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Entwurf**Raumfahrttechnik –
Elektrik und Elektronik;
Englische Fassung prEN 16603-20:2020**

Space engineering –
Electrical and electronic;
English version prEN 16603-20:2020

Ingénierie spatiale –
Électrique et électronique;
Version anglaise prEN 16603-20:2020

Anwendungswarnvermerk

Dieser Norm-Entwurf mit Erscheinungsdatum 2020-03-06 wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfs besonders zu vereinbaren.

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Nationales Vorwort

Dieses Dokument (prEN 16603-20:2020) wurde vom Technischen Komitee CEN/CLC/JTC 5 „Raumfahrt“ erarbeitet, dessen Sekretariat von DIN (Deutschland) gehalten wird.

Das zuständige deutsche Normungsgremium ist der Arbeitsausschuss NA 131-06-02 AA „Interoperabilität von Informations-, Kommunikations- und Navigationssystemen“ im DIN-Normungsausschuss Luft- und Raumfahrt (NL).

Dieses Dokument enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung von prEN 16603-20:2020.

Nationaler Anhang NA (informativ)

Begriffe

Die Benennungen der folgenden Begriffe sind identisch mit den Benennungen in der englischen Fassung.

3 Begriffe und Abkürzungen

3.1 Begriffe aus anderen Normen

- a) Für die Anwendung dieser Norm gelten die Begriffe nach ECSS-S-ST-00-01.
- b) Für die Anwendung dieser Norm gelten die folgenden Begriffe nach ECSS-E-ST-20-20:
 - 1) Sperrstrombegrenzer [en: latching current limiter (LCL)]
 - 2) nachtriggerbarer Sperrstrombegrenzer [en: retriggerable latching current limiter (RLCL)]

3.2 Für diese Norm spezifische Begriffe

3.2.1

Antennenfarm

Gruppe aller am Raumfahrzeug angebrachten Antennen, mit denen sämtliche Funksignale gesendet und empfangen werden

3.2.2

Antennenanschluss

Abstraktion der physikalischen Verbindung zwischen der Antenne und deren Zuleitungen, die mithilfe von Steckverbindern oder Hohlleiterflanschen erhalten wird

3.2.3

Antennenfunktette

Reihenfolge von Mikrowellenkomponenten, die zwischen einem Eingangsanschluss der Antenne oder einem Ausgangsanschluss des BFN und einem entsprechenden einzelnen abstrahlenden Bauteil eingefügt sind

ANMERKUNG Beispiele für Mikrowellenkomponenten sind: Orthomodenkoppler, Polarisatoren, Transformatoren sowie Filter.

3.2.4

Antennentragstruktur

Teil einer Antenne ohne elektrische Funktion, der jedoch seine elektrischen Leistungen entweder direkt durch Streuung oder indirekt beeinflussen kann

ANMERKUNG Ein Beispiel für eine indirekte Wirkung sind induzierte thermoelastische Verformungen.

3.2.5

Gruppenantenne

Antenne, die aus einer Anzahl von möglicherweise unterschiedlichen, Elementen besteht, die Funksignale direkt in den freien Raum abstrahlen und in Kombination betrieben werden, so dass alle oder ein Teil davon die gleichen Signale abstrahlen

3.2.6

Reflektorantenne mit Speisearray

Antenne, die aus einem oder mehreren optischen Elementen, z. B. Reflektoren und Linsen, und einem Speisearray besteht, das ein Strahlformungsnetzwerk enthalten kann oder auch nicht

3.2.7

Batteriesammelschiene

Sammelschiene mit Primärversorgung, die direkt an die Batterie angeschlossen ist

ANMERKUNG Die Batteriesammelschiene wird manchmal als unregelmäßige Sammelschiene bezeichnet (obwohl die Batterieladung geregelt ist).

3.2.8

Strahlformungsnetzwerk (BFN)

Wellenleiterstruktur, die aus einer Kette von Mikrowellenkomponenten und -vorrichtungen besteht, die dafür vorgesehen sind, die an den Eingangsanschlüssen eingespeiste HF-Leistung auf eine Anzahl von Ausgangsanschlüssen zu verteilen; in einer Sendeantenne wird die vom Sender eingespeiste HF-Leistung zu den abstrahlenden Bauteilen geleitet, in einer Empfangsantenne wird die von den abstrahlenden Bauteilen kommende HF-Leistung zu den mit dem Empfänger verbundenen Antennenanschlüssen geleitet

ANMERKUNG Beispiele für Mikrowellenkomponenten und -vorrichtungen sind Leitungen, Phasenschieber, Kupplungen und Verbraucher.

3.2.9

leitungsgeführte Emission (CE)

erwünschte oder unerwünschte elektromagnetische Energie, die sich entlang eines Leiters ausbreitet

3.2.10

kritischer Druck

Druck, bei dem eine Korona- oder Teilentladung in einem Gerät auftreten kann

3.2.11

Diffusionsvermögen

Fähigkeit eines Körpers, inkohärente diffuse Streuung aufgrund lokaler Rauigkeit, Inhomogenität oder Anisotropie zu erzeugen, wenn er mit Hochfrequenzwellen beleuchtet wird

3.2.12

Entladetiefe (DOD)

einer Batterie entnommene Amperestunde, angegeben als prozentualer Anteil der installierten Ladung

3.2.13

doppelte Isolierung

Barriere zwischen Leitern oder Elementen einer elektronischen Schaltung, so dass nach einem anzunehmenden Einzelausfall Leiter oder Elemente einer elektronischen Schaltung immer noch voneinander isoliert sind

3.2.14

elektrische Kontaktierung

Prozess des Verbindens von leitenden Teilen, so dass ein niederohmiger Pfad für Erdungs- und Schirmungszwecke hergestellt wird

3.2.15

elektromagnetische Verträglichkeit (EMC)

Fähigkeit eines Gerätes oder eines Elements, in seiner elektromagnetischen Umgebung zufriedenstellend zu funktionieren, ohne dass in dieser Umgebung unerträgliche elektromagnetische Störungen auftreten

3.2.16

Überwachung der elektromagnetischen Verträglichkeit

Reihe von Techniken zur wirksamen Regulierung der elektromagnetischen Störfeldumgebung oder der Empfindlichkeit einzelner Raumfahrtssystemkomponenten oder beidem

ANMERKUNG Sie umfassen u. a. anderem das Design, die Anordnung von Komponenten, die Schirmung und den Einsatz von Sperrfiltern.

3.2.17

elektromagnetische Störung (EMI)

unerwünschtes elektrisches Phänomen, das durch jedes Gerät, dessen normale Funktion von der Nutzung elektrischer Phänomene abhängt, erzeugt wird oder dieses nachteilig beeinflusst

ANMERKUNG Es ist durch Anzeichen einer Verschlechterung der Leistung eines Geräts, Übertragungskanal oder Elements gekennzeichnet, die durch eine elektromagnetische Störung verursacht wird.

3.2.18

Sicherheitsfaktor für elektromagnetische Störungen (EMISM)

Verhältnis zwischen der Empfindlichkeitsschwelle und der an einem Prüfpunkt vorhandenen Störung

3.2.19

Emission

elektromagnetische Energie, die sich durch Strahlung oder Übertragung ausbreitet

3.2.20

Energiebilanz

Situation, in der der Energiehaushalt des Raumfahrzeugs positiv ist, wenn er über einen bestimmten Zeitraum erarbeitet wird

ANMERKUNG 1 Energiehaushalt ist Erzeugung minus Verbrauch und Verluste.

ANMERKUNG 2 Der betrachtete Zeitraum kann ein Orbit, mehrere Orbits oder ein beliebiger relevanter Missionszeitraum sein.

3.2.21

Energiereserve

Energie, die von der Energiespeicherbaugruppe am ungünstigsten, am meisten erschöpften Punkt des Nennbetriebs verfügbar bleibt

ANMERKUNG Es ist wichtig, dass die Energiereserve ausreichend ist, damit beim Auftreten einer Anomalie ein sicherer Betriebsmodus erreicht wird.

3.2.22

wesentliche Funktion

Funktion, ohne die das Raumfahrzeug nach jedem denkbaren Ausfall an Bord oder am Boden nicht wiederhergestellt werden kann

ANMERKUNG Beispiele für irreparable Raumfahrzeuge sind Raumfahrzeuge, bei denen keine Befehle erteilt werden können, die Einstellung und Kontrolle des Raumfahrzeugs dauerhaft verloren gehen oder die Energiebilanz nicht länger sichergestellt ist oder die Verbrauchsmaterialien des Raumfahrzeugs (z. B. Hydrazin oder Xenon) in einem Ausmaß erschöpft sind, dass mehr als 10 % von dessen Lebensdauer beeinträchtigt oder die Sicherheit der Besatzung gefährdet ist.

3.2.23

fehlerhaftes Signal

von einem Stromkreis erzeugtes Signal, das an seiner Schnittstelle zu einem anderen Stromkreis auftritt und aufgrund eines Fehlers seinen Nennbereich verlässt

3.2.24

Foldback-Strombegrenzer (FCL)

nicht sperrstrombegrenzende Funktion, bei der sich die Strombegrenzung mit der Ausgangsspannung verringert

ANMERKUNG Diese Funktion wird für die Energieverteilung und den Schutz angewendet, üblicherweise für wichtige Verbraucher.

3.2.25

vollständig regulierte Sammelschiene

Sammelschiene, die bei Sonnenlicht und Finsternis mit einer geregelten Spannung Strom liefert

3.2.26

Erdung

Verfahren zum Herstellen von absichtlichen elektrischen Leiterbahnen zwischen einem Referenzstromkreis oder einem leitenden Teil und einem Gerätegehäuse oder einer Raumfahrzeugstruktur

ANMERKUNG Die Erdung erfolgt üblicherweise zu Sicherheits-, Funktions-, Signalintegritäts-, EMI-Kontroll- oder Ladungsableitungszwecken.

3.2.27

Telekommando mit hoher Priorität (HPC)

Befehl, der von der Bodenstation abgegeben und vom Fernsteuer-Decoder für wesentliche Raumfahrzeugfunktionen ohne Eingriff der bordseitigen Software ausgegeben wird

3.2.28

Hochspannung

Wechsel- oder Gleichspannung, bei der Teilentladungen, Corona-, Lichtbogen- oder hohe elektrische Felder auftreten können

3.2.29

Linsenantenne

Antenne, die aus mehreren Hochfrequenzlinsen und reflektierenden Oberflächen besteht und durch diese beleuchtet wird, die von einer Primärquelle, dem Speisearray, versorgt werden

3.2.30

indirekte Auswirkungen von Blitzen

aufgrund der Kopplung elektromagnetischer Felder durch Blitzeinschlag in Stromkreisen hervorgerufene elektrische Transienten

3.2.31

wesentliche Rekonfigurationsfunktion

Funktion zur Behebung von Systemausfällen der Kritikalität 1, 2 oder 3

ANMERKUNG Kritikalitätskategorien sind in ECSS-Q-ST-30 und ECSS-Q-ST-40 definiert.

3.2.32

installierte Ladung

vom Hersteller einer Energiespeicherzelle oder Batterie angegebene Kapazität

ANMERKUNG Sie wird in Amperestunden angegeben. Sie entspricht nicht notwendigerweise jeder messbaren Kapazität.

3.2.33

weniger wichtige Verbraucher

auf Geräte bezogene Verbraucher, durch die keine für das Raumfahrzeug wesentlichen Funktionen ausgeführt werden

3.2.34

passive Intermodulationsprodukte (PIM)

Störsignale, die durch nichtlineare Strom-Spannungs-Eigenschaften in Materialien und Übergängen erzeugt werden, die einer ausreichend Hochfrequenz ausgesetzt sind, die von geführten oder abgestrahlten Feldern und Strömen getragen wird, möglicherweise ausgelöst durch eine mikroskopisch kleine mechanische Bewegung

3.2.35

fotovoltaische Baugruppe (PVA)

Stromerzeugungsnetz, das die verbundenen Solarzellenbaugruppen, die Nebenschluss- und Sperrdioden, die Sammelschienen- und Kollektoremodulverdrahtung, die Strang-, Abschnitts- und Modulverdrahtung, den Flügeltransferkabelbaum, Steckverbinder, Ableitwiderstände und Thermistoren umfasst

3.2.36

Primärzelle oder -batterie

Batterie oder Zelle, die so ausgelegt ist, dass sie einmal entladen und niemals aufgeladen wird

3.2.37

Sammelschiene mit Primärversorgung

elektrischer Knoten des Raumfahrzeugs, der den Energiequellen am nächsten liegt, in der die Energie gesteuert und den Benutzergeräten zur Verfügung gestellt wird

3.2.38

Hochfrequenz (RF)

für die Übertragung elektromagnetischer Wellen verwendetes Frequenzband

3.2.39

gestrahlte Störaussendung (RE)

Strahlungs- und Induktionsfeldkomponenten in der Raumfahrt

3.2.40

Wiederaufladungsverhältnis (k)

aufgeladene Amperestunden geteilt durch die zuvor entladenen Amperestunden, Beginn und Ende im gleichen Ladezustand

ANMERKUNG Es ist auch als k-Faktor bekannt.

3.2.41

Reflektorantenne

Antenne, die aus mehreren reflektierenden Oberflächen und Hochfrequenzreflektoren besteht und durch diese beleuchtet wird, die von einer Primärquelle, dem Speisearray, versorgt werden

3.2.42

Funkkette

Reihenfolge von Mikrowellenkomponenten, die zwischen dem Hochfrequenzleistungsverstärker und dem Eingangsanschluss der Antenne eingefügt sind

3.2.43

Hochfrequenzlinse

Kunststoff-, Verbund- oder Metallstruktur, die auf gesendete Hochfrequenzwellen einwirkt, um das Antennenmuster zu steuern

ANMERKUNG Beispiele für Metallstrukturen sind Linsen für Wellenleiter-Arrays.

3.2.44

Hochfrequenzreflektor

Metall- oder Verbundstruktur, möglicherweise verspiegelt oder mit aufgedruckten oder eingebetteten Metallelementen, die auf reflektierte Hochfrequenzwellen einwirken, um das Antennenmuster zu steuern

ANMERKUNG Als Reflektoren gelten Frequenz- und Polarisationsflächen sowie andere voll- oder teilreflektierende und transmittierende Strukturen, die auch ein ungleichmäßiges oder anisotropes Streuverhalten aufweisen.

3.2.45

Sekundärzelle oder -batterie

Batterie oder Zelle, die so ausgelegt ist, dass sie mehrfach aufgeladen und entladen wird

3.2.46

solarer Aspektwinkel (SAA)

Winkel zwischen der Normalen zu einem Solarmodul und dem Sonnenvektor

3.2.47

Solarzellen-Baugruppe, Solarzellenanordnung (SCA)

Solarzelle zusammen mit Verbindungsleitung, Deckglas und, wenn angewendet, auch einer Bypass-Diode

3.2.48

Empfindlichkeit

Störung, Leistungsabfall oder Abweichung von den festgelegten Angaben zu den in den Spezifikationen der einzelnen Geräte oder Teilsysteme über die angegebenen Toleranzen hinaus als Reaktion auf andere als die beabsichtigten Reize

3.2.49

Empfindlichkeitsschwelle

Interferenzpegel an einem Prüfpunkt, der nur eine Störung der Einrichtung, des Subsystems oder des Systems verursacht

3.2.50

Vakuum

Umgebung mit einem Druck von höchstens 10 Pa

3.3 Abkürzungen

Für die Anwendung dieser Norm gelten die Abkürzungen nach ECSS-S-ST-00-01 und die folgenden Abkürzungen:

Abkürzung	Bedeutung
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A	Analyse (en: analysis)
AC	Wechselstrom (en: alternating current)
AR	Abnahme-Review (en: acceptance review)
BOL	Beginn der Lebensdauer (en: beginning-of-life)
CDR	kritisches Design-Review (en: critical design review)

Abkürzung	Bedeutung
DC	Gleichstrom (en: direct current)
DDF	Datei der Entwurfsdefinition (en: design definition file)
DJF	Datei zur Begründung des Entwurfs (en: design justification file)
DOD	Entladetiefe (en: depth of discharge)
DRB	Lieferungs-Untersuchungsausschuss (en: delivery review board)
DRD	Definition der Dokumentanforderungen (en: document requirements definition)
DRL	Dokumenten Anforderungsliste (en: document requirements definition)
EED	elektrisches Anzünd- und Zündmittel (en: electro-explosive device)
EGSE	elektrische Bodendienstgeräte (en: electrical ground support equipment)
EIDP	Endeinheit-Datenpaket (en: end item data package)
EMC	elektromagnetische Verträglichkeit (en: electromagnetic compatibility)
EMCAB	beratender Ausschuss für elektromagnetische Verträglichkeit (en: electromagnetic compatibility advisory board)
EMEVP	Prüfplan für elektromagnetische Auswirkungen (en: electromagnetic effects verification plan)
EMEVR	Prüfbericht für elektromagnetische Auswirkungen (en: electromagnetic effects verification report)
EMI	elektromagnetische Störung (en: electromagnetic interference)
EOL	Ende der Lebensdauer (en: end of life)
EPS	Energieversorgungssystem (en: electrical power subsystem)
ESA	Europäische Weltraumorganisation (en: European Space Agency)
ESD	elektrostatische Entladung (en: electrostatic discharge)
FCL	Foldback-Strombegrenzer (en: fold-back current limiter)
FDIR	Fehlererkennung und -isolierung sowie Wiederherstellung (en: failure detection isolation and recovery)
FMECA	Fehlermöglichkeits-, Einfluss- und Kritikalitäts-Analyse (en: failure modes, effects and criticality analysis)
INS	Inspektion
ICD	Schnittstellenüberwachungsdokument (en: interface control document)
I-V	Stromspannung (en: current-voltage)
LCL	Sperrstrombegrenzer (en: latching current limiter)
MPPT	Maximum Power Point Tracker
MRB	Herstellungs-Prüfausschuss (en: manufacturing review board)
OBC	Bordcomputer (en: on-board computer)
PCB	Leiterplatte (en: printed circuit board)
PDR	vorläufiges Design-Review (en: preliminary design review)
PVA	fotovoltaische Baugruppe (en: photovoltaic assembly)
QTR	Qualifikationsprüfbericht (en: qualification test report)

Abkürzung	Bedeutung
RF	Hochfrequenz (en: radio frequency)
RLCL	nachtriggerbarer Sperrstrombegrenzer (en: retriggerable latching current limiter)
ROD	Entwurfsbewertung (en: review of design)
PSA	Belastungsanalyse für Teile (en: part stress analysis)
SAA	solarer Aspektwinkel (en: solar aspect angle)
SADM	Mechanismus zum Drehen von Solarmodulen (en: solar array drive mechanism)
SCA	Solarzellen-Baugruppe, Solarzellenanordnung (en: solar cells assembly)
SEE	Auswirkungen durch ein Einzelereignis (en: single event effects)
SEU	Einzelereignis-Upsets (en: single event upsets)
SPF	Einzelausfall (en: single point failure)
SRR	Systemanforderungsüberprüfung (en: system requirements review)
T	Prüfung (en: test)
TRB	Ausschuss für die Bewertung der Prüfung (en: test review board)
TRR	Testbereitschafts-Review (en: test readiness review)
TM&TC	Telemetrie/Fernsteuern (en: telemetry/telecommand)
UV	ultraviolett (en: ultraviolet)
VCD	Verifizierungskontrolldokument (en: verification control document)
WCA	Analyse des ungünstigen Falls (en: worst case analysis)

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English version

Space engineering - Electrical and electronic

Ingénierie spatiale - Électrique et électronique

Raumfahrttechnik - Elektrik und Elektronik

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

If this draft becomes a European Standard, CEN and CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN and CENELEC in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN and CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation. Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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European Foreword

This document (prEN 16603-20:2020) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN (Germany).

This document (prEN 16603-20:2020) originates from ECSS-E-ST-20C Rev.1.

This document is currently submitted to the CEN Enquiry.

This document has been developed to cover specifically space systems and will therefore have precedence over any EN covering the same scope but with a wider do-main of applicability (e.g. : aerospace).

1

Scope

This Standard establishes the basic rules and general principles applicable to the electrical, electronic, electromagnetic, microwave and 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 ECSS-E-ST-10 “Space engineering – System engineering general requirements”.

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

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 revision 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 more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
EN 16603-10	ECSS-E-ST-10	Space engineering – System engineering general requirements
EN 16603-20-06	ECSS-E-ST-20-06	Space engineering – Spacecraft charging
EN 16603-20-07	ECSS-E-ST-20-07	Space engineering – Electromagnetic compatibility
EN 16603-20-08	ECSS-E-ST-20-08	Space engineering - Photovoltaic assemblies and components
EN 16603-20-20	ECSS-E-ST-20-20	Space engineering - Electrical design and interface requirements for power supply
EN 16603-33-11	ECSS-E-ST-33-11	Space engineering – Explosive systems and devices
EN 16603-50-05	ECSS-E-ST-50-05	Space engineering – Radio frequency and modulation
EN 16603-50-14	ECSS-E-ST-50-14	Space engineering – Spacecraft discrete interfaces
EN 16602-30-11	ECSS-Q-ST-30-11	Space product assurance – Derating – EEE components
EN 16602-40	ECSS-Q-ST-40	Space product assurance – Safety
	IEEE 145-1993	Antenna terms
	Impedance Specifications for Stable DC Distributed Power Systems, EEE transactions on power electronics, Vol. 17, no. 2, March 2002	Impedance Specifications for Stable DC Distributed Power Systems, X. Feng, J. Liu, F.C. Lee, IEEE Transactions on power electronics, Vol. 17, no. 2, March 2002

Terms, definitions and abbreviated terms

3.1 Terms from other standards

- a. For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply.
- b. For the purpose of this Standard, the following terms and definitions from ECSS-E-ST-20-20 apply:
 - 1. latching current limiter (LCL)
 - 2. retriggerable latching current limiter (RLCL)

3.2 Terms specific to the present standard

3.2.1 antenna farm

ensemble of all antennas accommodated on the spacecraft and provides for all the transmission and reception of RF signals

3.2.2 antenna port

abstraction of the physical connection among the antenna and its feeding lines, realised by means of connectors or waveguide flanges

3.2.3 antenna RF chain

sequence of microwave components inserted between an antenna input port or a BFN output port and a corresponding individual radiating element

NOTE Examples of microwave components are: ortho-mode transducers, polarisers, transformers as well as filters.

3.2.4 antenna support structure

part of an antenna having no electrical function, which can however impact its electrical performances, either directly due to scattering or indirectly

NOTE Example of indirect effect is induced thermo-elastic deformations.

3.2.5 array antenna

antenna composed by a number of, possibly different, elements that radiate RF signals directly into free space operating in combination, such that all or a part of them radiate the same signals

3.2.6 array-fed reflector antenna

antenna composed by a feed array, which can include or not a beam forming network, and one or more optical elements like reflectors and lenses

3.2.7 battery bus

primary power bus directly connected to the battery

NOTE Battery bus is sometimes called unregulated bus (although the battery charge is regulated).

3.2.8 beam forming network (BFN)

wave-guiding structure composed a chain of microwave components and devices aimed at distributing the RF power injected at the input ports to a number of output ports; in a transmitting antenna the RF power injected from the transmitter is routed to the radiating elements, in a receiving antenna the RF power coming from the radiating elements is routed to the antenna ports connected to the receiver

NOTE Examples of microwave components and devices are lines, phase shifters, couplers, loads.

3.2.9 conducted emission (CE)

desired or undesired electromagnetic energy that is propagated along a conductor

3.2.10 critical pressure

pressure at which corona or partial discharge can occur in an equipment

3.2.11 diffusivity

ability of a body to generate incoherent diffuse scattering due to local roughness, inhomogeneity or anysotropy when illuminated by RF waves

3.2.12 depth of discharge (DOD)

ampere-hour removed from a battery expressed as a percentage of the nameplate capacity

3.2.13 double insulation

barrier between conductors or elements of an electronic circuit such that after any credible single failure, conductors or elements of an electronic circuit are still insulated from each other

3.2.14 electrical bonding

process of connecting conductive parts to each other so that a low impedance path is established for grounding and shielding purposes

3.2.15 electromagnetic compatibility (EMC)

ability of equipment or an element to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

3.2.16 electromagnetic compatibility control

set of techniques to effectively regulate the electromagnetic interference environment or susceptibility of individual space system components or both

NOTE They include, among others, the design, placement of components, shielding, and employment of rejection filters.

3.2.17 electromagnetic interference (EMI)

undesired electrical phenomenon that is created by, or adversely affects any device whose normal functioning is predicated upon the utilization of electrical phenomena

NOTE It is characterized by the manifestation of degradation of the performance of an equipment, transmission channel, or element caused by an electromagnetic disturbance.

3.2.18 electromagnetic interference safety margin (EMISM)

ratio between the susceptibility threshold and the interference present on a test point

3.2.19 emission

electromagnetic energy propagated by radiation or conduction

3.2.20 energy balance

situation in which the spacecraft energy budget is positive when elaborated over a considered period of time

NOTE 1 Energy budget is generation minus consumption and losses.

NOTE 2 The considered period of time can be one orbit, several orbits or any relevant mission period.

3.2.21 energy reserve

energy that remains available from the energy storage assembly at the worst-case, most depleted, point of nominal operations

NOTE It is important that the energy reserve is sufficient to permit reaching a safe operating mode upon occurrence of an anomaly

3.2.22 essential function

function without which the spacecraft cannot be recovered following any conceivable on-board or ground-based failure

NOTE Examples of unrecoverable spacecraft is when spacecraft cannot be commanded, or permanently losses attitude and control, or the energy balance is no longer ensured, or the spacecraft consumables (e.g. hydrazine or Xenon) are depleted to such an extent that more than 10% of its lifetime is affected, or the safety of the crew is threatened.

3.2.23 faulty signal

signal generated by a circuit, appearing at its interface to another circuit, going out of its nominal range because of a failure

3.2.24 foldback current limiter (FCL)

non latching current-limiting function where the current limit decreases with the output voltage

NOTE This function is used for power distribution and protection typically for essential loads.

3.2.25 fully regulated bus

bus providing power during sunlight and eclipse periods with a regulated voltage

3.2.26 grounding

process of establishing intentional electrical conductive paths between an electrical circuit reference or a conductive part and equipment chassis or space vehicle structure

NOTE grounding is typically performed for safety, functionality, signal integrity, EMI control or charge bleeding purpose.

3.2.27 high Priority telecommand (HPC)

command originated from ground and issued by the telecommand decoder for essential spacecraft functions without main on board software intervention

3.2.28 high voltage

AC or DC voltage at which partial discharges, corona, arcing or high electrical fields can occur

3.2.29 lens antenna

antenna composed by a number of RF lenses and reflecting surfaces illuminated by a primary source, the feed

3.2.30 lightning indirect effects

electrical transients induced by lightning in electrical circuits due to coupling of electromagnetic fields

3.2.31 major reconfiguration function

function used to recover from system failures of criticality 1, 2 or 3

NOTE Criticality categories are defined in ECSS-Q-ST-30 and ECSS-Q-ST-40.

3.2.32 nameplate capacity

capacity stated by the manufacturer of an energy storage cell or battery

NOTE It is given in ampere-hours. It is not necessarily equal to any measurable capacity.

3.2.33 non essential loads

loads related to units which do not implement essential functions for the spacecraft

3.2.34 passive intermodulation products (PIM)

spurious signals generated by non-linear current-voltage characteristics in materials and junctions exposed to sufficiently RF high power carried by guided or radiated fields and currents, possibly triggered by microscopic mechanical movement

3.2.35 photovoltaic assembly (PVA)

power generating network comprising the interconnected solar cell assemblies, the shunt and blocking diodes, the busbars and wiring collection panels, the string, section and panel wiring, the wing transfer harness, connectors, bleed resistors and thermistors

3.2.36 primary cell or battery

battery or cell that is designed to be discharged once and never to be recharged

3.2.37 primary power bus

spacecraft electrical node closest to the power sources where power is controlled and made available to the user equipment

3.2.38 radiofrequency (RF)

frequency band used for electromagnetic waves transmission

3.2.39 radiated emission (RE)

radiation and induction field components in space

3.2.40 recharge ratio (k)

ampere-hours charged divided by the ampere-hours previously discharged, starting and finishing at the same state of charge

NOTE It is also known as the k factor.

3.2.41 reflector antenna

antenna composed by a number of reflecting surfaces, RF reflectors, illuminated by a primary source, the feed

3.2.42 RF chain

sequence of microwave components inserted between the RF power amplifier and the antenna input port

3.2.43 RF lens

plastic, composite or metallic structure acting on transmitted RF waves to control the antenna pattern

NOTE Example of metallic structures are waveguide array lenses.

3.2.44 RF reflector

metallic or composite structure, possibly metallised or with printed or embedded metallic elements, acting on reflected RF waves to control the antenna pattern

NOTE Frequency and polarisation surfaces as well as other fully reflecting or partially reflecting and transmitting structures, also having non-uniform or anisotropic scattering behaviour, are considered reflectors

3.2.45 secondary cell or battery

battery or cell that is designed to be charged and discharged multiple times.

3.2.46 solar aspect angle (SAA)

angle between the normal to a solar panel and the sun vector

3.2.47 solar cell assembly (SCA)

solar cell together with interconnector, coverglass and if used, also a by-pass diode

3.2.48 susceptibility

malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification in response to other than intended stimuli

3.2.49 susceptibility threshold

interference level at a test point which just causes malfunction in the equipment, subsystem, or system

3.2.50 vacuum

environment with a pressure of 10 Pa or below

3.3 Abbreviated terms

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

Abbreviation	Meaning
A	analysis
AC	alternating current
AR	acceptance review
BOL	beginning-of-life
CDR	critical design review
DC	direct current
DDF	design definition file
DJF	design justification file
DOD	depth of discharge
DRB	Delivery review board
DRD	document requirement definition
DRL	document requirement list
EED	electro-explosive device
EGSE	electrical ground support equipment
EIDP	end item data-package
EMC	electromagnetic compatibility
EMCAB	EMC Advisory Board
EMEVP	electromagnetic effects verification plan
EMEVR	electromagnetic effects verification report
EMI	electromagnetic interference
EOL	end of life
EPS	electrical power subsystem
ESA	European space agency
ESD	electrostatic discharge
FCL	fold-back current limiter
FDIR	failure detection isolation and recovery
FMECA	failure mode effect and criticality analysis
INS	inspection
ICD	interface control document
I-V	current-voltage
LCL	latching current limiter
MPPT	maximum power point tracker
MRB	manufacturing review board

Abbreviation	Meaning
OBC	on-board computer
PCB	printed circuit board
PDR	preliminary design review
PVA	photovoltaic assembly
QTR	qualification test report
RF	radio frequency
RLCL	retriggerable latching current limiter
ROD	review of design
PSA	Part stress analysis
SAA	solar aspect angle
SADM	solar array drive mechanism
SCA	solar cells assembly
SEE	single event effects
SEU	single event upsets
SPF	single point failure
SRR	system requirement review
T	test
TRB	test review board
TRR	test readiness review
TM&TC	telemetry/telecommand
UV	ultraviolet
VCD	verification control document
WCA	worst case analysis

3.4 Nomenclature

The following nomenclature applies throughout this document:

- a. The word “shall” is used in this Standard to express requirements. All the requirements are expressed with the word “shall”.
- b. The word “should” is used in this Standard to express recommendations. All the recommendations are expressed with the word “should”.

NOTE It is expected that, during tailoring, recommendations in this document are either converted into requirements or tailored out.

- c. The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive

permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.

- d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

NOTE In ECSS “may” and “can” have completely different meanings: “may” is normative (permission), and “can” is descriptive.

- e. The present and past tenses are used in this Standard to express statements of fact, and therefore they imply descriptive text.

General requirements

4.1 Interface requirements

4.1.1 Overview

ECSS-E-ST-10 specifies that interfaces external or internal to a system are adequately specified and verified. The following requirements address this issue and are processed in phase B, C and D of a project (see ECSS-E-ST-10).

4.1.2 Signals interfaces

- a. Interface engineering shall ensure that the characteristics on both sides of each interface are compatible, including source and load impedances, the effects of the interconnecting harness and the grounding network between both sides comprising: common mode impedance conducted and radiated susceptibility and emission.
- b. In order to minimize the number of interface types, standard interface circuitry shall be defined to be applied throughout a project.
- c. Reconfiguration, high level or high priority command lines shall be immune to spurious activation.
- d. The application of the nominal signals or a faulty signal to an un-powered interface shall not cause damage to that interface.

NOTE This requirement covers all types of interfaces.
Standard interfaces are covered in clauses 4.2.4.3 and 4.2.4.4 of ECSS-E-ST-50-14.

- e. An undetermined status at the interfaces of a powered unit shall not cause damage to an un-powered interface.

NOTE Undetermined status includes: non-nominal operating modes, permanent and non-permanent failure modes, powered and un-powered interfaces.

- f. Signal interfaces shall withstand without damage positive or negative nominal voltages that are accessible on the same connector, coming from the unit itself, from the interfaced units or from EGSE.

4.1.3 Commands

- a. Every command (intended to be sent to the spacecraft) shall be assessed for criticality at equipment level, and confirmed at subsystem/system level.

NOTE 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. The definition of criticalities can be found in ECSS-Q-ST-30 and ECSS-Q-ST-40.

- b. All executable commands shall be explicitly acknowledged by telemetry.
- c. High Priority telecommand decoding and generation shall be independent from the main on-board processor and its software.

NOTE For failure case, refer to requirement 4.2.1a.

- d. With the exception of pyrotechnic commands, the function of an executable command shall
1. not change throughout a mission, and
 2. not depend on the history of previous commands.
- e. For commands of category 1 and 2 criticality, at least two separate commands for execution: an arm/safe or enable/disable followed by an execute command shall be used.

NOTE For criticality categories, see ECSS-Q-ST-30 or ECSS-Q-ST-40.

- f. The functionality shall be provided to repeat the transmission of all the executable commands without degradation of the function or a change of its status.
- g. In case of critical commands of category 1 and 2, at least two physically independent electrical barriers, including associated control circuits, shall be implemented for arming and executing the command.

NOTE 1 For criticality categories, see ECSS-Q-ST-30 or ECSS-Q-ST-40.

NOTE 2 Mechanical barriers can be considered.

NOTE 3 Physically independent electrical barriers and associated control circuits are the ones not sharing any hardware function and without risk of reciprocal failure propagation.

- h. Processor and simple logic circuits shall not be able to issue category 1 and 2 critical commands without a ground commanded arm/safe or enable/ disable command.

NOTE To avoid inadvertent activation of processes enabled/disabled by category 1 or 2 critical commands during ground operations and in low earth orbit phases, it is necessary to foresee safety barriers (arm/safe commands) to inhibit

the execution of such critical commands. Such safety barriers might be spacecraft skin connections (to be established or broken just before flight) or connections/disconnection plugs to be activated by launcher stages release (in flight). The activation/deactivation of such barriers has to be independent from on board processor.

- i. Any on-board processing which issues commands to reconfigure subsystems or payloads shall be overridable and potentially inhibited by ground command.

NOTE For criticality categories, see ECSS-Q-ST-30 or ECSS-Q-ST-40.

- j. No valid command shall be issued until the transmitter power supply is within operational voltage range and ready to transmit the command.

4.1.4 Telemetry

- a. Telemetry data devoted to the spacecraft subsystem and payloads monitoring shall allow
 - 1. the retracing of the overall configuration at least up to all reconfigurable elements.
 - 2. the location of any failure able to impact the mission performances and reliability at least up to all reconfigurable elements.
- b. The operational status (On/Off, enabled/disabled, active/not-active) of each element of any telemetry acquisition chain should be provided to the on-board computer in order to determine without ambiguity the validity of the telemetry data at the end of the overall chain.
- c. Primary bus load currents shall be monitored by telemetry, to enable, together with the bus voltage telemetry, a complete monitoring of a primary bus power load.
- d. Telemetry shall be implemented to monitor the evolution of the power-energy resources and the source temperatures during the mission.

4.2 Design

4.2.1 Failure containment and redundancy

- a. Failure propagation shall meet the following conditions:
 - 1. A single hardware failure does not propagate to neighbouring components circuits or interfaces in an undetermined way.
 - 2. Failure propagation is verified by analysis.

3. Mechanical, thermal or electrical propagation of single hardware failures does not impair the corresponding protection or redundancy implemented at equipment or system level.
4. Single hardware failure does not propagate to equipment or functions under different contractual responsibility than the item where the failure takes place.

NOTE 1 4.2.1a.4 is normally covered by specification of fault emission and tolerance conditions.

NOTE 2 Component assembly (e.g. single cavity hybrid) and integrated circuits, especially if they contain redundancy or protection, require special attention."

- b. Redundant signal or power lines should be segregated via physically separated connectors and harnesses.
- c. Routing of redundant power or signal lines within common harness or connector shall be justified by analysis showing that inside the electrical unit and at external connector interface level there is no potential single failure leading to affect both nominal and redundant lines or to generate electrical or electromagnetic interference between both.

NOTE 1 Typical analysis for demonstrating compliance is provided within FMEA and EMC coupling analysis.

NOTE 2 Potential single failure includes short-circuit cases."

- d. Redundant functions shall be physically separated with no risk of failure propagation by thermal or other coupling and as a minimum, contained within different integrated circuits to avoid failure propagation.
- e. For redundant functions implemented on the same PCB, a physical separation shall be provided, with no risk of thermal or other failure propagation.

NOTE Example of physical separation are by a minimum distance, insulation, or cut-out.

- f. For redundant functions implemented on the same PCB, any deviation of the physical separation specified in 4.2.1e shall be tracked in the Critical item List.

- g. <<deleted>>

- h. In case a cold redundant function is simultaneously activated together with the nominal one, by a deliberate or wrong command or due to a fault, this shall not induce permanent degradation of either of the two functions or loss of the mission before FDIR action.

NOTE E.g. thermal and EMC functions.

- i. <<deleted>>

- j. Any active equipment, excluding heaters, dissipating more than 20 W in nominal or failure condition shall include a temperature monitoring available to the system.

- k. In case of signal cross-strapping, no single failure of either interface circuit shall propagate to the other one.
- l. In the case of hot redundant essential functions, latching protection shall not be used unless it has an autonomous periodic reset.
- m. Disabling critical on-board autonomous functions shall be allowed only if an interlock mechanism is implemented, which prevents the disabling of both main and redundant functions at the same time.

NOTE Critical functions refers to functions which prevent the satellite from being recovered when both main and redundant are switched off, e.g. RF receiver or command decoder.

- n. Any protection latch, which does not have autonomous reset capability, shall be at least re-settable from ground command.
- o. Any protection of an essential function shall not share with the essential function itself the same component or integrated circuit nor utilize common references or auxiliary supply.
- p. Essential functions shall not be lost upon a single failure of other functions which are centrally powered or controlled.

NOTE 1 E.g. on synchronization and auxiliary supply.

NOTE 2 That can imply the capability of an equipment performing an essential function of operating independently of any external synchronization and auxiliary power supply if these are not SPF free.

- q. For essential functions supplied by an FCL, lock-up phenomenon requiring recovery via the removal of external power shall be prevented.
- r. All units to be powered during launch shall be designed for operation with critical pressure.
- s. A venting analysis shall be performed for all units not designed to operate under critical pressure and not powered during launch, to determine when they can safely be turned-on.
- t. Any on-board autonomous function, the failure of which can result in malfunctions of category 1 and 2 criticality, shall have override capability.

NOTE Examples of override are:

- a simple inhibition or isolation (e.g. cold or hot redundant chain[s] exists)
 - an H/W reset (e.g. in case of SEU)
 - an inhibition + by-pass (e.g. a stepper motor control loop by-passed by a direct step by step command as back-up)
- u. Any on-board autonomous protection override, leading to hazardous situation for the mission (category 1 and 2 criticality), shall not be implemented.

NOTE E.g. an LCL function for instance protecting the main power Bus against a short circuit at Bus user level or Main Bus over-voltage protection.

- v. SEE shall not activate protection circuits of essential functions.

NOTE Mitigation techniques can be implemented to avoid such phenomena: filtering, majority voting, etc

- w. The spacecraft electrical system shall be single failure tolerant for unmanned mission and double failure tolerant for manned mission.
- x. Occurrence of a non-destructive SEE after a failure shall not lead to the loss of the mission.

NOTE Accordingly, a non-destructive SEE cannot derail a reconfiguration process after first hardware failure.

4.2.2 Data processing

4.2.2.1 Overview

All operational and mission specific data are processed for acquisition, algorithm application, transmission, storage. On board time is managed by data handling subsystem, in line with the mission requirements. Data processing includes the man machine, interface if any. The data processing system includes all hardware and software elements used for that purpose (e.g. microprocessor and its instruction set, interface means, data busses and remote terminals).

4.2.2.2 Provisions

- a. For technical budgets and margin policy the requirements of ECSS-E-ST-10 clause 5.4.1.2 shall be applied.
- b. The margin for available memory size and load factors of processors should be
1. for new developments, 50 % as a minimum at PDR for new on board software parts;
 2. 25 % at launch.
- c. The margin on the throughput of on-board communication networks should be
1. for new developments, 50 % as a minimum at PDR on the average throughput;
 2. such that real time overflow is avoided.
- d. In the absence of specific mission requirements the following applies: After error correction, reset or data corruption of main functions at equipment level should be kept to a rate of occurrence less or equal to 10^{-4} per day for worst case conditions of environment.

- e. For programmable logic devices, the available margin of unused blocks and margin with respect to clock frequency and propagation time should be, for new developments, 50 % as a minimum at PDR.

4.2.3 Electrical connectors

- a. A connector carrying source power or external test connectors on units shall have no contact areas exposed to possible short circuit during mating and de-mating process.

NOTE They generally are female type connectors.

- b. All external test connectors on a unit and spacecraft skin connectors shall be covered for flight.

NOTE Umbilical connectors (detached during launch) are not part of skin connectors (detached or connected before launch).

- c. The test connector covers should be metallic or metallized and grounded to structure.
- d. The use of a connector saver for ground testing shall not alter the performance of the equipment.

NOTE RF savers are known to introduce extra insertion losses, in the range of 0,1 dB.

- e. It shall be ensured that erroneous mating is avoided by connector keying or marking.

NOTE The requirement is met either by harness routing, or by using keyed connectors, or adequate positioning of connectors, or connectors of different type or size, or connector marking.

- f. If the equipment has several connectors, visibility and clearance around each of them should be such as to enable mating or de-mating without disturbing others already in place or necessitating custom-made tooling.

NOTE A usual practice is the insertion of a breakout box for trouble shooting.

- g. For supplies and signals of pyrotechnics and non-explosive single shot device drivers, different connectors should be used for different classes of electrical functions.
- h. When 4.2.3g is not met, power, signals, and telemetry shall be separated in the connector by a set of unused pin locations.
- i. Except when pin allocation is imposed by a standard specification, spare contacts or sockets should be available on each connector.
- j. For new developments, when the connection is not aligned to a defined standard, 10% spare contacts at unit PDR and at least 5 % at CDR shall be achieved with in any case a minimum of two spare contacts available at CDR.

- k. In the absence of grounding provision at connector shell level, at least one contact per connector shall be connected to the unit structure as provision for potential additional grounding at subsystem or system level.
- l. Provision shall be taken to avoid arcing or short circuits in connectors.
 - NOTE For example: unused pins, placed between positive and return lines; specific connector design.
- m. The following shall be performed for any connector the loss of which can lead to the loss of the mission:
 - 1. Document the connector in the single point failure list
 - 2. Verify and document its integrity up to the highest spacecraft integration level, to avoid accidental demating.
- n. <<deleted>>
- o. Battery and solar array power shall be distributed by multiple contacts on both positive and return lines.

4.2.4 Testing

- a. Test-stimulus points shall be accessible without the need of modifying the electrical configuration of an item of equipment.
- b. Test-stimulus points shall be protected for flight operation.
- c. For the purpose of meeting requirement 4.2.4a and 4.2.4b, dedicated test connectors should be used.
- d. <<deleted>>
- e. Test points on equipment shall be protected against damage up to the maximum fault voltage present on the connector either coming from the equipment or the EGSE.
 - NOTE It is expected that the design of the EGSE incorporates protections limiting the fault voltage emission to a level acceptable by the unit.
- f. Test points on equipment shall be such that unintentional connection of these points to ground does not damage the equipment.
- g. The redundancy of parts and functions, which failure can lead to the loss of the mission or human injury, shall be verified by test simulating the failure event.
- h. Circuits meant for on-ground testing or unused circuits shall not create or be sensitive to the noise expected during operation.
 - NOTE For example spacecraft stimuli, unit test points, unused operational amplifiers or comparators.

- i. The protection of functions, which failure can lead to the loss of the mission or human injury, shall be verified by test simulating the failure event.
- j. The test of a protection function or a redundant function shall present no risk of stress or failure propagation due to the injection of stimuli.
- k. <<deleted>>
- l. Hot redundant functions and protection functions that cannot be tested beyond unit level shall be identified in the critical item list.
- m. All redundant functions and protection functions shall be tested, up to the highest possible level of integration of the unit.
- n. Redundant units within a system shall be verified by test at system level.
- o. Protection functions within a unit protecting other units shall be verified by test at system level or at unit level with representative interfaces.

NOTE 1 This is the case e.g. of a battery discharge regulator switching OFF autonomously at low input voltage to protect a Li-ion battery against irreversible damage to overdischarge.

NOTE 2 In the case of the LCL in power distribution, the limitation of current at turn-on is considered representative for validation of the protection at system level.

4.2.5 Mechanical: Wired electrical connections

- a. Wired electrical connections shall contain stress relief.

NOTE The objective is to avoid excessive mechanical loads on wires.

4.2.6 Miscellaneous

- a. 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.
- b. The uniformity of the electrical performance characteristics of the units shall enable equipment interchange provided a minimum set of adjustments and recalibration as described in the unit user's manual.
- c. When components operating in a single event are used, 4 times the quantity to be used for flight units shall be procured as one lot: 25 % for the lot acceptance test, 25 % for flight use, 25 % for spares and 25 % for a confirmation test near to the launch date.

NOTE Example of such components are fuses.

- d. The number of components to be procured shall be defined to ensure, as a minimum, the quantity needed for flight and flight spares, plus the number of components to be tested at incoming reception and components to be tested just before launch in case of alert or failure.

4.3 Verification

4.3.1 Provisions

- a. The requirements of this Clause 4 should be verified by the verification methods and at the verification points listed in Table 8-3.

NOTE 1 Table 8-3 can be used as a starting point for the definition of the verification methods.

NOTE 2 For more details on the verification strategy see also ECSS-E-ST-10-02 in particular the requirements 5.2.1c, d and e.

- b. In case verification by analysis of an electrical part or circuit is not possible by lack of data, complementary verification by test shall be performed.

NOTE Electrical part or circuit encompasses in particular to EEE components, solar cell or solar array, battery cell or battery assembly.

4.3.2 Documentation

- a. The design report, PSA, WCA, FMECA, thermal analysis, radiation analysis, EMC analysis and the detailed circuit diagrams including component values, shall be part of the Design Definition and Justification Files.
- b. Failure modes of all components used in a unit shall be defined.
- c. FMECA shall be performed and based on the failure modes previously defined at component level.
- d. The Design Definition and Justification Files shall be delivered by the supplier to the customer at the agreed verification points in compliance with Table 8-3.

Table 4-1: <<deleted, merged with new Table 8-3>>

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 subsystem and budgets

5.2.1 General

- a. Budgets and margins shall be established during Project phase B, and reviewed in all subsequent phases of the project.

5.2.2 Provisions

5.2.2.1 Power subsystem

- a. The power subsystem of a spacecraft shall be able to generate, store, condition, distribute and monitor the electrical power used by the spacecraft throughout all mission phases in the presence of all environments actually encountered.

NOTE For passivation, refer to ECSS-U-AS-10.

5.2.2.2 Engineering process

- a. An analysis of power demand versus power available shall be performed, including average peak power, for all phases of the mission.
- b. An analysis of the energy demand versus energy available shall be performed in all phases of the missions, including inrush power demands, eclipses, solar aspect angle and depointing and also failure mode affecting the power system.

NOTE Failure modes can result in transient or permanent overconsumption.

- c. A power budget shall be established based on the peak power values and an energy budget based on the average power values for all mission phases.
- d. A plan shall be established for the maintenance and periodical review of the budget established in requirement 5.2.2.2c during all project phases.

NOTE These budgets take into account:

- spacecraft–sun distance,
 - sun and eclipse durations,
 - solar aspect angle,
 - shadowing,
 - pointing accuracy,
 - environmental temperature and degradation effects,
 - reliability and safety aspects,
 - any one failure in the system (two failures for manned mission) not counting solar array string and battery cell failure, that are provisioned for achieving reliability of these item, but including transient or permanent overconsumption of a load,
 - Failure detection, isolation and recovery scenarios.
- e. A system margin of not less than 5 % at AR on available power and energy shall be included in the budget, available (as a minimum) with the solar array string losses as defined by the customer with the minimum of one string lost and one battery cell failed during all the designed life of the power system including all spacecraft modes of operation.
 - f. When actually using a MPPT, it shall be ensured that the transferred power is at least the required power, independent of the solar array operating conditions or environment.

NOTE The factors affecting the transferred power include in particular the following ones:

- Consideration of possible multiple local maximum power points,
- Different illumination (e.g. resulting from different SAA) for different SA sections,
- Temperature dispersion,
- Shadowing,
- Dispersion of the SA string I/V curves,
- Tracking accuracy and response time of MPPT control,
- Dynamic stability of MPPT control loop,

- Power conversion efficiency of MPPT converters.

5.3 Failure containment and redundancy

- a. Any protection function of a power converter or regulator preventing failure propagation shall:
 1. not be implemented in the same integrated circuit, and
 2. not utilize common references.
- b. It shall not be possible to inhibit a protection feature if such an inhibition can lead to the loss of the main primary power bus in case of a single failure at spacecraft level.
- c. In flight operation, if primary power bus shutdown happens, the system, including the power subsystem, shall be able to restart.

NOTE 1 Startup is possible as soon as sufficient power is available for a sufficient time from any source of the primary power bus, without considering failure for unmanned mission, or after single failure for manned mission.

NOTE 2 This requirement can imply that the battery is sufficiently recharged before its energy starts to be provided, for example to recover spacecraft attitude.

- d. <<deleted>>

5.4 Electrical power interfaces

- a. The electrical power interface internal or external to the power subsystem shall be specified, including source and load impedance.

NOTE Main examples of internal power interface are battery to conditioning electronics, SA to conditioning electronics. Main examples of external power interface are primary power conditioning electronics to loads, EGSE to and from primary power conditioning electronics, umbilical to and from primary power conditioning electronics. Docked modules on board of spacecraft, like orbiter or rover, are concerned as well.

- b. <<deleted>>
- c. The availability of the specified solar array power up to the power conditioning electronics shall be verified as follows:
 1. on solar array level, availability of the specified solar array power up to and including the solar array connector by means of flasher tests, supported by correlated analysis,

2. on spacecraft level, full steady-state solar array power conditioning capability from solar array connector to power conditioning electronics, including solar array drive mechanism if any and harness, using solar array simulator,
 3. and finally, on spacecraft level, correct electrical connection of the solar array to the power conditioning unit by means of a flood test, that is by illumination of the solar array with a portable continuous lamp, checking if the generated voltage and current are detected at power conditioning side.
- d. The solar array interface voltage shall be defined at the solar array connector interface.
 - e. The solar array interface voltage shall include voltage losses within the electrical circuitry of the solar array, including at least blocking diodes, wiring resistance and losses associated with harness interconnections in operational conditions.

5.5 Power generation

5.5.1 Solar cell, coverglass, SCA and PVA qualification

For the qualification of solar cells, protection diodes, coverglass, SCA and PVA, see ECSS-E-ST-20-08.

5.5.2 Solar array specification and design

- a. The solar array shall be specified to provide the requested power and ensure the energy balance in each mission phase during operational life including any string loss tolerance defined by the customer, spacecraft charging effects and worst case conditions.

NOTE 1 The solar array is designed to be single-failure tolerant at string level.

NOTE 2 In order to meet the solar array reliability requirements, the impact of other loss factors can lead to the addition of other spare strings.

NOTE 3 The computation of the energy balance is a typical task for the large system integrator based on defined power points expressed as a specification to the SA manufacturer.

- b. <<deleted>>
- c. <<deleted>>
- d. Provision shall be made against potential failure propagation in case of short-circuit failure of a solar array section or short circuit of its connection to the power subsystem.

NOTE In particular short-circuit of solar array interface (for example during ground operations) can lead to short-circuit of the main bus or the battery if no protections (e.g. blocking diodes in conditioning electronics) are implemented.

- e. The solar array design shall be such that charging phenomena do not degrade the performance of the solar array below the ones specified in 5.5.2a and 5.5.2c and meeting the requirements specified in clauses 7.1 and 7.2 of ECSS-E-ST-20-06.

NOTE Good practices in accordance with the present state of the art (maximum current of 0,6 A) are to:

- limit the differential voltage in between cells to 30 V (this relates to a factor of 2,3 margin with respect to Table 7-1 from ECSS-E-ST-20-06) in all conditions if the minimum accepted gap between adjacent non-directly connected cells is 0,5 mm;
- implement string blocking diodes;
- have a coverglass extending beyond the solar cell limits.

- f. For voltages in between cells higher than 30V, ESD testing shall be performed in line with ECSS-E-ST-20-06 demonstrating a minimum safety margin of 2,3 for the voltage.

NOTE This means no sustained arcing for voltages being 2,3 times V_{max} (with V_{max} being the maximum possible voltage between two adjacent cells of different strings at the minimum gap distance that can occur and at the highest currents that can occur).

- g. In the flight configuration, solar array conductive panels and spacecraft structure shall be insulated from each other, disregarding the bleed resistor.

NOTE 1 Examples of such structural parts of the SA panel are hold-down mechanisms, yokes, hinges and CCL (Closed Cable Loop).

NOTE 2 Typical value of insulation is in the order of 100 M Ω , and typical bleed resistor is in between 2 k Ω to 20 k Ω .

- h. In the flight configuration, means to prevent differential voltage due to electrostatic charging between solar array structure and the spacecraft electrical ground reference shall be implemented.

- i. In the flight configuration, bleeding resistors shall be implemented.

NOTE Bleeding resistors are used to control both electrostatic charging and power loss from the