mC	millicoulomb
MGSE	mechanical ground support equipment
min	minimum
Ni-Cd	nickel cadmium
$Ni\text{-}H_2$	nickel hydrogen
PCB	printed circuit board

PCDU	power control and distribution unit
PCU	power control unit
PDU	power distribution unit
PF	power specification format
PR	power standard rationale
PS	power standard
PSS	procedures, specifications and standards.
PWM	pulse width modulation
S/C	spacecraft
S^3R	sequential switching shunt regulator
SMT	surface mounting technique
SSPC	solid state power controller
TBD	to be defined
TC/TM	telecommand and telemetry
VDC	DC volt
Veod	end of discharge voltage
Yr(s)	year(s)

4. ELECTRICAL REQUIREMENTS

In this chapter, all system requirements specifying a parameter are applicable under worst-case conditions.

4.1 GENERAL REQUIREMENTS

4.1.1 Power bus type

On board a spacecraft, power shall be generated and distributed via one or more DC voltage-regulated buses.

The definition of a regulated voltage bus is given in Section 4.2 and more details about regulated buses are given in the Reference documents 1 to 5.

4.1.2 Bus voltages

The recommended nominal bus voltage shall be 28 V, 50 V or 120 VDC. The regulated bus voltage in volts shall be greater than:

the nearest bus voltage above
$\sqrt{P}$ (V) for LEO

the nearest bus voltage above
$\sqrt{0.5P}$ (V) for GEO, where:

P = bus power capability (W)

Any deviation from these bus voltages shall be justified by the contractor and approved by the Agency.

4.1.3 Location of the common ground point (CGP)

The return of a voltage regulated bus shall be grounded to the spacecraft structure at the negative side of the main bus capacitor (CGP). The negative side of the main bus capacitor is the preferred connection except when the platform ground reference configuration requires another connection.

4.1.4 Bonding to structure

The bonding of a unit (e.g. PCU, PCDU, PDU, BCR or BDR) chassis to spacecraft structure and of connector shells to unit chassis shall be done with a bonding resistance of less than 2.5 mΩ and an inductance of less than 50 nH. During life the bonding resistance shall not degrade to a value exceeding 25 mΩ. This shall be verified by assessing the technology used or by analysis. Each bonding point shall be capable of withstanding the maximum power source current without a change in resistance.

4.1.5 Power/energy budget

During operational life a power bus shall be able to satisfy each average power / energy and maximum peak power demand with a margin of not less than 10%.

4.1.6 Power budget parameters

A power budget analysis shall verify the power budget by considering the following EOL parameters:

Maximum battery cell voltage (charge)
Average battery cell voltage (charge)
Average battery cell voltage (discharge)
Minimum battery cell voltage (discharge)
Battery K-factor
Percentage power distribution loss
Solar array loss factors
Percentage solar array harness loss
Percentage power conditioning efficiency
Eclipse duration GEO/LEO
Sunlight duration GEO/LEO
Solar array power
Battery DOD
Battery temperature
Number of battery cell failures allowed

Guidelines to the most appropriate values for these parameters will be found in the rationale.

4.1.7 Safety assurance

The requirements on the applicable document ESA PSS-01-40 on hazard control shall apply and more specifically: no single-point failure in the electrical system or equipment shall cause the loss of the spacecraft. For manned missions a minimum of two-failure tolerance is required. Any deviation from this requirement must be submitted to the Agency with supporting justification for approval.

4.1.8 Redundant functions: General

Redundant functions shall be routed via redundant harness and physically separated connectors.

4.1.9 Redundant functions: Physical location

Redundant functions shall be physically separated, as a minimum, in a different package (e.g. PCB, hybrid, IC), to avoid failure propagation. For multi-cavity hybrids, redundant / protection functions as a minimum shall be in a different cavity.

4.1.10 Essential functions

Essential functions are those functions without which:

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

Equipment shall not rely on essential functions (e.g. synchronisation or auxiliary power supply) **centrally generated**. Any equipment shall be capable of operating independently of any external synchronisation and auxiliary power supply.

4.1.11 Single-point failure free

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. For manned missions a minimum of two-failure tolerance is required. Any deviation from this requirement must be submitted to the Agency with supporting justification for approval.

4.1.12 Temperature monitoring

Any equipment that can dissipate more than 20 W in normal or failure mode shall provide an analogue-temperature telemetry signal.

4.1.13 Component derating

Components used in a voltage-regulated bus shall follow the derating requirements stated in applicable document ESA PSS-01-301.

4.1.14 Telecommand/Telemetry: General

The telecommand and telemetry types and interface requirements are defined in the following applicable documents:

ESA PSS-04-106: Packet telemetry standard
ESA PSS-04-107: Packet telecommand standard

4.1.15 Telecommand: Noise discrimination

Telecommand interfaces shall use 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.

4.1.16 Telecommand/Telemetry: voltage-transient protection

Telecommand and telemetry interfaces shall be protected against positive or negative voltages that are generally accessible on the spacecraft (e.g. main bus voltage and any external auxiliary supply voltages).

4.1.17 Telecommand and telemetry: unit protection

The application of telecommands and external synchronisation to a non-powered unit shall not cause damage to that unit.

4.1.18 Telecommand and telemetry: ESD protection

All signal interfaces shall be capable of withstanding the application of a capacitor of 100 pF charged to 1 kV with either polarity.

4.2 SOURCE REQUIREMENTS

A voltage-regulated bus can be built from the association of one or several primary sources of power (e.g. solar array) and/or one or several primary storage (e.g. fuel cell)/secondary storage (e.g. Ni-Cd battery) power sources and/or one or several external power sources (e.g. another spacecraft bus).

Where the voltage-regulated bus results from the association of several power sources, one can define several domains of operation according to which source (sources) supplies the power. Dependent on the number of separate power/energy sources, there will be reference to one domain or multi-domain operation in some of the following requirements.

4.2.1 Bus-voltage regulation

A voltage-regulated bus is a bus that has a controlled voltage (at the regulation point) with steady-state tolerances within the ±1% range (with respect to the nominal voltage), which applies for the entire range of utilisation (temperature, load, life, radiation, initial calibration etc.).

The voltage-tolerance breakdown (±) shown in Table 4.1 applies:

VOLTAGE TOLERANCE BREAKDOWN	PERCENTAGE VOLTAGE TOLERANCE (±)
Load regulation	< 0.1 %
Variation with temperature	< 0.4 %
Variation over life	< 0.4 %
Initial calibration accuracy	< 0.1 %
Total voltage tolerance	< 1 %

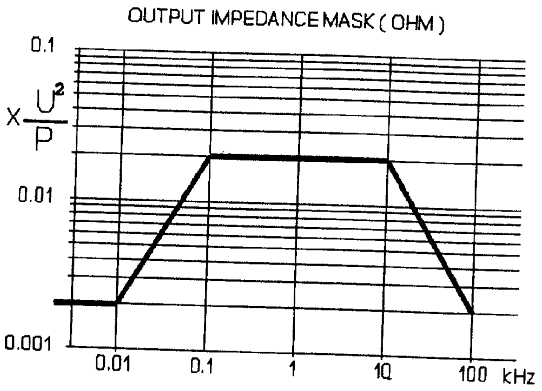
Table 4.1

4.2.2 Location of the regulation point

The regulation point of a voltage-regulated bus shall be within the power system at the main bus voltage regulator output capacitor (e.g. in the PCU/PCDU).

4.2.3 Bus impedance at the regulation point: operation in one domain

At the point of regulation the impedance of a voltage-regulated bus, operating in one domain, shall be below the impedance mask shown in Figure 4.1.



U = NOMINAL REGULATED OUTPUT VOLTAGE (VOLT)
P = POWER CAPABILITY (WATT)

Figure 4.1

4.2.4 Domain bus transient

Bus transients at the regulation point due to interdomain operation shall not produce a transient voltage of more than ±1% of the nominal bus voltage with a time constant less than 2 ms. For multiple domain excursions, the worst-case transient shall not exceed ±4% of the nominal bus voltage with a time constant less than 2 ms.

4.2.5 Bus stability

The phase margin of the voltage-regulated bus shall be 60° or greater. The associated gain margin shall be 10 dB or greater. The stability shall be verified by analysis and test.

4.2.6 Steady-state bus ripple voltage at the regulation point

The bus ripple voltage (point of regulation) in the time domain shall be less than 0.5% peak to peak of the nominal bus voltage under nominal bus conditions.

The requirement shall be verified by the following test condition:

The bus load shall be resistive and the measurement shall be performed with an oscilloscope having a BW of at least 50 MHz.

4.2.7 Steady-state bus commutation spike voltage (at the regulation point)

The bus spike voltage (point of regulation) in the time domain shall be less than 2% peak to peak of the nominal bus voltage.

The requirement shall be verified by the following test condition:

The bus load shall be resistive and the measurement shall be performed with an oscilloscope having a BW of at least 50 MHz.

SOLAR ARRAY

4.2.8 Solar array capability

The solar array shall be able to satisfy each average power demand (including battery recharge power) during operational life in sunlight.

4.2.9 Solar cell qualification

If silicon solar cells are used, they shall be qualified according to ESA PSS-01-604.

4.2.10 Solar array section: general

The solar array shall be divided into sections. Each solar-array section dedicated to the power bus shall be controlled by a dedicated shunt dump.

4.2.11 Solar array section: slip ring

The qualified current capability of a slip ring shall be higher than the best-case BOL-solar-array section current when operated into a short circuit. The slip ring should also be capable of withstanding the dynamic current caused by the discharge of the solar- array-section capacitance.

4.2.12 Solar array section: parameters

The design of each solar-array section shall consider the following parameters:

- I-V characteristic including BOL and EOL: the solar array shall minimise the BOL/EOL current ratio while maintaining a maximum EOL current.

- Operating point versus the maximum power point: the operating voltage shall always be lower than the maximum power voltage.

- Use of blocking diodes; if applicable.

- BOL (i.e. calibration, seasonal effect, standard cell, etc.) and EOL (including life and radiation) loss factors.

- Maximum effective capacitance at solar-array-section level when switching (e.g shunt or series regulator) between the two stable operating points.

- Distribution resistance from solar-array section to spacecraft interface.

- Distribution inductance from solar-array section to spacecraft interface.

BATTERY

The battery types considered in this section are limited to Ni-Cd and Ni-H_2 which have been used for the vast majority of ESA spacecraft to date. It is not the intention to exclude other technologies (such as Ag-Cd, Li, fuel cells). When they become more widely used and their performance better characterised they will be added to the standard.

4.2.13 Battery electrical design: cell matching

The battery cells in a battery shall be matched under mission-representative cycling profiles. The cell capacity shall match within ±3%.

4.2.14 Battery electrical design: electrical isolation

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 VDC). A double isolation is required. The electrical isolation between the cell terminals and the battery structure shall also be more than 1 MΩ (measured at 500 VDC).

4.2.15 Battery electrical design: bonding

The elements of the battery structure shall be provided with bonding studs with a resistance of less than 2.5 mΩ. Connector shells shall be also bonded to the battery structure.

4.2.16 Battery electrical design: monitoring connector

The battery shall have a dedicated connector for ground testing.

4.2.17 Battery electrical design: monitoring

Cells shall be monitored in groups small enough to allow detection of the reversal of any one cell at any time.

4.2.18 Cell by-pass protection (e.g. using series redundant diodes) for Ni-H_2 batteries

Cell by-pass protection, capable of sustaining continuously the highest charge and discharge currents, shall be incorporated across each cell if the Ni-H_2 battery needs to be single-cell-failure tolerant.

4.2.19 Battery mechanical design: Ni-Cd cell pressure constraint

The Ni-Cd battery cells in a battery package shall be clamped between flanges (e.g. held by tie rods) in order to withstand the cell pressure at end of charge and in order to avoid deformation of the cell case.

A safety factor of at least four shall be applied with regard to the maximum cell pressure expected.

4.2.20 Battery mechanical design: battery-to-cell mass ratio

The recommendations given in the rationale shall be considered.

4.2.21 Battery thermal design: general

The recommendations given in the rationale shall be considered.

4.2.22 Battery thermal design: thermal gradient

The maximum thermal gradient between any pair of cells within one battery shall not exceed 5°C. In the case of batteries operated in parallel, a 5°C maximum temperature difference applies between any two batteries.

4.2.23 Battery DC magnetic field design

In the case of applications requiring a high level of magnetic cleanliness, silver-based technologies (Ag-Cd) shall be considered.

4.2.24 Battery safety: Ni-H_2 battery

The safety requirements related to the pressure vessel are defined in Reference Documents 7 and 8 and in the **ESA fracture control requirements** standard ESA PSS-01-401.

4.2.25 Battery management: GEO charging technique

The charging technique shall be designed to ensure that the batteries are adequately recharged without excessive overcharge. Typical recharge ratios lie in the range 1.05 to 1.1 (excluding trickle charge). At least two independent-end-of charge criteria must be implemented to ensure absence of excessive overcharge after one failure. End-of-charge voltage criteria must accommodate the effect of variable temperature and battery ageing.

The minimum charge rate shall be C/20 for average battery temperatures not exceeding 10°C and C/10 for higher temperatures. Following charge, an additional trickle charge shall be applied at a rate sufficient to compensate for self-discharge (typically in the range C/200 to C/70). Self-discharge compensation is also required during solstice periods.

4.2.26 Battery management: LEO charging technique

To minimise the rate of degradation of battery performance, it is necessary that the recharge ratio (K-factor) be maintained to the lowest value that ensures adequate recharge. A minimum of two independent charge-termination criteria shall be implemented so as to avoid excessive overcharge in the case of one failure.Whenever possible it is also beneficial to reduce the charge current from its nominal value towards the end of charge.

4.2.27 Battery management: reconditioning capability for GEO

For GEO missions of long duration, reconditioning capability during the mission shall be implemented.

4.2.28 Battery management: reconditioning capability for LEO

In the case of Ni-Cd batteries, reconditioning capability shall be implemented if there would otherwise be a risk that the battery voltage will fall below the minimum value needed to support the bus any time during the (nominal) mission. See Section 4.2.30 of Vol 2 for data on the minimum cell voltage to be expected under various conditions.

Note: These data are derived from a limited range of space-qualified European battery types cycled with taper charging and higher than currently recommended recharge ratio. Until more data are available, a generous margin (20 mV) on cell end-of-discharge voltage shall be considered.

In the case of $Ni\text{-}H_2$ batteries, it has not yet been clearly established whether or not reconditioning can offer a worthwhile improvement in performance.

4.2.29 Number of parallel batteries

The current sharing shall be such that worst-case values are within ±5% of the nominal design values.

4.2.30 Battery DOD versus life: Ni-Cd application

The maximum DOD, which may be used to meet a given mission life time depends on several factors, including temperature and the minimum acceptable battery voltage on discharge.

The recommendations given in the rationale shall be considered.

(a) Low earth orbit applications:

Recommended values of DOD for Ni-Cd batteries are presented in Table 4.2. The values in brackets are extrapolated from test data and hence are less reliable.

MAXIMUM DOD (%)	TEMP. RANGE (°C)	VEOD-CORRECTED AFTER 5 YR NO RECOND.	VEOD-CORRECTED AFTER 5 YR 0.5 YR RECOND.	TIME TO FAILURE (YEARS)
10	-5 to +25	1.23	1.25	> 7
20	-5 to +25	1.16	1.21	> 7
30	-5 to +15	1.12	(1.20)	> 5
30	25	1.12	(1.15)	(5)
40	-5 to +15	1.12	(1.20)	> 4
40	25	1.08		3.2

Table 4.2

Here Veod-corrected is the end-of-discharge voltage at cell level excluding the voltage drop due to the cell's internal resistance.

(b) Geosynchronous applications:

For Ni-Cd cells operating within the temperature range and the management scheme detailed in Section 4.2.22, a nominal GEO mission with maximum DOD up to 80% (to 90%) of the **NAME PLATE CAPACITY** is acceptable.

The measured relation between battery life, Veod(EOL) and DOD (referred to name plate capacity) is shown in Table 4.3:

DOD (%)	NI-CD (YEARS)	NI-CD VEOD(EOL)	NI-H_2 (YEARS)	NI-H_2 VEOD(EOL)
70	13	1.13	13	1.10
80	13	1.08	10	1.05
90	10	1.03	-	-

Table 4.3

4.2.31 Battery DOD versus life: Ni-H_2 application

The life-test data are limited. The recommendations given in the rationale shall be considered.

4.2.32 Storage and destorage of batteries

The following requirements apply to Ni-Cd, Ni-H_2 and Ag-Cd cells and batteries.

(a) Storage

To maintain specified performance and lifetime capabilities, it is essential that cells and batteries be stored under controlled conditions when not in use for longer than the period specified by the manufacturer.

All cells must be in a completely discharged state and the environmental temperature kept below the specified maximum.

(b) Re-conditions after storage

After prolonged storage, cells and batteries must first be allowed to warm slowly to ambient temperature. Attempts immediately to charge at high rates will result in damage and it is essential to perform low-rate conditioning cycles before nominal performance can be obtained. Detailed conditioning requirements are provided by the manufacturer and must be followed.

Procurement of cells and batteries will require the procurer to agree on precise storage and reactivation requirements, which shall specify, as a minimum:

- maximum ground storage life (wet life of cells);
- maximum period of non-use;
- storage procedure, storage temperature, cell-discharge requirements, humidity and environmental requirements, packaging for storage;

- reactivation procedure, reconditioning, charge rates, voltage limits and temperature profile.

These requirements will be signed by both manufacturer and procurer, will be approved by the Agency's representative and will then become a binding requirement for the specific programme.

Any requests for waiver of these recommendations require ESTEC approval.

CONVERTER OR REGULATOR

The following requirements apply if the source for a regulated bus is a converter or regulator:

4.2.33 External synchronisation

If external synchronisation is applicable, multi-phase synchronisation shall be applied to modular converters or regulators. Protection shall be incorporated to ensure automatic disconnection of clock signals if the synchronisation frequency equals or exceeds double the nominal value. Provision shall also be made to ensure that the synchronisation signals can be connected or disconnected by telecommand.

4.2.34 Free running frequency

The free running frequency shall be lower than the synchronisation frequency by at least 10%.

4.2.35 Essential function protection

Any function supporting essential functions in converters or regulators shall not be implemented in the same hybrid package nor utilise common references or auxiliary supplies. A definition of an essential function is given in Section 4.1.10.

4.2.36 Conducted common-mode current

Unit design shall be such that the peak-to-peak time-domain noise current flowing between the electrical reference and unit case via a low impedance shorting path is less than

$$0.05\ P/U\ (A)$$

where:

P = maximum power (W)
U = nominal bus voltage (V)

The current measurement shall be performed with an oscilloscope having a BW of at least 50 MHz.

4.2.37 Conducted common-mode voltage

The conducted common-mode peak-to-peak voltage shall not exceed 1% of the nominal bus voltage.

4.2.38 Electrical isolation: DC

The electrical zero-volt reference shall be isolated from unit case by more than 1 kΩ. However, the isolation resistance shall be more than 20 kΩ for satellites with stringent magnetic-field requirements.

4.2.39 Electrical isolation: AC

The capacitance between the electrical reference and the unit case shall be less than 50 nF.

Page intentionally left blank

5. DISTRIBUTION AND PROTECTION REQUIREMENTS

All requirements in this chapter specifying a parameter are applicable under worst-case EOL conditions.

5.1 GENERAL REQUIREMENTS

5.1.1 Protection: general

All interfaces with a power bus shall be protected against shorting the bus. The protection shall be implemented as close as possible, but in any case not further than 50 cm from the main bus regulation point.

5.1.2 Protection: non-protected sections

All otherwise non-protected sections of the distribution system shall be protected as a minimum by double isolation.

5.1.3 Current limitation: bus capability

The current shall not exceed the total bus capability during nominal operation of the power bus at start up or during failure of any load (with the exception of a fuse clearance).

5.1.4 Current limitation: general

All power interfaces supplied by a regulated bus shall be current limited so that the incremental current above the nominal shall not exceed $\Delta I_{peak} \leq 0.1$ times the bus current capability $(=P_{busmax}/U_{bus})$.

5.1.5 Current limitation: safety

Current limitation shall not cause cable and internal unit temperature ratings to exceed the design ratings.

5.1.6 Single point failure free

Equipment connected to independent, redundant power buses shall ensure that no single failure will cause the loss of more than one power bus. For manned missions a minimum of two-failure tolerance is required. Any deviation from this requirement must be submitted to the Agency with supporting justification for approval.

5.1.7 Disconnection of non-essential loads

All non-essential loads (loads which could be switched off without endangering the survival of a spacecraft) shall be switched off automatically in the case of a bus or battery(ies) under voltage of more than 10% (with respect to the minimum voltage) for a duration of more than 50 ms.

5.1.8 Protection: harness over current

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

5.1.9 Protection: slip ring

Power supplied through a slip ring to a payload shall be limited so that the nominal energy capability of the contacts of the slip ring is never exceeded even in fault condition.

5.1.10 Harness resistance

The power distribution harness resistance (line and return) from the point of regulation of the regulated bus to the load shall be less than

$$0.005\ U^2/P\ (\Omega)$$

where:

U = nominal bus voltage (V)
P = maximum power supplied to the load (W)

5.1.11 Harness inductance up to 100 kHz

The power distribution harness inductance common to multiple loads (line and return), from the distribution node of the regulated bus to the load, shall be less than

$R/2 \pi f$ (H)

where:

R = actual harness resistance (Ω)
f = frequency at 5 kHz

(A distribution node is a common point to which more than one user is connected.)

5.2 RELAYS AND FUSES

The use of fuse protection must be justified. This justification must be submitted to ESA for approval.

The following requirements apply to a relay / fuse type power distribution:

5.2.1 Bus recovery from a fuse clearance

The bus voltage at any distribution node, during recovery of a fuse clearance, shall not produce a transient peak voltage of more than 4% above its nominal bus voltage range with a time constant less than 2 ms.

5.2.2 Fuse clearance time

The worst-case fuse clearance time shall be specified.

5.2.3 Current inrush

The integrated inrush surge current (i.e. Coulomb discharge from C_{bus}) for currents greater than the nominal load current at switch-on shall be less than:

$$0.02\ UC_{bus}\ (\mathrm{As})$$

where:

U = nominal bus voltage (V)
C_{bus} = actual bus capacitance (F)

The inrush current is the initial transient current drawn by equipment or payload when the bus voltage is applied to it or when it switches on.

5.2.4 Peak relay switch current

The peak relay switch current shall not exceed the derated value specified in ESA PSS-01-301.

5.2.5 Peak relay switch voltage

The peak voltage across the contacts at switch off shall not exceed

$$1.1\ U\ (\mathrm{V})$$

where:

U = nominal bus voltage (V)

5.2.6 Load switching induced transients

The voltage transient due to the load commutation shall be less than

0.02 U (V) with a time constant less than 2 ms.

where:

U = nominal distribution node voltage (V)

5.2.7 DC distribution resistance excluding harness

The DC distribution resistance excluding harness (e.g. relay, fuse, current sense etc.) shall not exceed

$0.005\ U^2/P\ (\Omega)$

where:

U = nominal bus voltage (V)
P = maximum power (W)

5.3 SSPCs

The following requirements apply to a solid state power controller (SSPC) type power distribution:

5.3.1 SSPC DC series resistance

The SSPC DC series resistance shall not exceed the following values

0.25 volt / I_{sspc} (Ω) for the 28 V and 50 V bus

0.50 volt / I_{sspc} (Ω) for the 120 V bus

where:

I_{sspc} = SSPC current capability (1, 5, 10 or 20 A)

5.3.2 SSPC equivalent series inductance

The equivalent series inductance of the SSPCs shall not exceed the following values

$4 / I_{sspc}$ (µH) for 28 V and 50 V bus

$8 / I_{sspc}$ (µH) for 120 V bus

where:

I_{sspc} = SSPC current capability (1, 5, 10 or 20 A)

5.3.3 SSPC inrush capability

The SSPC shall be capable of delivering its limiting current during inrush for at least 5 ms without reaching the thermal rating.

5.3.4 Current slew rate

The current slew rate shall not exceed 1 A/µs at switch-on and switch off.

6. REQUIREMENTS ON EQUIPMENT AND PAYLOADS

All requirements in this chapter specifying a parameter are applicable under worst-case conditions.

6.1 GENERAL REQUIREMENTS

6.1.1 Secondary voltage requirement

The main power distributed in a spacecraft is derived from the regulated DC bus or DC buses. Any power required by a load at a voltage different from the regulated bus voltage has to be **generated locally** and distributed at equipment or payload level.

6.1.2 FAILURE PROPAGATION

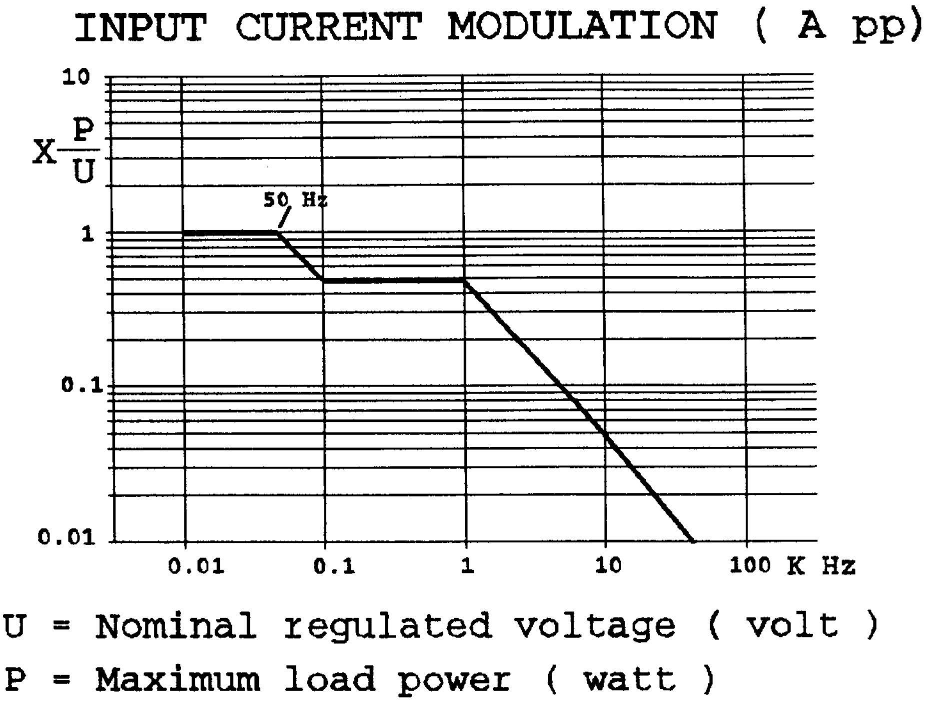
No failure shall lead to the loss of an essential spacecraft function. The requirements specified in Chapter 4, Sections 4.1.10 and 4.1.11 shall apply.

6.1.3 POWER CONDITIONING COMPONENT CURRENT

The peak current (excluding initial surge) per power cell shall not exceed 15 A. This recommendation shall be followed and any deviation shall be approved by the Agency.

6.1.4 CONDUCTED INPUT CURRENT MODULATION

The input current modulation shall be less than the mask shown in Figure 6.1.



U = Nominal regulated voltage (volt)
P = Maximum load power (watt)

Figure 6.1

6.1.5 ESSENTIAL FUNCTION PROTECTION

Any function supporting essential functions shall not be implemented in the same hybrid package nor utilise common references or auxiliary supplies. An essential function is defined in Chapter 4 Section 4.1.10.

6.1.6 SAFE OPERATION: GENERAL

Every piece of equipment shall be so designed that no safety critical or damaging power dissipation can result from normal-operation or single-failure modes.

6.1.7 SAFE OPERATION DURING SWITCH ON AND SURVIVAL

Every piece of equipment shall be so designed that safety critical or damaging current or voltage stress across switches do not occur during switch-on, power outages or with any applied DC supply voltages in the range from zero volt to the nominal bus voltage.

6.1.8 PROTECTION: TEST POINTS

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

6.1.9 PROTECTION: STIMULUS POINTS

Stimulus points on equipment and payload have to be protected from provoking unwanted operation.

6.1.10 PROTECTION: TC/TM POLARITY INVERSION

Each piece of equipment shall be protected against inversion of polarity on telecommand and telemetry.

6.1.11 MAXIMUM INRUSH CURRENT

The maximum over current shall be less than 10% of the bus current capability (= 0.1 times P_{busmax}/U_{bus}). A means to ensure this shall be provided in the equipment if not already provided by the power distribution (see Chapter 5).

6.1.12 INTEGRATED INRUSH CURRENT

At switch-on, the integrated inrush surge current (i.e. Coulomb discharge) for currents greater than the nominal load current, shall be less than

$$0.02\ UC_{bus}\ \text{(As)}$$

where:

U = the nominal bus voltage (V)
C_{bus} = actual bus capacitance (F)

6.1.13 HYBRIDS: REQUIREMENTS

Whenever hybrids are used, the generic specification format for hybrid microcircuits has to be used: see applicable document ESA PSS-01-608.

6.1.14 HYBRIDS: DESIGN

The design guidelines for thick-film hybrid microcircuits given in applicable document ESA PSS-01-610 shall be followed when such circuits are used.

6.1.15 HYBRIDS: DESIGN ANALYSIS

Hybrid circuit design analysis shall be coherent with reliability requirements of the equipment which includes the hybrid circuit.

6.1.16 DC ISOLATION

The electrical zero volt reference shall be isolated from unit case by more than 1 kΩ. However, the isolation resistance shall be more than 20 kΩ for satellites with stringent magnetic-field requirements.

6.1.17 AC ISOLATION

The capacitance between the electrical reference and the unit case shall be less than 50 nF.

6.2 CONVERTER TYPE LOADS

The following requirements apply to loads containing one or more regulated converters.

6.2.1 CONVERTER STABILITY

The phase margin of the voltage-regulated converter shall be 60° or greater. The associated gain margin shall be 10 dB or greater. The stability shall be verified by analysis and test.

6.2.2 CONVERTER INPUT RIPPLE CURRENT

The peak-to-peak time domain input ripple current (steady state) shall be less than

$0.05\ P/U\ (A)$

where:

P = maximum converter input power (W)
U = nominal bus voltage (V)

6.2.3 CONDUCTED COMMON MODE CURRENT

Unit design shall be such that the peak-to-peak time domain-noise current flowing between the electrical reference and unit case via a low-impedance shorting path is less than

$0.05\ P/U\ (A)$

where:

P = maximum converter input power (W)
U = nominal bus voltage (V)

6.2.4 FREE RUNNING FREQUENCY

The free running frequency shall be at least 10% less than the synchronisation frequency.

Page intentionally left blank

7. THERMAL AND MECHANICAL REQUIREMENTS

7.1 MEANS OF POWER DISSIPATION

For each item of equipment or payload, the means of dissipating power shall be defined (radiative, conductive...) and the extreme temperatures of the cold plate with the dissipation capability in W/cm^2 defined when applicable.

7.2 MECHANICAL INTERFACE

For each item of equipment or payload, the mechanical interface shall be defined, including the fixation points, acceleration loads in the three axes and amplification coefficients.

7.3 CONNECTOR MATING

All connectors shall be so constructed that an inadvertent reversed connection or a wrong connection cannot be made.

7.4 CONNECTOR ACCESS

If equipment has several connectors, visibility and clearance around each of them shall be such that one can be connected or disconnected without disturbing the others already in place and without the use of custom-made tooling.

7.5 CONNECTOR TYPE

All connectors carrying source power shall use socket-type connectors.

7.6 CONNECTOR SAVERS

For interfacing with ground support-equipment during ground testing, all flight connectors shall be provided with connector savers.

7.7 CONNECTOR SAVER USE

The use of a connector saver shall in no way alter the performance of equipment.

7.8 CONNECTORS: INTERNAL

Single internal connectors shall not be used to interconnect mission-critical assemblies in closed equipment. Mission-critical assemblies shall use physically separated connectors and boards.

7.9 TEST/STIMULUS POINTS

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.

7.10 THERMAL FINISH

Thermal finishes shall be applied in accordance with the **Spacecraft thermal-control design data handbook** ESA PSS-03-108.

Thermal finishes shall be applied in accordance with and shall conform to the thermal standard ESA PSS-03-10.

7.11 PARTS, MATERIAL AND PROCESSES

Parts, material and process selections are specified by the applicable document: **Component selection, procurement and control for ESA space systems** ESA PSS-01-60.

All parts and materials used by equipment suppliers must be approved by the prime contractor and ESA before use.

7.12 SOLDERING

Soldering shall be performed in accordance with the applicable documents ESA PSS-01-707 and -708.

7.13 WIRING AND CONNECTORS

Wiring and connectors shall be in accordance with applicable document: **Guidelines for spacecraft power and signal cabling** (to be developed).

7.14 PRINTED CIRCUIT BOARDS: GENERAL

Printed circuit boards (PCBs) shall be qualified and procured according to applicable document ESA PSS-01-710.

7.15 HARNESS: GENERAL

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

7.16 HARNESS: POWER

For transmission of power, each line shall be twisted with its return to minimise current loop area.

7.17 PACKAGING

For packaging, each item of equipment or payload including a power converter shall be designed as a Faraday cage with an electrical continuity between the various pieces of the cage better than 2.5 mΩ and using a material having an electrical resistance better than 2.5 mΩ per metre.

7.18 CONNECTORS

As a rule, different connectors shall be used for power and for telecommand telemetry. When this is not possible, it is required, as a minimum, that the power signals and telecommand and telemetry signals should be separated in the connector by a set of unused pins in order to avoid failure propagation.

7.19 TEST CONNECTORS

Test connectors shall be separated from all the functional connectors.

8. RELIABILITY REQUIREMENTS

8.1 ANALYSIS

In conformity with applicable document ESA PSS-01-30, all the following analyses have to be performed at system and equipment level:
- reliability analysis
- FMECA
- outage analysis
- contingency analysis
- parts stress analysis
- worst-case analysis
- radiation analysis
- single-point-failure analysis
- critical-item analysis
- trade-off analysis
- stability analysis

8.2 APPLICABLE FAILURE RATES

In the performance of reliability analysis, the failure rates listed in ESA PSS-01-302 and in MIL-HDBK 217 shall be used with the provision stated in ESA PSS-01-30.

Page intentionally left blank

9. SAFETY REQUIREMENTS

The requirements of applicable document PSS-01-40 concerning hazard analysis fully apply and in particular for power systems the following requirements have to be met:

9.1 PRESSURE VESSELS

9.1.1 LEAK BEFORE BURST

The design of pressure vessels shall be such that they leak to prevent any burst.

9.1.2 MAXIMUM OPERATING PRESSURE

The condition of operation shall be such that the maximum allowable operating pressure shall not be exceeded.

9.2 PYROTECHNICS

9.2.1 PYRO POWERING

Pyro shall, as a first principle, be powered from energy storage elements. Where not feasible, means shall be provided to ensure that it is impossible to overload the main bus both during and after firing.

9.2.2 PROTECTION AGAINST SPURIOUS FIRING

Sequential-event interlocks, electrical arm/disarm firing-circuit interrupts and mechanical safe-and-arm devices shall be used to preclude a single failure from initiating pyrotechnic events.

9.2.3 CONNECTORS

Separate connectors shall be used for pyro functions.

9.2.4 CIRCUIT BREAKERS AND ACTIVATION SWITCHES

Circuit breakers and activation switches which are used to arm and initiate pyrotechnic devices shall be located, guarded, placarded and procedurally protected to avoid inadvertent activation.

9.2.5 SAFE-AND-ARM CONTROL AND MONITORING

Safe-and-arm device control and monitor circuits shall be completely independent of the firing circuits with separate non-interchangeable electrical connectors.

Arming and monitoring shall not initiate pyrotechnics.

9.2.6 VISUAL INSPECTION

It shall be possible to verify visually the safety of hazardous pyrotechnic functions prior to launch.

9.2.7 ELECTROSTATIC DISCHARGE

Spurious firing due to electrostatic discharge shall be prevented.
The requirements of ESA PSS-02-20 apply.

10. PARTS, MATERIALS AND PROCESSES

10.1 GENERAL REQUIREMENTS

The requirements on material and process selection of ESA PSS-01-70 shall apply.

10.2 ESA PREFERRED PARTS LIST

The reliability level of electronic parts used for construction is specified in the applicable document ESA PSS-01-603: **ESA preferred parts list.**

10.3 OUTGASSING AND CONTAMINATION CONTROL

Only space-qualified parts, materials and processes shall be used.

10.4 PRINTED CIRCUIT BOARDS

Printed circuit boards shall be repaired or modified according to applicable document ESA PSS-01-728.

10.5 MOISTURE, FUNGUS GROWTH AND CORROSION

The resistance of any power equipment to moisture, fungus growth and corrosion shall meet the requirements specified in applicable document ESA PSS-01-802, **Environment requirements specification for space equipment: unit-level environmental test specification.**

Page intentionally left blank

11. MAINTAINABILITY AND AVAILABILITY REQUIREMENTS

11.1 INTERCHANGEABILITY

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 are to be sufficiently uniform to permit equipment interchange without adjustments and recalibration.

11.2 WORKMANSHIP

Performances and reliability shall not be varied by the workmanship. (In other words, there should, for a given part number, not be variation of performance from one to another depending on how it has been built.)

11.3 EQUIPMENT IDENTIFICATION

Each equipment shall be identified in accordance with the requirements of applicable document ESA PSS-01-11: **Configuration management and control for ESA space systems.**

11.4 TRANSPORT AND HANDLING OF EQUIPMENT

Each equipment or system shall be designed to meet the requirements for transport and handling according to applicable document ESA PSS-01-202.

11.5 EQUIPMENT LIFE

Each item of electrical equipment, except batteries and radioisotope sources, shall be designed to be held for 10 years in its packing case under normal storage conditions as defined in applicable document ESA PSS-01-202.

11.6 FUSE ACCESSIBILITY

When used, fuses shall be easily accessible for replacement.

Page intentionally left blank

12. OPERABILITY REQUIREMENTS

12.1 DIAGNOSTIC REQUIREMENTS

Sufficient telemetry monitoring points shall be provided to allow diagnostic analysis of the power subsystem during all mission phases and during ground check-out.

12.2 TELEMETRY PRECISION

The precision of any telemetry channel shall allow an assessment of the nominal or out-of-tolerance status of the monitored parameter.

As a minimum, sufficient telemetry shall be available to permit verification of the power budget with an accuracy of better than ±5% and other mission critical parameters with an accuracy of better than ±3% or ±1°C for temperature.

12.3 TELEMETRY SAMPLING RATE

The telemetry sampling rate shall allow an assessment of the nominal or out-of-tolerance status of the monitored parameters.

12.4 TELEMETRY CHANNELS

The telemetry channel types and allocations in the telemetry format are defined in ESA PSS-04-106: Packet Telemetry Standard .

12.5 TELECOMMAND STANDARD

Operation by telecommand shall be in accordance with the applicable document ESA PSS-04-107: Packet Telecommand Standard.

12.6 POWER SYSTEM TELECOMMAND CAPABILITY

The power system shall have a sufficient telecommand capability to allow power system operation after one failure in the required modes of the various mission phases.

12.7 TELECOMMAND ACCESS TO PROTECTION CIRCUITS

Provisions shall be included to inhibit or enable all mission-critical automatic protection circuits by telecommand and to monitor their separate status by telemetry.

13. QUALITY ASSURANCE REQUIREMENTS

13.1 GENERAL REQUIREMENTS

The general requirements for product assurance provisions are specified in applicable document ESA PSS-01-20: **Quality assurance requirements for ESA space systems.**

13.2 RESPONSIBILITY FOR INSPECTION AND TEST

Unless otherwise contractually specified, the supplier is responsible for all inspections and tests to be carried out on the equipment.

Tests may be conducted in the supplier's facilities or any commercial laboratory conforming to all requirements of this specification subject to prior approval by the prime contractor and ESA.

13.3 WITNESS TO INSPECTION AND TEST

The prime contractor and ESA shall have the option to witness all inspections and formal tests, all environmental exposures, verify all test equipment and calibration data, and examine all performance data and records appropriate to the product configuration.

13.4 PREPARATION FOR DELIVERY

Packing, preservation and packaging for shipment shall be according to the requirements of applicable document ESA PSS-01-202: **Preservation, storage, handling and transportation of ESA spacecraft hardware.**

Page intentionally left blank

14. QUALIFICATION AND TESTING REQUIREMENTS

14.1 GENERAL REQUIREMENTS

The environmental test requirements are specified in the applicable document ESA PSS-01-802: **Environment requirements specification for space equipment: unit-level environmental test specification**.

14.2 QUALIFICATION ASSURANCE OF TEST HOUSES

The quality assurance of test houses for ESA spacecraft and associated equipment is given in applicable document ESA PSS-01-203.

14.3 TEST: GENERAL

Each subsystem, item of equipment or payload shall be designed to be tested and the testability shall be verified by design review.

14.4 TEST: REDUNDANT FUNCTIONS

It shall be possible to test the presence of the redundant functions of a closed unit.

14.5 TEST: SELECTION ON TEST

Each **select on test** component shall be documented and justified separately.

14.6 TEST: POWER SYSTEM REQUIREMENTS

All requirements of Chapters 4, 5 and 6 shall be verified by analysis and/or test.

14.7 TEST: CONDUCTED EMISSION AND CONDUCTED SUSCEPTIBILITY

As a minimum, conducted emission and susceptibility shall be verified by test at equipment or payload level.

14.8 LIFE TESTS

All electromechanical (e.g. relays), thermomechanical (e.g. HV capacitors or HV transformers) and electrochemical (e.g. battery) components shall be submitted to a life test for qualification according to the use and life duration required by the application, following the rules set out in ESA PSS-01-60. ESA PSS-02-303 defines the requirements for HV transformers and components used in electronic power conditioners.

KEY WORD / REQUIREMENT CROSS REFERENCE

ac isolation 40
analysis 3, 4, 9, 12, 17, 40, 41, 47, 49, 55, 59
applicability 2
applicable documents 2, 3, 14, 44
applicable failure rates 47
battery 5, 7, 9, 12, 15, 19, 21-26, 32, 60
battery dc magnetic field design 22
battery dod versus life 24, 26
battery electrical design 21
battery management 23, 24
battery mechanical design 22
battery safety 23
battery thermal design 22
bonding 12, 21
bus impedance 16
bus recovery from a fuse clearance 33
bus ripple voltage 18
bus spike voltage 18
bus stability 17
bus voltages 11
cell by-pass protection 22
common ground point 9, 11
component current 37
component derating 14
conducted common mode current 41
conducted common-mode current 28
conducted common-mode voltage 29
connector 12, 21, 43, 45
connectors 13, 43-45, 49, 50
converter input ripple current 41
converter or regulator 28
converter stability 41
converter type loads 41
current inrush 34
current limitation 31
current slew rate 36
dc isolation 40
diagnostic requirements 55

distribution and protection 31
distribution node 33, 35
electrical isolation 21, 29
emc requirements 2, 5
emc standard 2
energy budget 12
eps 3, 1, 9
equipment and payloads 37
equipment identification 53
equipment life 53
esa standardisation policy 1
essential function protection 28, 38
essential functions 13, 14, 28, 38
external synchronisation 14, 15, 28
failure propagation 13, 32, 37, 45
free running frequency 28, 41
fuse accessibility 53
fuse clearance time 33
harness 12, 13, 32, 33, 35, 45
harness inductance 33
harness resistance 32, 33
hybrids 13, 40
input current modulation 38
inspection and test 57
integrated inrush current 39
interchangeability 53
life tests 60
load switching induced transients 35
maintainability and availability 53
maximum inrush current 39
non-essential loads 32
operability requirements 55
parts, material and processes 44
peak relay switch current 34
peak relay switch voltage 34
power budget 12, 55
power bus type 11
preparation for delivery 57
pressure vessels 49
printed circuit boards 5, 45, 51

protection 13, 15, 22, 28, 31-33, 38, 39, 49, 56
pyrotechnics 49, 50
qualification and testing requirements 59
qualification assurance of test houses 59
quality assurance requirements 3, 57
reconditioning 23, 24, 27
redundant functions 13, 59
reference documents 3, 7, 11, 23
regulation point 16-18, 31
relays and fuses 33
reliability requirements 40, 47
safe operation 38, 39
safety assurance 13
safety requirements 3, 4, 23, 49
scope 1
secondary voltage requirement 37
single point failure free 32
slip ring 19, 32
solar array 7, 12, 15, 19
solar array capability 19
solar array section 19
solar cell qualification 19
soldering 4, 5, 44
source requirements 15
sspc 10, 35, 36
storage and destorage of batteries 26
telecommand 6, 10, 14, 15, 28, 39, 45, 55, 56
telecommand access 56
telecommand capability 55
telecommand standard 6, 14, 55
telemetry 6, 10, 14, 15, 39, 45, 55, 56
telemetry channels 55
telemetry precision 55
telemetry sampling rate 55
temperature monitoring 14
terms, definitions, ... 9
test 3, 1-5, 7, 17, 18, 24, 26, 39, 41, 44, 45, 51, 57, 59, 60
test connectors 45
thermal and mechanical requirements 43
transport and handling 53

wiring and connectors 44
witness to inspection and test 57
workmanship 53