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Nationales Vorwort

Dieses Dokument (FprEN 16603-33-01:2016) wurde vom Technischen Komitee CEN-CENELEC/TC 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-Normenausschuss Luft- und Raumfahrt (NL).

Dieses Dokument (FprEN 16603-33-01:2016) basiert auf ECSS-E-ST-33-01C Rev.1 DIR1.

Dieses Dokument enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung von FprEN 16603-33-01:2016.

Dieses Dokument wurde speziell zur Behandlung von Raumfahrtsystemen erarbeitet und hat daher Vorrang vor jeglicher Europäischer Norm, die denselben Anwendungsbereich hat, jedoch über einen größeren Geltungsbereich (z. B. Luft- und Raumfahrt) verfügt.

Nationaler Anhang NA (informativ)

Begriffe und Abkürzungen

Die Benummerung der folgenden Begriffe und Abkürzungen ist identisch mit der Benummerung in der englischen Fassung.

3 Begriffe und Abkürzungen

3.1 Begriffe aus anderen Normen

Für die Anwendung dieses Dokuments gelten die Begriffe nach ECSS-S-ST-00-01 und insbesondere die folgenden Begriffe:

- 1) Reinheit;
- 2) Komponente;
- 3) Schnittstelle;
- 4) Produkt.

3.2 Für diese Norm spezifische Begriffe

3.2.1

Auslöser

Komponente, welche die Bewegungsfunktion eines Mechanismus umsetzt

Anmerkung 1 zum Begriff: Ein Auslöser kann entweder ein elektrischer Motor oder eine andere mechanische (z. B. eine Feder) oder elektrische Komponente oder ein Bauteil sein, welches das Drehmoment oder die Kraft zur Bewegung des Mechanismus liefert.

Anmerkung 2 zum Begriff: Dieser Begriff wird in dieser Norm mit einer anderen Bedeutung als in ECSS-S-ST-00-01 definiert. Der Begriff mit der hier definierten Bedeutung gilt nur für die vorliegende Norm.

3.2.2

Steuersystem

System (mit offenem oder geschlossenem Regelkreis), welches die relative Bewegung des Mechanismus steuert bzw. kontrolliert

3.2.3

erreichbares Abtriebsdrehmoment

T_L

Drehmoment am Abtrieb des Mechanismus oder des Stellantriebs

Anmerkung 1 zum Begriff: Das erreichbare Drehmoment oder die erreichbare Kraft können vom Kunden festgelegt werden ohne den Zweck zu definieren und dabei die tatsächliche Leistung des Mechanismus zu beeinflussen.

Anmerkung 2 zum Begriff: Zum Beispiel: Ein theoretisches Drehmoment oder eine theoretische Kraft eines Robotermechanismus (Servicewerkzeug) für welchen keine bestimmte Funktion außer Drehmoment oder Kraft in der frühen Phase der Projektentwicklung festgelegt werden kann.

3.2.4

erreichbare Abtriebskraft

F_L

Kraft am Mechanismus oder Abtrieb des Stellantriebs

3.2.5

elementare Funktion

Funktion niederster Ebene

Anmerkung 1 zum Begriff: Zum Beispiel: Ein Freiheitsgrad (Rotation und Translation), Erzeugung eines Drehmoments oder einer Kraft, Sensoreinsatz.

3.2.6

Trägheitswiderstandskraft

F_D

Kraft zur Beschleunigung der Masse

3.2.7

Trägheitswiderstandsmoment

T_D

Moment zur Beschleunigung der Trägheit

3.2.8

Verbindungselement

Einheit zur Befestigung zweier oder mehr separater Teile, Komponenten oder Baugruppen

Anmerkung 1 zum Begriff: Zum Beispiel: Verbindungselemente dienen dazu, Teile miteinander zu verbinden und einen Pfad der Strukturbelastung zwischen den Teilen vorzusehen oder, falls diese als Sicherungsteil eingesetzt werden, eine ordnungsgemäße Verortung der zu sichernden Teile sicherzustellen.

3.2.9

Spülen oder Entleerung

Kontrolle der Umgebung des Mechanismus durch Umhüllung des Mechanismus mit einem bestimmten gasförmigen oder flüssigen Medium, welches den Mechanismus umgibt, diesen passiert oder durch ihn hindurchgeht

3.2.10

Einrasten oder Verriegeln

absichtliche Einschränkung eines oder mehrerer zuvor nicht eingeschränkter Freiheitsgrade, welche nicht ohne Ausführung einer bestimmten Aktion wieder freigegeben werden können

3.2.11

Schmierung

Einsatz bestimmter Oberflächeneigenschaften eines Materials oder eines aufgetragenen Materials zwischen zwei in Kontakt stehenden oder sich bewegenden Oberflächen, um die Reibung, den Verschleiß oder die Haftung zu reduzieren

3.2.12

Mechanismus

Baugruppe von Teilen, welche zur Ermöglichung einer relativen Bewegung gekoppelt sind

3.2.13

Entlastung

vollständige oder teilweise Entlastung eines Teils oder einer Baugruppe von einer anfänglichen Vorbelastung

Anmerkung 1 zum Begriff: Die Entlastung dient in der Regel dazu, einen Teil eines Mechanismus oder eine Baugruppe vor den Lasten beim Start oder anderen verursachten Lasten zu schützen.

3.2.14

Phasenrand

Anzeige für die Stabilität von dynamischen Steuerungssystemen

3.2.15

formschlüssig verriegelt

formschlüssige Verriegelung in eine definierte Position, aus welcher eine Freigabe nur durch Anwendung einer bestimmten Betätigungskraft möglich ist

3.2.16

positive Statusanzeige

direkte Überwachung des Zustands einer Primärfunktion auf der Ausgabeebene des Mechanismus

3.2.17

Primärfunktion

Funktion hoher Ebene

Anmerkung 1 zum Begriff: Zum Beispiel: Halten, freigeben, einsetzen, verfolgen und zielen.

3.2.18

sicherheitskritischer Mechanismus

mechanisches Produkt mit dem Potenzial einer kritischen oder katastrophalen Gefährdung

3.2.19

Befestigungselement mit Gewinde

Verbindungselement mit Gewindeteil

Anmerkung 1 zum Begriff: Zum Beispiel: Schrauben, Bolzen und Stiftschrauben.

3.2.20

Reibungslehre

Fachdisziplin, welche sich mit der Konstruktion, der Reibung, dem Verschleiß und der Schmierung von in Wechselwirkung stehenden Oberflächen bei relativer Bewegung zueinander befasst

3.2.21

Entlüften

Ausgleich der internen Druckumgebung des Mechanismus mit der umgebenden Druckumgebung

Anmerkung 1 zum Begriff: Zum Beispiel: Einsatz von dedizierten Entlüftungsöffnungen oder -passagen

3.3 Abkürzungen

Für die Anwendung dieses Dokuments gelten die Abkürzungen nach ECSS-S-ST-00-01 und die folgenden Abkürzungen:

Abkürzung	Bedeutung	
A/D	analog zu digital	(en: analogue to digital)
AC	Wechselstrom	(en: alternating current)
COG	Schwerpunkt	(en: centre of gravity)
CVCM	gesammelte flüchtige, kondensierbare Bestandteile	(en: collected volatile condensable material)
D/A	digital zu analog	(en: digital to analogue)
DC	Gleichstrom	(en: direct current)
DFMR	Gestaltung für ein minimales Risiko	(en: design for minimum risk)
DLL	Bemessungsgrenzlasten	(en: design limits loads)
EMC	elektromagnetische Kompatibilität	(en: electromagnetic compatibility)
ESD	elektrostatische Entladung	(en: electrostatic discharge)
F	Betätigungskraft	(en: actuation force)
F_D	Trägheitswiderstandskraft	(en: inertial resistance force)
F_L	erreichbare Abtriebskraft	(en: deliverable output force)
FMECA	Fehlermöglichkeits-, Einfluss- und Kritikalitäts-Analyse	(en: failure mode effects and criticality analysis)
F_{min}	notwendige Mindestbetätigungskraft	(en: minimum actuator force required)
FOS	Sicherheitsbeiwert	(en: factor of safety)
F_R	Reibungsmoment oder Reibungskraft	(en: friction torque or force)
GSE	Bodendienstgerät	(en: ground support equipment)
H_A	Moment- oder Kraftaufnahmen von Leitungsbündeln und anderen Teilen	(en: harness and other torque or force resistances)
H_D	Haftmoment oder Haftkraft	(en: adhesion torque or force)
HV	Vickershärte	(en: hardness Vickers)
H_Y	Hysterese des Moments oder der Kraft	(en: hysteresis torque or force)
I	Trägheitswiderstand (linear oder winkelförmig)	(en: inertia resistance (linear or angular))
I/F	Schnittstelle	(en: interface)

Abkürzung	Bedeutung	
LEO	erdnahe Umlaufbahn	(en: low Earth orbit)
M	Masse	(en: mass)
MAV	Analytische Verifikation eines Mechanismus	(en: mechanism analytical verification)
MDD	Konstruktionsbeschreibung eines Mechanismus	(en: mechanism design description)
MUM	Benutzerhandbuch eines Mechanismus	(en: mechanism user manual)
MLI	mehrschichtige Isolierung	(en: multilayer insulation)
MOI	Trägheitsmoment	(en: moment of inertia)
MOS	Sicherheitsmarge	(en: margin of safety)
MS	Sicherheitsmarge der Festigkeit	(en: strenght safety margin)
MSVP	Verifikationsplan für sicherheitskritische Mechanismen	(en: safety critical mechanisms verification plan)
MSVR	Verifikationsbericht für sicherheitskritische Mechanismen	(en: safety critical mechanisms verification report)
n.a.	nicht anwendbar/anzuwenden	(en: not applicable)
SMS	Spezifikation eines bestimmten Mechanismus	(en: specific mechanism specification)
RML	verbleibender Masseverlust	(en: recovered mass loss)
S	Federkraft	(en: spring force)
SI	Internationales Einheitensystem	(en: International System of Units)
S/C	Raumfahrzeug	(en: spacecraft)
SMS	Spezifikation eines bestimmten Mechanismus	(en: specific mechanism specification)
T	Betätigungsmoment	(en: actuation torque)
T_D	Trägheitswiderstandsmoment	(en: inertial resistance torque)
T_L	erreichbares Abtriebsdrehmoment	(en: deliverable output torque)
T_{min}	notwendiges Mindestbetätigungsmoment	(en: minimum actuator torque required)
TML	totaler Masseverlust	(en: total mass loss)
UV	ultraviolett	(en: ultraviolet)

— Leerseite —

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Table of contents

Foreword	4
Introduction.....	5
1 Scope.....	6
2 Normative references	7
3 Terms, definitions and abbreviated terms.....	9
3.1 Terms from other standards.....	9
3.2 Terms specific to the present standard	9
3.3 Abbreviated terms.....	11
4 Requirements.....	14
4.1 Overview	14
4.2 General requirements	14
4.2.1 Overview	14
4.2.2 Mission specific requirements	14
4.2.3 Units	15
4.2.4 Product characteristics.....	15
4.2.5 Reliability and redundancy	16
4.2.6 Flushing and purging.....	17
4.3 Mission and environments	18
4.4 Functional.....	18
4.4.1 System performance	18
4.4.2 Mechanism function	18
4.5 Constraints	18
4.5.1 Overview.....	18
4.5.2 Materials	19
4.5.3 Operational constraints	20
4.6 Interfaces.....	21
4.6.1 Overview.....	21
4.6.2 Thermo-mechanical interfaces	21
4.7 Design requirements.....	21

4.7.1	Overview	21
4.7.2	General design.....	21
4.7.3	Tribology	22
4.7.4	Thermal control	25
4.7.5	Mechanical design and sizing	26
4.7.6	Pyrotechnics	37
4.7.7	Electrical and electronic	37
4.7.8	Open-loop and closed-loop control system for mechanisms.....	39
4.8	Verification.....	41
4.8.1	General	41
4.8.2	Verification by analysis.....	41
4.8.3	Verification by test.....	46
4.9	Production and manufacturing	53
4.9.1	Manufacturing process.....	53
4.9.2	Manufacturing drawings	53
4.9.3	Assembly	53
4.10	Deliverables.....	53
Annex A (normative) Specific mechanism specification (SMS) - DRD		55
Annex B (normative) Mechanism design description (MDD) - DRD		59
Annex C (normative) Mechanism analytical verification (MAV) - DRD		61
Annex D (normative) Mechanism user manual (MUM) - DRD		63
Annex E (informative) Documentation technical items.....		67
Annex F (normative) Safety critical mechanisms verification plan (MSVP) - DRD		68
Annex G (normative) Safety critical mechanisms verification report (MSVR) - DRD		71
Bibliography.....		73
 Tables		
Table 4-1: Outgassing limits		23
Table 4-2: Minimum uncertainty factors		28
Table 4-3: Minimum uncertainty factors		32
Table 4-4: Life test duration factors		50
Table 4-5: Examples of lifetime to be demonstrated by test.....		50
Table E-1 : Documentation technical items.....		67

Foreword

This document (FprEN 16603-33-01:2016) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN (Germany).

This document (FprEN 16603-33-01:2016) originates from ECSS-E-ST-33-01C Rev.1 DIR1.

This document is currently submitted to the Unique Acceptance Procedure.

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 domain of applicability (e.g.: aerospace).

Introduction

This document has been established to provide mechanism engineering teams with a set of requirements, design rules and guidelines based on the state of the art knowledge and experience in the field of space mechanisms.

The use of this document helps mechanisms developers to establish generic mechanisms designs and to derive application specific requirements.

The main objectives are to achieve reliable operation of space mechanisms in orbit and to prevent anomalies during the development phase influencing schedule and cost efficiency of space programmes.

1

Scope

This Standard specifies the requirements applicable to the concept definition, design, analysis, development, production, test verification and in-orbit operation of space mechanisms on spacecraft and payloads in order to meet the mission performance requirements.

This version of the standard has not been produced with the objective to cover also the requirements for mechanisms on launchers. Applicability of the requirements contained in this current version of the standard to launcher mechanisms is a decision left to the individual launcher project.

Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organise and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards. Complementary non ECSS handbooks and guidelines exist to support mechanism design.

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

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS standard. For dated references, subsequent amendments to or revisions of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the 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 16603-10-02	ECSS-E-ST-10-02	Space engineering – Verification
EN 16603-20	ECSS-E-ST-20	Space engineering – Electrical and electronic
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 16603-31	ECSS-E-ST-31	Space engineering – Thermal control general requirements
EN 16603-32	ECSS-E-ST-32	Space engineering – Structural
EN 16603-32-01	ECSS-E-ST-32-01	Space engineering – Fracture control
EN 16603-32-10	ECSS-E-ST-32-10	Space engineering – Structural factors of safety for spaceflight hardware
EN 16603-33-11	ECSS-E-ST-33-11	Space engineering – Explosive systems and devices
EN 16602-30	ECSS-Q-ST-30	Space product assurance - Dependability
EN 16602-40	ECSS-Q-ST-40	Space product assurance – Safety
EN 16602-70	ECSS-Q-ST-70	Space product assurance – material, mechanical part and process
EN 16602-70-36	ECSS-Q-ST-70-36	Space product assurance – Material selection for controlling stress corrosion cracking
EN 16602-70-37	ECSS-Q-ST-70-37	Space product assurance – Determination of the susceptibility of metals to stress corrosion cracking
EN 16602-70-71	ECSS-Q-ST-70-71	Space product assurance – Data for selection of space materials and processes
	ISO 76 (2006)	Rolling bearings – Static load rating
	ISO 128 (1996)	Technical drawings

EN reference	Reference in text	Title
	ISO 677 (1976)	Straight bevel gears for general engineering and for heavy engineering – Basic rack
	ISO 678 (1976)	Straight bevel gears for general engineering and for heavy engineering – Modules and diametral pitches
	ISO 6336-1 (2006)	Calculation of the load capacity of spur and helical gears — Part 1: Basic principles, introduction and general influence factors
	ISO 6336-2 (2006)	Calculation of the load capacity of spur and helical gears — Part 2: Calculation of surface durability (pitting)
	ISO 6336-3 (2006)	Calculation of the load capacity of spur and helical gears — Part 3: Calculation of tooth bending strength

Terms, definitions and abbreviated terms

3.1 Terms from other standards

- a. For the purpose of this Standard, the term and definition from ECSS-S-ST-00-01 apply, and in particular the following:
 - 1. cleanliness
 - 2. component
 - 3. interface
 - 4. product

3.2 Terms specific to the present standard

3.2.1 actuator

component that performs the moving function of a mechanism

NOTE 1 An actuator can be either an electric motor, or any other mechanical (e.g. spring) or electric component or part providing the torque or force for the motion of the mechanism.

NOTE 2 This term is defined in the present standard with a different meaning than in ECSS-S-ST-00-01. The term with the meaning defined herein is applicable only to the present standard.

3.2.2 control system

system (open or closed loop) which controls the relative motion of the mechanism

3.2.3 deliverable output torque (T_L)

torque at the mechanism or actuator output

NOTE 1 The deliverable output torque or force can be specified by the customer for an undefined purpose and not affect the actual performance of the mechanism.

NOTE 2 For example: A theoretical torque or force of a robotic mechanism (service tool) for which no specific function except torque or force provision

can be specified at an early stage in the project development.

3.2.4 deliverable output force (F_L)

force at the mechanism or actuator output

3.2.5 elementary function

lowest level function

NOTE For example: One degree of freedom (rotation and translation), torque or force generation, sensing.

3.2.6 inertial resistance force (F_D)

force to accelerate the mass

3.2.7 inertial resistance torque (T_D)

torque to accelerate the inertia

3.2.8 fastener

item used to provide attachment of two or more separate parts, components or assemblies

NOTE For example: Fasteners have the function of locking the parts together and providing the structural load path between the parts or, if used as a securing part, to ensure proper locating of the parts to be secured.

3.2.9 flushing or purging

control of the mechanism environment by enclosing the mechanism in specific gaseous or fluid media which are surrounding, passing over or through the mechanism

3.2.10 latching or locking

intentional constraining of one or more previously unconstrained degrees of freedom which cannot be released without specific action

3.2.11 lubrication

use of specific material surface properties or an applied material between two contacting or moving surfaces in order to reduce friction, wear or adhesion

3.2.12 mechanism

assembly of parts that are linked together to enable a relative motion

3.2.13 off-loading

complete or partial unloading of a part or assembly from an initial pre-load

NOTE Off-loading is usually employed so as not to expose a mechanisms part or assembly to launch loads or other induced loads.

3.2.14 phase margin

indicator for the stability of dynamic control systems

3.2.15 positively locked

form-locked into a defined position from which release can only be obtained by application of a specific actuation force

3.2.16 positive indication of status

direct monitoring of the state of the primary function at the output level of the mechanism

3.2.17 primary function

high level function

NOTE For example: To hold, to release, to deploy, to track, and to point.

3.2.18 safety critical mechanism

mechanical product having a critical or catastrophic hazard potential

3.2.19 threaded fastener

fastener with a threaded portion

NOTE For example: Screws, bolts and studs.

3.2.20 tribology

discipline that deals with the design, friction, wear and lubrication of interacting surfaces in relative motion to each other

3.2.21 venting

compensation of the internal mechanism pressure environment with its surrounding pressure environment

NOTE For example: Use of dedicated venting holes or passages

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/D	analogue to digital
AC	alternating current
COG	centre of gravity
CVCM	collected volatile condensable material
D/A	digital to analogue
DC	direct current
DFMR	design for minimum risk
DLL	design limits loads
EMC	electromagnetic compatibility
ESD	electrostatic discharge
F	actuation force
F_D	inertial resistance force
F_L	deliverable output force
FMECA	failure mode effects and criticality analysis
F_{min}	minimum actuator force required
FOS	factor of safety
F_R	friction torque or force
GSE	ground support equipment
H_A	harness and other torque or force resistances
H_D	adhesion torque or force
HV	hardness Vickers
H_Y	hysteresis torque or force
I	inertia resistance (linear or angular)
I/F	Interface
LEO	low Earth orbit
M	mass
MAV	mechanism analytical verification
MDD	mechanism design description
MUM	mechanism user manual
MLI	multi-layer insulation
MOI	moment of inertia
MOS	margin of safety
MS	strength safety margin
MSVP	safety critical mechanisms verification plan
MSVR	safety critical mechanisms verification report
n.a.	not applicable

Abbreviation	Meaning
SMS	specific mechanism specification
RML	recovered mass loss
S	spring force
SI	International System of Units
S/C	spacecraft
SMS	specific mechanism specification
T	actuation torque
T_D	inertial resistance torque
T_L	deliverable output torque
T_{min}	minimum actuator torque required
TML	total mass loss
UV	ultraviolet

4

Requirements

4.1 Overview

This Standard addresses the requirements related to the generic aspects of the engineering steps for the various engineering disciplines involved in the achievement of the specified space mechanism performance.

The following requirements are identified considering interfaces and interactions of mechanisms with those disciplines: thermal control, structures, functional operations, materials and parts, pyrotechnics, propulsion, electrical and electronics, and servo-control interactions. Where interactions with other European space regulation are identified, reference is made to the related regulation.

4.2 General requirements

4.2.1 Overview

Requirements of clause 4.2 cover the interaction of mechanisms engineering with project management, processes, parts and components, product assurance, and the related requirements affecting the conceptual definition, design, sizing, analysis, development, and hardware production of mechanisms.

In view of the criticality of space mechanisms, which are often potential mission critical single point failures, particular attention is placed upon the reliability and redundancy of space mechanisms (see clause 4.2.5).

4.2.2 Mission specific requirements

- a. A dedicated specific mechanism specification (SMS) shall be established in conformance with Annex A for each individual mechanism in a project, and agreed by the customer.

NOTE The SMS specification identifies all specific requirements for a specific mechanism in a project, that are not covered by the present standard.

4.2.3 Units

- a. SI-units and associated symbols system shall be used.

4.2.4 Product characteristics

4.2.4.1 Marking and labelling

4.2.4.1.1 Specific identification

- a. The identification of delivered pieces of hardware, parts, components, sub-assemblies and assemblies shall carry at least the equipment title.

NOTE 1 For the identification of pieces of hardware, parts, components, sub-assemblies, and assemblies of the mechanism, see clause 5.3.1.5 of ECSS-M-ST-40.

NOTE 2 The identification can be removable.

NOTE 3 The identification number and the equipment title can be defined by the contracting authority.

4.2.4.1.2 Marking

- a. Marking shall be applied on non-functional surfaces.
- b. Bearings shall not be marked by the use of vibro-etch marks on the lateral faces of the bearing races.

NOTE Etched marks on the lateral faces of the bearing races affect the mounting tolerances of the bearing in the housing and the bearing's tribological performance characteristics.

4.2.4.2 Parts and components

- a. Existing parts and components used in mechanisms shall have been previously qualified for the intended application according to a qualification procedure approved by the customer.

NOTE Existing parts and components relate to parts and components that were not specifically developed for this specific application and cover commercially available and off-the-shelf hardware.

- b. Existing parts and components used in mechanisms should have been previously qualified at part or component level.
- c. Flight proven parts and components should be used.

NOTE For the selection of not-flight proven parts and components, see ECSS-Q-ST-60 for EEE components and ECSS-Q-ST-70 for materials and parts.

4.2.4.3 Interchangeability

- a. All items having the same identification number shall be functionally and dimensionally interchangeable.

4.2.4.4 Maintainability

- a. The mechanism should be designed to be maintenance free during storage and ground life.
- b. If the design is not maintenance free, the maintenance requirements shall be documented in the SMS, justified, agreed by the customer.
- c. If ground maintenance during storage or ground operation is not avoided, the maintenance procedures shall be provided.

4.2.5 Reliability and redundancy

4.2.5.1 Reliability

- a. For all mechanisms, which are critical to mission success, conformance to the specified reliability figure shall be demonstrated according to the following methods:
 - 1. electronic components: by parts count as a minimum or other methods approved by the customer;
 - 2. mechanical parts: by stress analysis or other methods approved by the customer;
 - 3. mechanical limited-life: by life test approved by the customer.
- b. For non-critical mechanisms, conformance to the reliability figure shall be demonstrated by simplified methods or other methods accepted by the customer.

NOTE 1 The methods to achieve by design, derive by analysis, and demonstrate by test the specified reliability figures are presented in ECSS-Q-ST-30.

NOTE 2 An example of a simplified method is parts count.

- c. Failure of one part or element shall not result in consequential damage to the equipment or other spacecraft components.
- d. For structural reliability aspects ECSS-E-ST-32 shall apply.
- e. For safety critical mechanisms in a crewed space mission where structural failure can cause a catastrophic hazardous event, fasteners and load carrying paths within mechanisms shall be designed in conformance with fracture control requirements from ECSS-E-ST-32-01.

NOTE Definitions of catastrophic and critical hazardous events are provided in ECSS-Q-ST-40. Fracture control requirements are provided in ECSS-E-ST-32-01.

- f. For safety critical mechanisms in case of non-crewed space mission the applicability of fracture control requirements shall be specified by the customer.

4.2.5.2 Redundancy

- a. During the design of the mechanism, all single point failure modes shall be identified.
- b. All single points of failure should be eliminated by redundant components.
- c. If single points of failure cannot be avoided, they shall be justified by the supplier and approved by the customer.
- d. Redundancy concepts shall be agreed by the customer.

NOTE Redundancy concepts are selected to minimize the number of single points of failure and to conform to the reliability requirements.

- e. Where a single point failure mode is identified and redundancy is not provided, compliance with the reliability, availability and maintainability requirements specified in ECSS-Q-ST-30 shall be demonstrated.
- f. Unless redundancy is achieved by the provision of a complete redundant mechanism, active parts of mechanisms, such as sensors, motor windings, brushes, actuators, switches and electronics, shall be redundant.
- g. Failure of one element or part shall not prevent the other redundant element or part from performing its intended function, nor the mechanism from meeting its performance requirements specified in the specific mechanism specification.

NOTE High-reliability of a mechanism can be incorporated in a design by including component redundancy or high design margins. The aim is to deliver a design which is single failure tolerant.

4.2.6 Flushing and purging

- a. If operating the mechanism in air is detrimental to the performance of the mechanism over its complete mission, means for flushing the critical parts with an inert clean dry gas shall be provided.

NOTE Example of detrimental cause to operate the mechanism in air is the presence of moisture or other deleterious contamination.

- b. Only lubricants qualified in respect to the residual humidity of the dry gas shall be used.