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EUROPEAN COOPERATION FOR SPACE STANDARDIZATION

Space engineering

Mechanisms

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Foreword

This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS-E-ST-33-01 Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

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Change log

ECSS-E-30 Part 3A	First issue
ECSS-E-ST-33-01B	Never issued
ECSS-E-ST-33-01C 6 March 2009	Second issue The following is a summary of changes between ECSS-E-30 Part 3A and the present issue: • Complete review, restructuring and rewording of standard to be in line with ECSS drafting rules and formatting • Addition of DRDs • Deletion of the Tailoring information formerly contained in Annex A • Harmonization of the standard with other ECSS standards • Review and update of cross-references to other ECSS standards

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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.

This standard may be tailored for the specific characteristic and constrains 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.

ECSS-S-ST-00-01	ECSS system — Glossary of terms
ECSS-E-ST-10-02	Space engineering – Verification
ECSS-E-ST-20	Space engineering – Electrical and electronic
ECSS-E-ST-20-06	Space engineering – Spacecraft charging
ECSS-E-ST-20-07	Space engineering – Electromagnetic compatibility
ECSS-E-ST-31	Space engineering – Thermal control general requirements
ECSS-E-ST-32	Space engineering - Structural
ECSS-E-ST-32-10	Space engineering – Structural factors of safety for spaceflight hardware
ECSS-E-ST-33-11	Space engineering – Explosive systems and devices
ECSS-Q-ST-30	Space product assurance - Dependability
ECSS-Q-ST-40	Space product assurance – Safety
ECSS-Q-ST-70	Space product assurance – material, mechanical part and process
ECSS-Q-ST-70-36	Space product assurance – Material selection for controlling stress corrosion cracking
ECSS-Q-ST-70-37	Space product assurance – Determination of the susceptibility of metals to stress corrosion cracking
ECSS-Q-ST-70-71	Space product assurance – Data for selection of space materials and processes
ISO 76, Edition 2, Amendment 1	Rolling bearings – Static load rating
ISO 128	Technical drawings
ISO 677	Straight bevel gears for general engineering and for heavy engineering – Basic rack

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

3 Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the term and definition from ECSS-S-ST-00-01 apply, and in particular the following:

interface

3.2 Terms specific to the present standard

3.2.1 actuator

component that performs the moving function of a mechanism

NOTE 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.

3.2.2 cleanliness

level in both particulate contamination and molecular contamination that contaminates the part or assembly

3.2.3 component

assembly or any combination of parts, subassemblies and assemblies, and assemblies mounted together and normally capable of independent operation in a variety of situations

3.2.4 control system

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

3.2.5 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.

3.2.6 deliverable output force (F_L)

force at the mechanism or actuator output

3.2.7 elementary function

lowest level function

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

3.2.8 inertial resistance force (F_D)

force to accelerate the mass

3.2.9 inertial resistance torque(T_D)

torque to accelerate the inertia

3.2.10 fasteners

part 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.

3.2.11 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

3.2.12 latching or locking

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

3.2.13 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

3.2.14 mechanism

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

3.2.15 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.

3.2.16 phase margin

indicator for the stability of dynamic control systems

3.2.17 positively locked

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

3.2.18 primary function

high level function

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

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
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
n.a.	not applicable
SMS	specific mechanism specification
RML	recovered mass loss
S	spring force
S/C	spacecraft
T	actuation torque
T_D	inertial resistance torque
T_L	deliverable output torque
T_{min}	minimum actuator torque required
TML	total mass loss

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

This group of requirements covers 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 parts 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 (e.g. parts count or other methods accepted by the customer).

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

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. Where structural failure of a mechanism can cause a catastrophic or critical hazardous event, fasteners and load carrying paths within mechanisms shall be designed in conformance with fracture control principles.

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

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 elements 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.

4.3 Mission and environments

a. The mechanism engineering shall consider every mission phase identified for the specific space programme and conform to the related mission requirements and environmental constraints.

NOTE The mission starts with on-ground life of the mechanisms after assembly and is completed at the end of operational life of the space system.

4.4 Functional

4.4.1 System performance

a. The mechanism functional performance shall conform to the system performance requirements.

4.4.2 Mechanism function

a. The kinematic requirements applicable to each position change shall be specified.

NOTE For example, position over time, velocity and acceleration.

b. Mechanical interface, position accuracy or velocity tolerances shall be specified and verified that they conform to the functional needs.

c. The envelope of movement for each moving part shall be defined.

d. The movement of each part shall ensure that there is no mechanical interference with any other part of the mechanism, the spacecraft, the payload or the launcher.

4.5 Constraints

4.5.1 Overview

This group of requirements covers the constraints to which mechanisms are designed, manufactured and operated.

For the physical constraints, it is important to ensure that the requirements for climatic protection and for sterilization are defined in the SMS, as identified in A.2.1<4>.

4.5.2 Materials

4.5.2.1 Material selection

a. Materials shall be selected in conformance with ECSS-Q-ST-70 clause 5, or be verified that they conform to requirements, approved by the customer.

NOTE 1 For general requirements on materials used for space mechanisms, see ECSS-E-ST-32-08. The material requirements in 4.5.2.2 to 4.5.2.7 are specific to mechanisms.

NOTE 2 For selection of materials, see ECSS-Q-ST-70-71.

NOTE 3 For additional requirements relating to tribology, see clause 4.7.3.

4.5.2.2 Corrosion

a. For corrosion, ECSS-Q-ST-70-71 clause “Chemical (corrosion)” shall apply.

4.5.2.3 Dissimilar metals

a. For dissimilar metals, ECSS-Q-ST-70 clause 5.1.12 “Galvanic compatibility” shall apply.

NOTE To fulfil requirement 4.5.2.3a, dissimilar metals should not be used in contact with each other, unless they have been treated in accordance to 4.5.2.3b or are resistant.

b. Materials treatments to prevent galvanic and electrolytic corrosion shall be approved by the customer.

4.5.2.4 Stress corrosion cracking

a. Materials shall be selected as specified in ECSS-Q-ST-70-36.

b. Materials with unknown characteristics shall be tested in conformance with ECSS-Q-ST-70-37.

c. ECSS-Q-ST-70-71 clause “Stress corrosion resistance” shall apply.

4.5.2.5 Fungus protection

a. For fungus protection, ECSS-Q-ST-70-71 clause “Bacterial and fungus growth” shall apply.

4.5.2.6 Flammable, toxic and unstable materials

a. For flammable materials, ECSS-Q-ST-70-71 clause “Flammability” shall apply.

b. For toxic materials, ECSS-Q-ST-70-71 clause “Offgassing and toxicity” shall apply.

c. In manned space systems, flammable, toxic and unstable materials shall not be used.

4.5.2.7 Induced emissions (stray light protection)

a. Materials and their coatings shall be selected so that their surface properties reduce induced emissions (stray light and others) below the levels of stray light specified in the SMS.

4.5.2.8 Radiation

a. The exposure to radiation shall not degrade the functional performance of the mechanism below the minimum functional performances specified in the SMS, over the complete mission.

b. ECSS-Q-ST-70-71 clause “Radiation” shall apply.

4.5.2.9 Atomic oxygen

a. The exposure to atomic oxygen shall not degrade the functional performance of the mechanism below the minimum functional performances specified in the SMS, over the complete mission.

b. ECSS-Q-ST-70-71 clause "Atomic oxygen" shall apply.

4.5.2.10 Fluid compatibility

a. For fluid compatibility, ECSS-Q-ST-70-71 clause "Fluid compatibility" shall apply.

4.5.3 Operational constraints

a. The mechanism should not impose any operational constraints on the spacecraft and mission.

b. If operational constraints are imposed by the mechanism, they shall be identified, justified and approved by the customer.

c. All operational constraints shall be documented in the mechanism user manual.

NOTE For the contents of the user manual, see Annex D.

d. Mechanisms moving with limited oscillatory travel shall be identified.

e. All oscillatory rolling elements should be exercised over a complete revolution at regular intervals, according to an operational procedure agreed by the customer.

NOTE Examples of oscillatory rolling elements are: ball bearing and nuts.

f. Operational procedures to exercise the mechanism beyond the oscillatory travel range shall be defined.

4.6 Interfaces

4.6.1 Overview

This group of requirements covers the interfaces of mechanisms on spacecraft and payload. Most of the interfaces requirements are application specific, and therefore are covered by the SMS, as identified in A.2.1<5>.

4.6.2 Thermo-mechanical interfaces

a. Thermo-mechanical interfaces shall be designed to take into account the stresses induced by the structure between the mechanism and its I/F attachment points.

4.7 Design requirements

4.7.1 Overview

This clause covers general design, tribology, thermal control, mechanical design and sizing, pyrotechnics, electric and electronics, and control engineering.

The requirements for tribology (see clause 4.7.3) cover the tribological related issues of mechanisms on the spacecraft and payload. The tribology of surfaces that separate or move relative to one another play a key function in the conceptual definition, design, analysis, test verification, launch, and in-orbit performance of the mechanisms.

The thermal requirements (see clause 4.7.4) cover the interaction of mechanisms engineering with thermal control and its related requirements affecting mechanisms engineering. General thermal control requirements are covered in ECSS-E-ST-31.

The requirements for mechanical design and sizing (see clause 4.7.5) cover the overall conceptual design, the mechanical sizing of parts, components and assemblies, and the detailed design definition of mechanisms. General structural requirements, including design loads (for example, pyrotechnical shock), are covered in ECSS-E-ST-32.

The requirements for electrical and electronics (see clause 4.7.7) cover the interaction of mechanisms engineering with electrical and electronic engineering and its related requirements affecting mechanisms engineering. General requirements for electrical and electronic are covered in ECSS-E-ST-20. If no electrical or electronic provisions are applied on the mechanism, the applicability of ECSS-E-ST-20 is limited to the potential compatibility requirements of mechanical systems with electrical and electronic systems.

4.7.2 General design

a. The mechanism design shall be compatible with operation on ground in ambient and thermal vacuum conditions.

4.7.3 Tribology

4.7.3.1 General

a. Mechanisms shall be designed with a lubrication function between surfaces in relative motion in order to ensure they conform to the mechanism performance requirements specified in the specific mechanism specification, throughout the specified lifetime.

NOTE The lubrication function aims to provide the motorization margins and minimize wear.

b. Mechanisms shall use only lubricants or lubricating surfaces qualified for the mission.

NOTE 1 For example, environment, lifetime, contact pressure, temperature, number of cycles, minimum and maximum velocity of surfaces in relative motion.

NOTE 2 For space environment, see ECSS-E-ST-10-04.

NOTE 3 Vacuum is one of the main concerns regarding lubrication.

c. It shall be verified that the degradation of the lubricant in the on-ground and in-orbit environments does not lead to a mechanism performance degradation below the limits specified in the SMS.

NOTE Examples of such degradation are friction, wear and lubricant performance variability.

d. The use of sliding surfaces shall be avoided.

e. If requirement 4.7.3.1d cannot be met, sliding surfaces are used one of the surfaces shall be hard and the other shall be lubricated or shall be composed of a self-lubricating material.

NOTE Example of self-lubricating material: polyimide resins.

f. Metal to metal tribological contacts should be composed of dissimilar materials, in conformance with 4.5.2.3.

g. Metal to metal tribological sliding contacts shall be composed of dissimilar materials in conformance with 4.5.2.3.

h. Prior to the application of lubricant and in order to facilitate adhesion or wetting of lubricant on the substrate surface, the surfaces shall be cleaned in conformance with a procedure approved by the customer.

i. The cleaning of the surfaces prior to lubricant application shall not degrade the lubricating action.

j. The lubricant shall conform to the molecular and particulate contamination requirements specified for the entire mission.

NOTE For molecular and particulate contamination, see ECSS-Q-ST-70-01.

4.7.3.2 Dry lubrication

a. During the lubrication of mechanism tribological surfaces, samples of representative material, surface roughness, surface cleanliness and surface orientation shall be co-deposited in each process run with the flight components so that verification checks can be performed.

b. The thickness and adhesion of the lubricant on samples defined in requirement 4.7.3.2a shall be verified.

c. The dry lubricant application process shall be verified with respect to lubricant performance and repeatability.

4.7.3.3 Fluid lubrication

4.7.3.3.1 Amount of fluid lubricant

a. The quantity of lubricant used shall be determined.

NOTE This determination allows quantifying a surplus of lubricant at the end of the total lifetime of the mechanism.

b. The quantity of lubricant shall take into account outgassing, creep and other sources of absorption or degradation.

c. The effect of exposure to on-ground storage and related gravity effects, and other ground or in-orbit accelerations on lubricant distribution shall be validated.

4.7.3.3.2 Outgassing

a. The outgassing rate of fluid lubricants shall be measured by a screening test approved by the customer.

NOTE See ECSS-Q-ST-70-02.

b. The limits of acceptance for material outgassing shall be in conformance with Table 4-1.

NOTE The limits in Table 4-1 can be more stringent if the materials concerned are later used in critical areas. The use of materials conforming to the limits stated in Table 4-1 does not ensure that the spacecraft system or component remains uncontaminated. Specific requirements for mission involving advanced optical instruments are covered by the SMS, as identified in A.2.1<6>c.

Table 4-1: Outgassing limits

Application	TML [%]	RML [%]	CVCM [%]
General applications	< 1	n.a.	< 0,1
Optical device applications	n.a.	< 0,1	< 0,01

4.7.3.3.3 Anti-creep barriers

a. Anti-creep barriers shall be used to avoid migration of fluid lubricants to the external sensitive equipment agreed by the customer.

NOTE It is also important to use the anti-creep barriers for sensitive equipment within the mechanism.

b. Anti-creep barriers shall be used when migration of fluids lubricants causes a change of the lubricant amount on the parts to be lubricated resulting in mechanism performance degradation below the limits specified in the SMS.

c. The integrity of the anti-creep barrier shall be verifiable by indicators.

NOTE For example, UV-detectable.

4.7.3.4 Tribological components

4.7.3.4.1 Life

a. The life of tribological components shall be verified under worst case ground and flight conditions.

4.7.3.4.2 Bearing pre-loading

a. Ball bearings shall be pre-loaded with a load calculated in order to withstand the mechanical environment during launch and throughout the mission.

b. The calculation specified in requirement 4.7.3.4.2a shall be made available to the customer.

c. Pre-loading should be applied by solid pre-load or flexible pre-load produced by loading techniques without sliding at the bearing mounting interfaces.

d. If pre-loading is not applied by 4.7.3.4.2c solutions, sliding shall be facilitated by a lubricated sliding sleeve, bush or dedicated tribological coating.

e. If bearing gapping occurs during vibration, adequacy of lubricant and potential consequential mechanisms damage or degradation due to bearing components or shaft motion shall be demonstrated to conform to the specified functional performance and lifetime.

f. Any set pre-load at component level shall be measured.

g. Bearing preload should be measured after final mechanism assembly.

h. If bearing preload is not measured after final mechanism assembly, it shall be assessed by means of measurements approved by the customer.

i. If bearing preload can be affected by the running-in process, the preload shall be confirmed after running-in.

4.7.3.4.3 Mechanical cables

a. Mechanical cables under friction used on moving parts or assemblies shall be lubricated in conformance with 4.7.3.1, 4.7.3.2 and 4.7.3.3.

4.7.4 Thermal control

4.7.4.1 Thermal engineering

a. The mechanism engineering shall conform to the thermal engineering requirements specified by the customer.

NOTE For thermal control, see ECSS-E-ST-31.

4.7.4.2 Mechanisms thermal design and sizing

a. The thermal design of the mechanism shall ensure that all components are maintained within their qualification temperature range under all specified ground, test, launch and in-orbit conditions throughout the lifetime of the mechanism.

b. The mechanism shall be compatible with on-ground thermal vacuum testing representative of in-orbit thermal conditions.

c. The following minimum temperature margins defined in ECSS-E-ST-31 clause 3.2 shall be applied:

1. Acceptance margin: 5 K above specification

2. Qualification margin: 10 K above specification

d. Unless the use of active thermal control is previously agreed with the customer, thermal control shall be passive.

e. The mechanism design shall take into account the worst-case combinations (including uncertainties) of:

1. extremes of operational and survival steady-state,

2. transient temperatures,

3. mechanism heat dissipation, and

4. the temperature gradients across the mechanism.

NOTE Failure to consider the effects of differential expansion can lead to a catastrophic failure.

4.7.4.3 Multi-layer insulation (MLI)

a. When using MLI, supported at discrete positions at the distance of not more than 100 mm, the following shall be provided:

1. between structural components and MLI hardware a minimum clearance of 20 mm (in out-of-plane direction to the MLI),

2. between MLI protected moving parts and other MLI hardware a minimum clearance of 35 mm (in out-of-plane direction to the MLI).

NOTE Clearance is relative to moving parts of mechanisms or on spacecraft structure close to its moving paths.

b. For other design solutions, it shall be verified that clearances with margins, agreed by the customer, are maintained throughout the mission.

NOTE Example of such design solutions are MLI not supported at discrete positions or MLI supported at discrete positions which are more than 100 mm apart.

c. The MLI clearance assessment shall take into account the dynamic envelopes of the MLI during vibration exposure and venting or purging or in orbit environment.

NOTE For example, spin.

4.7.5 Mechanical design and sizing

4.7.5.1 General

a. Mechanisms shall be designed to meet the mechanical performance requirements and to withstand the specified environment during handling, transportation, testing, storage, launch and operation in orbit for the specified lifetime.

4.7.5.2 Structural dimensioning

4.7.5.2.1 General

a. Mechanisms in their different configurations shall conform to the specified stiffness, strength and safety requirements derived from the launcher and the spacecraft structural requirements.

4.7.5.2.2 Loads

a. The load general requirements of ECSS-E-ST-32, shall apply in-orbit loads.

b. The operational loads shall be added to the in-orbit loads.

NOTE Operational loads are the loads generated by the mechanism during operation, including thermoelastic effects.

c. The operational loads of the mechanisms shall be derived according to the functional dimensioning requirements based on dynamic performance analyses or test measurements in worst-case conditions.

d. For the derivation of the operational loads, the related induced reaction of the spacecraft shall be taken into account.

4.7.5.2.3 Limit loads

a. The worst-case condition requirements of ECSS-E-ST-32 clause 4.2.7 shall apply with the following modifications; for cases where a statistical distribution of the loads cannot be demonstrated, the limit loads shall be defined based on the worst-case conditions.

NOTE Examples of cases where a statistical distribution of the loads cannot be demonstrated are mechanisms operating loads.

4.7.5.2.4 Material allowables

For the allowable A-values of materials, to be used for structural sizing, see ECSS-E-ST-32, clause 4.5.

NOTE For metallic materials, A-values data can be found in the latest version of the document: Metallic Material Properties Development and Standardisation (MMPDS).

4.7.5.2.5 Margin of safety (MOS)

a. For structural margin of safety requirements, ECSS-E-ST-32 shall apply.

b. Mechanisms shall be designed with a positive margin of safety against yielding and against ultimate under all environmental and operational load conditions.

c. The actual stress or load shall be considered at their worst case qualification level.

d. The margin of safety (MOS) shall be derived from stresses or load.

e. The margin of safety (MOS) shall employ the factors of safety (FOS) identified in clause 4.7.5.2.6.

f. The margin of safety (MOS) shall be the smallest of the following values:

MOS = (allowable stress limit / (actual stress x FOS)) -1, or

MOS = (allowable load limit / (actual load x FOS)) -1

g. The margin of safety (MOS) shall be greater than zero.

4.7.5.2.6 Factors of safety (FOS)

a. For the structural factors of safety, requirements of ECSS-E-ST-32-10 shall apply.

b. In the computation of safety margins the following minimum factors of safety shall be used for standard metallic materials:

1. yield stress factor of safety: 1,25
2. ultimate stress factor of safety: 1,5
3. buckling factor of safety: 2
4. minimum fatigue factor (cycles): 4

c. Fatigue verification shall take into account thermoelastic cycles over all lifetime.

d. Factors of safety for other materials shall be approved by the customer on a case by case basis.

e. The following specific factors of safety shall apply:

1. For cables, stress factor of safety against rupture 3
2. For stops, shaft shoulders and recesses, against yield 2

4.7.5.3 Functional dimensioning (motorization)

4.7.5.3.1 Motorization factors

a. Actuators shall be sized to provide throughout the operational lifetime and over the full range of travel actuation torques (or forces) in conformance with 4.7.5.3.1d or 4.7.5.3.1e.

NOTE 1 Example of actuators are electrical, mechanical and thermal.

NOTE 2 Components providing helping torques or forces are treated as motorization.

b. To derive the factored worst-case resistive torques (or forces), the components of resistance, considering in-orbit worst-case conditions (environmental effects), shall be multiplied by the minimum uncertainty factors specified in the resistive component columns of the Table 4-2.

NOTE Example of such environmental effects are vacuum, temperature, and zero G.

Table 4-2: Minimum uncertainty factors

Component of resistance	Symbol	Theoretical Factor	Measured Factor
Inertia	I	1,1	1,1
Spring	S	1,2	1,2
Motor mag. losses	H_M	1,5	1,2
Friction	F_R	3	1,5
Hysteresis	H_Y	3	1,5
Others (Harness)	H_A	3	1,5
Adhesion	H_D	3	3

c. The theoretical uncertainty factors in Table 4-2 may be reduced to the measured factors providing that the worst-case measured torque or force resistive components are determined by measurement according to a test procedure approved by the customer and demonstrate the adequacy of the uncertainty factor with respect to the dispersions of the resistive component functional performances.

d. The minimum actuation torque (T_{min}) shall be derived by the equation:

$$T_{\min} = 2 \times (1{,}1\,I + 1{,}2\,S + 1{,}5\,H_M + 3\,F_R + 3\,H_Y + 3\,H_A + 3\,H_D) + 1{,}25\,T_D + T_L$$

where:

— I is the inertial torque applied to a mechanism subjected to acceleration in an inertial frame of reference (e.g. spinning spacecraft, payload or other).

— T_D is the inertial resistance torque caused by the worst-case acceleration function specified by the customer at the mechanism level.

— T_L is the deliverable output torque, when specified by the customer.

e. The minimum actuation force (F_{min}) shall be derived by the equation:

$$F_{\min} = 2 \times (1{,}1\,I + 1{,}2\,S + 1{,}5\,H_M + 3\,F_R + 3\,H_Y + 3\,H_A + 3\,H_D) + 1{,}25\,F_D + F_L$$

where:

— I is the inertial force applied to a mechanism subjected to acceleration in an inertial frame of reference (e.g. spinning spacecraft, payload or other).

— F_D is the inertial resistance force caused by the worst-case acceleration function specified by the customer at the mechanism level.

— F_L is the deliverable output force, when specified by the customer.

NOTE 1 Margins against any dynamic coupling between the mechanism and its payload are not covered by the above formulae, and they are addressed on a case by case basis when appropriate.

NOTE 2 The inertial resistance torque (T_D) or force (F_D) (specified by the customer) apply to mechanisms which have a specified acceleration requirement or for which an indirect acceleration requirement can be deduced from speed, time or other (dynamic) requirements.

NOTE 3 When a function of the mechanism is to deliver output torques (T_L) or forces (F_L) for further actuation at higher level, the output torque or force is derived by the customer according to the torque or force requirements specified in 4.7.5.3.1d and 4.7.5.3.1e., taking into account the specified uncertainty factors on the individual components of resistance and applying a motorization factor of two as presented as :

$$T_L = 2 \times (1{,}1\,I' + 1{,}2\,S' + 1{,}5\,H'_M + 3\,F'_R + 3\,H'_Y + 3\,H'_A + 3\,H'_D)$$

$$F_L = 2 \times (1{,}1\,I' + 1{,}2\,S' + 1{,}5\,H'_M + 3\,F'_R + 3\,H'_Y + 3\,H'_A + 3\,H'_D)$$

where all components of resistance in the two equations above are related to the customer specific actuation application.

f. The kinetic energy of the moving components, and its effects, shall not be taken into account to meet the specified motorization factor.

NOTE Such effects are acceleration and deceleration force and torque of moving components.

4.7.5.3.2 Actuation torque (or force) dimensioning.

a. The actuation torque T (or force F) is the summation of all the actuating components as specified in the following clauses 4.7.5.3.2c., 4.7.5.3.2d., 4.7.5.3.2e.

NOTE Examples of actuating components are electro magnetic, pneumatic, active components, acting spring, and acting inertia.

b. T (or force F) shall be greater or equal than T_{min} (or F_{min}) as calculated in the clause 4.7.5.3.1.

c. When the actuation torque (or force) is supplied by an electronic controlled device, the actuation torque (or force) supplied by this device shall be derived considering worst-case conditions.

NOTE 1 Example of such electronic devices are an electromagnetic motor, or piezo actuator, or pneumatic, or active components.

NOTE 2 Example of such worst case conditions are supplied voltage, current, and frequency.

d. When part of the actuation torque (or force) is provided by inertia means, the actuation torque (or force) supplied by the inertia shall:

   1. be derived considering worst-case conditions defined and agreed by the customer.

   2. be multiplied by the maximum uncertainty factor of 0,9 and then comply with the equations in clause 4.7.5.3.1.

      NOTE Inertia is calculated in the appropriate reference frame and according to the type of movement.

e. When the actuation torque (or force) is supplied by a spring actuator, the actuation torque (or force) supplied by the spring, shall be derived considering worst-case conditions, and be multiplied by the maximum uncertainty factor of 0,8.

f. Spring actuators shall be redundant unless it is

   1. agreed by the customer,

   2. verified by analysis and test that the spring sizing and functional performance characteristics meet the specified reliability of the mission, and

   3. verified that a spring failure can not cause any catastrophic, critical or major hazardous event in conformance with ECSS-Q-ST-40, clause 6.4.

g. Actuating torques or forces based on hysteresis, harness generated, or any item whose primary function is not to provide torques or forces, should not be used as a motorization source.

h. If torques (or forces) based on hysteresis, harness generated, or any item whose primary function is not to provide torques or forces are used as motorization sources their use shall:

   1. be justified,

   2. agreed by the customer, and

   3. the adequacy of the uncertainty factor with respect to the dispersion of the component actuation functional performances verified by analysis and test.

4.7.5.4 Other mechanical design and sizing requirements

4.7.5.4.1 Replaceable elements

a. Where parts or components are intended for possible replacement or re-installation, they shall be designed to ensure they can only be installed in the correct orientation and position.

b. Mechanisms using deformable elements shall be designed to ensure they can only be installed in the correct orientation and position.

   NOTE Examples of such mechanisms are crush dampers.

c. The design of replaceable items shall inhibit the reuse in the mechanism or spacecraft in the un-refurbished state.

4.7.5.4.2 Status monitoring

a. Unless monitored at spacecraft system level, the design of mechanisms shall include means to monitor the execution of its main functions.

b. Mission critical mechanisms shall be designed in such way that monitoring information of its critical functions is accessible to the spacecraft telemetry.

NOTE For telemetry requirements, see ECSS-E-ST-70-11, clause 5.9.5

4.7.5.4.3 Latching or locking

a. Latching mechanisms used to assure positive locking shall be designed to avoid inadvertent opening by vibration or shock occurring during the mission.

b. Unless agreed by the customer, locking or latching mechanisms shall provide an indication of whether the latch or lock is open or closed.

c. Electrically actuated deployable items shall use positive latching or locking.

d. The latch capture range shall ensure capture of the mechanism over the complete range of temperatures or temperature gradients and manufacturing and assembly tolerances.

e. The design shall not prevent subsequent successful latching if latching is not achieved on the initial completion of motion.

f. Latches shall be self locking.

g. Latches shall be resettable for ground testing.

h. Off-load mechanisms shall be capable of being operated manually.

i. Shock loads for latches and locks shall be derived by analysis or test, and specified in the mechanism requirements specification.

4.7.5.4.4 End stops

a. Mechanisms with restricted travel or rotation shall be provided with regular or emergency mechanical end stops to limit their motion and travel extremes to the maximum position specified in the SMS.

b. End stops shall be provided to prevent interference with interfacing equipment.

NOTE Regular end stops are provided for proper functioning of the actuated item.

c. The mechanical end stops and arresting mechanisms shall be designed to withstand without damage the maximum shock loads with the structural margins defined in clause 4.7.5.4.5.

d. The end stop sizing shall conform to the separable contact surfaces requirements specified in 4.7.5.4.5.

e. The end stop sizing shall take into account the worst-case loads, including the shock loads.

f. Contact with an end stop shall not result in a non-recoverable situation.

NOTE In case of specific application where this requirement is a main design driver, an alternative solution for emergency end stop can be adopted if agreed by the customer.

g. Electrical deployment indicators shall not be used as mechanical end stops.

NOTE Example of electrical deployment indicators are micro-switches.

h. The mating surfaces used in separable end stops shall be R_a <0,4 μm.

4.7.5.4.5 Separable contact surfaces (other than gears, balls and journal bearings)

a. Except for gears and ball or journal bearings, separable contact surfaces shall be designed to maintain adhesion forces below the specified limits.

b. Except for gears and ball or journal bearings, the contact between the mating surfaces shall be characterized.

NOTE Characterisation includes surfaces roughness, hardness, material properties, and contact geometry.

c. Except for gears and ball or journal bearings, the repeatability of the contact between the mating surfaces shall be verified and agreed by the customer.

NOTE Repeatability includes contact loads, contact area, contact stress, and alignment.

d. Except for gears and ball or journal bearings, the peak hertzian contact stress shall be verified to be below 93 % of the yield limit of the weakest material.

e. Except for gears and ball or journal bearings, sliding at the separable contact surfaces before separation shall be prevented, in order to avoid potential contact surface property changes.

f. Except for gears and ball or journal bearings, the functional dimensioning of the actuator which separates the contact surfaces shall be

1. sized in conformance with clause 4.7.5.3, and

2. verified by test under representative environmental conditions to conform to clause 4.7.5.3.

g. Except for gears and ball or journal bearings, and unless one surface is a self-lubricating material, when metallic material mating or separating surfaces subject to relative motion are used, they shall

1. have a minimum hardness of 500 HV, and

2. either:

(a) be composed of dissimilar material, or

(b) at least one of the two surfaces have a dissimilar coating.

NOTE 1 Example of self-lubrificating material is bronze.

NOTE 2 Examples of dissimilar coatings are nitride, carbide or oxide.

NOTE 3 The use of bonded or sputtered MoS_2 or polymeric materials is not excluded.

4.7.5.4.6 Ball bearings

a. Ball bearings made of hardened steel as defined in ISO 76 Edition 2 Amendment 1 subclause 1, shall be sized concerning the static load rating in conformance with ISO 76 Edition 2 Amendment 1 subclause 2, with respect to the maximum allowable hertzian contact stress.

b. The sizing of ball bearings made of materials other than hardened steel shall be agreed by the customer.

c. Ball bearings should be shielded.

4.7.5.4.7 Gears

a. Dimensioning and sizing of gears shall be performed in conformance with, ISO 6336, ISO 677, and ISO 678.

4.7.5.4.8 Mechanical clearances

a. When designing and locating mechanisms, clearance shall be provided to prevent movable and actuating elements from:

1. interfering (collision) with the structure,
2. contacting with electrical wiring and components, thermal insulation, or other subsystem components,
3. puncturing of fluid lines, valves and tanks, and
4. blocking optical paths.

b. Clearances shall be verified by analysis using worst-case tolerance budgets including thermoelastic effects and operational loads.

c. Clearances shall be verified by inspection.

d. Clearances should be at least 3 times its associated tolerance.

4.7.5.4.9 MLI clearance

a. For MLI clearance, clause 4.7.4.3 shall apply.

4.7.5.4.10 Threaded parts or locating devices

a. Threaded parts and locating devices shall use secondary, positive locking.

b. Threaded fasteners shall be made from materials, which are not susceptible to stress corrosion cracking.

NOTE 1 For materials preferred list, see ECSS-Q-ST-70-36. For other materials validation, see ECSS-Q-ST-70-37.

NOTE 2 For manufacturing of threaded fasteners see ECSS-Q-ST-70-46.

c. Threaded fasteners shall be designed to be fail-safe.

4.7.5.4.11 Venting

a. Unless the mechanism is hermetically sealed or sized in all its functions and performances for internal pressure build-up, all closed cavities shall be provided with a venting hole sized according to the launch ascent depressurisation profile.

b. The method and design of venting shall prevent particles contamination of bearings, optics and external sensitive components agreed by the customer.

NOTE 1 It is important to prevent also particles contamination of the sensitive components within the mechanism.

NOTE 2 Filters with mesh size of 1 to 2 microns placed in the venting path are means to prevent particles contamination.

c. If venting to the outside of a lubricated enclosure is implemented, compatibility of the lubricant with the other spacecraft materials used and with contamination requirements specified in the specific mechanism specification shall be verified.

4.7.5.4.12 Release and locking devices with pyrotechnics or other actuators

a. Pyrotechnic and other release and locking device actuators should be redundant.

NOTE Example of such actuators are thermal knives, memory metal and paraffin actuators.

b. Where no actuator redundancy is provided, redundancy shall be provided by duplicating up to and including the level of the initiators, heating element or equivalent for non-pyrotechnic devices, and its power supply.

c. The conformity of the design, material and manufacture of elements to be cut used in release and locking devices to the reliability requirements specified in the SMS shall be verified by test.

NOTE Example of such elements are bolts, rods and cables.

d. The operation of release devices shall be compatible with the cleanliness requirements.

e. All debris shall be contained.

f. If critical, contamination shall be measured.

g. Shock loads for release and locking devices shall be derived by analysis or test, and specified in the mechanism requirements specification.

4.7.6 Pyrotechnics

a. Pyrotechnic actuators shall be designed in conformance with ECSS-E-ST-33-11.

4.7.7 Electrical and electronic

4.7.7.1 Electrical design

4.7.7.1.1 General

a. Mechanisms shall be designed to meet all the requirements regarding electrical interfaces and performances.

b. Mechanisms shall exhibit stable electrical characteristics and electromechanical transfer functions throughout their specified period of life.

c. Electrical power consumption, generation and thermal dissipation shall be quantified by design.

d. Fault propagation shall be prevented.

e. Generated electrical disturbances shall conform to the project specific EMC requirements.

f. If brush motors are used, it shall be verified under representative environment and over specified lifetime that debris generation does not result in contamination.

g. If brush motors are used, it shall be verified under representative environment and over specified lifetime that debris generation does not result in electrical failure.

NOTE For example, short circuit of commutators.

h. If brush motors are used, it shall be verified under representative environment and over specified lifetime that brush wear does not result in functional performance degradation.

i. If brush motors are used, it shall be verified under representative environment and over specified lifetime that long storage period does not result in functional performance degradation.

4.7.7.2 Insulation

a. Electrical wires shall be insulated from the structure and from each other by not less than 10 MΩ measured with a DC voltage of 500 V applied.

b. Electric motor windings shall be insulated from the structure and from each other by not less than 100 MΩ measured with a DC voltage five times the worst-case flight operating voltage.

4.7.7.3 Dielectric

a. Electrical wires shall be designed to withstand a high voltage of 500 V AC (50 Hz) applied between each other or between wires and the structure without causing disruptive discharges.

b. Electric motor windings shall be designed to withstand the following high voltage applied between each other or between windings and the structure without causing disruptive discharge:

1. 250 V AC (worst flight operating motor voltage up to 50 V),
2. 500 V AC (worst flight operating motor voltage up to 100 V).

4.7.7.4 Grounding

a. Each mechanism shall be electrically bonded to the spacecraft structure or its carrying equipment.

b. If electronic or electrical components are mounted internally to or externally on the mechanism a ground bonding strap shall be used between the mechanism housing and the mounting ground plane.

c. If electronic or electrical components are mounted internally to or externally on the mechanism, the length-to-width ratio of the bonding strap should be smaller than four.

d. If electronic or electrical components are mounted internally to or externally on the mechanism, the DC resistance, between the mechanism bonding reference point and the mounting ground plane or carrying equipment ground plane in both polarities, shall be less than 10 mΩ.

e. If electronic or electrical components are mounted internally to or externally on the mechanism, the DC resistance, between any point on the mechanism housing and the bonding point reference of the mechanism, shall be less than 5 mΩ.

f. Where the grounding is to provide protection against electrostatic discharge only and the mechanism contains no electronics, the DC resistance shall be less than 0,1 Ω.

4.7.7.5 Electrical connectors

a. With the exception of the bonding strap for grounding, all electrical connections to the mechanism shall be made through electrical connectors of a type qualified for the intended application.

b. Flying leads should be avoided.

c. Connector types and configurations shall be selected to preclude damage or inadvertent operation resulting from mis-mating.

NOTE For example, for the number of pins.

d. Electrical connectors shall be redundant.

4.7.7.6 Over current protection

a. Mechanisms containing electrical parts and circuitry shall be protected against overcurrent due to abnormal applied voltage or internal conditions in conformance with ECSS-E-ST-20, clause 5.8.1.

NOTE The current protection can be provided externally.

b. The mechanism shall be protected against the generation of over voltage in conformance with ECSS-E-ST-20, clause 5.8.1.

4.7.7.7 Strain on wires

a. Routing shall be designed to be reproducible.

b. Implementation shall be verified.

c. Resistive torques or forces shall be measured under worst-case conditions.

d. The relative position of cables within the harness shall not change during motion.

NOTE The four previous requirements are introduced in order to achieve reproducible resistive torques or forces of moving cable harness.

e. Connections shall be protected from harness induced loads.

4.7.7.8 Magnetic cleanliness and ESD or EMC protection

a. Mechanisms shall conform to the spacecraft system requirements on magnetic cleanliness in conformance with ECSS-E-ST-20-07, and conductivity of surfaces for electrostatic discharge (ESD) protection in conformance with ECSS-E-ST-20-06.

4.7.8 Open-loop and closed-loop control system for mechanisms

4.7.8.1

a. The gain margin shall be higher than a factor of two (2) throughout the operational lifetime for linear or quasi-linear control systems, including A/D and D/A conversions effects.

b. Non-linear control systems stability margin value and assessment method shall be agreed by the customer.

4.7.8.2

a. The phase margin shall be higher than 30 degrees throughout the operational lifetime of the equipment and under worst-case combination of parameters (drift and temperature effects), including A/D and D/A conversions effects.

4.7.8.3

a. The bandwidth of the control system shall be designed to achieve the commanded action within the specified response time.

4.7.8.4

a. The damping ratio of the control system shall be greater than 0,05.

NOTE This is the same than require an equivalent Q value (amplification factor) of less than 10.

4.7.8.5

a. The control system shall not excite mechanism eigenmodes.

b. The control system shall take into account aliasing effects.

c. The control system shall not excite structural resonances of the spacecraft as specified by the customer.

4.7.8.6

a. The control system should be decoupled between the six directions of movement (three translations and three rotations).

b. If requirement 4.7.8.6a is not met, then coupling effects shall be characterized.

NOTE Multidimensional methods provide the best results.

4.7.8.7

a. The control system shall be compatible with the specified maximum angular and linear rates and accelerations of the spacecraft.

4.7.8.8

a. To prevent excessive amplification of the noise, transfer functions of the controller should not contain pure derivative terms.

b. The ratio between the derivative time constant and the time constant limiting the high frequency gain should not exceed 20.

4.7.8.9

a. Harnesses and cables to moving parts shall be characterized in terms of hysteresis and stiffness in representative configuration over the full range of displacement and over the specified qualification levels in terms of temperature range, lifetime, speed effects.

b. Harnesses and cables to moving parts shall be taken into account in the control system design.

4.7.8.10

a. If the sampling frequency results in aliasing of the sampled data, an anti-aliasing filter to reduce the bandwidth of the analogue signal (to be sampled) shall be used.

4.7.8.11

a. The resolution of sensors used in the control system to feedback information should be at least a factor of 5 (five) better than the specified resolution of the complete system.

4.8 Verification

4.8.1 General

a. Development of space mechanisms shall include a verification process in conformance with ECSS-E-ST-10-02.

NOTE 1 The mechanisms verification requirements are subdivided into analytical and test verification requirements.

NOTE 2 The model definition are provided in ECSS-E-HB-10-02.

b. A verification matrix shall be established by the supplier and provided to the customer for agreement.

4.8.2 Verification by analysis

4.8.2.1 General

a. The mechanisms parts, components and assembly analytical verification shall include the analysis specified in 4.8.2.2 to 4.8.2.19.

b. If any of the analysis specified in requirement 4.8.2.1a is not performed, justification shall be provided and agreed by the customer.

c. The analyses specified in requirement 4.8.2.1a shall cover

1. the combinations of range of extreme conditions for the flight system and which do not necessarily all occur during qualification testing

   NOTE For example, worst-case friction levels.

2. the effect of on-ground environmental conditions

   NOTE For example, air pressure, gravity effects, and test rigs perturbations.

3. the worst or extreme case conditions.

4.8.2.2 Worst-cases identification

a. The worst-case operational and non-operational sizing of a mechanism shall be identified according to the environmental, load and functional performance characteristics for the particular spacecraft and mechanism.

4.8.2.3 Thermal analysis

a. For the derivation of margins of safety clause 4.7.4.1 shall apply.

NOTE See ECSS-E-ST-31 for thermal analysis of mechanisms.

4.8.2.4 Structural analysis

a. For the derivation of margins of safety clause 4.7.5.2 shall apply.

NOTE 1 Structural analysis includes stiffness, stress or strength, thermo-mechanical effects, fatigue and fracture control. See ECSS-E-ST-32 for structural analysis of mechanisms.

NOTE 2 The objective is to demonstrate adequate sizing of the component and the overall assembly for all sizing cases.

4.8.2.5 Pre-load and tolerance budget analysis

a. Mechanisms pre-load and tolerance budget analysis shall take into account the relevant combination of the worst-cases environmental, functional, residual loads (including external and induced loads, and thermo-mechanical effects) and manufacturing tolerances.

b. Mechanisms pre-load and tolerance budget analysis shall verify the adequacy of mechanical plays in the worst-case conditions.

4.8.2.6 Functional performance analysis

4.8.2.6.1 General

a. Functional performance analysis shall be performed in all specified environments under all operational conditions (based on worst-case identification) to derive sizing loads, time shocks, speed, dimensional stability and positional accuracy.

4.8.2.6.2 Functional model requirements

a. The analysis shall be based on an analytical or numerical model, which represents the flight hardware mechanisms and its components, including interface conditions and overall spacecraft characteristics, with respect to

1. mass,
2. inertia,
3. location of the centre of mass,
4. structural stiffness,

5. actuation forces or torques, and

6. resistances for conditions specified in clause 4.7.5.3.

b. The model specified in requirement 4.8.2.6.2a shall be such that the following can be performed:

1. a parametric study of all the mechanical variables, and

2. an update of input parameters during the design and test phase.

4.8.2.6.3 Analysis requirements

a. It shall be demonstrated by analysis that the mechanism conforms to

1. the specific mechanism requirement specification (SMS), and

2. the mechanical design and sizing requirements (see clause 4.7.5) under worst-case parameter combinations.

b. Failure cases shall be analysed and, where identified, contingency scenarios shall be established and validated by analysis.

c. An integrity check of the results of the analysis shall be performed.

NOTE For example, energy or momentum balance.

d. A sensitivity analysis (parameter variation) covering the uncertainty of parameters shall be carried out.

e. If test results do not match predictions, the reason of the disagreement shall be found, and the analysis shall be updated accordingly.

f. Remaining deviations between test results and analyses shall be justified with respect to performance acceptability.

4.8.2.7 Hertzian contact and contact stress

a. An analysis shall be provided of the predicted hertzian contact or yield or bending stresses of moving surfaces in contact (for both, separable and sliding contacts, and bearings) under worst-case conditions to verify the compliance with the material allowables of the chosen material couple, lubricant and other coating used.

b. An analysis shall be provided to verify sizing of ball bearings in conformance with ISO 76 Edition 2 Amendment 1 subclauses 2, 4, 5, 6 and 7.

4.8.2.8 Functional dimensioning analysis

a. Conformance of mechanisms to specified requirements on functional dimensioning shall be verified by analysis.

NOTE Example of such requirements are torque, force, and kinematics.

4.8.2.9 Reliability analysis, FMECA

a. The reliability of a mechanism shall be determined.

NOTE For reliability, see ECSS-Q-ST-30. For FMECA, see ECSS-Q-ST-30-02.

4.8.2.10 Gear analysis

a. An analytical verification of the conformity of dimensioning and sizing of gears shall be performed.

NOTE For gear dimensioning and sizing see ISO 6336.

4.8.2.11 Shock generation and susceptibility

a. The conformity of the mechanism to the requirements for shock generation and susceptibility specified in the SMS shall be verified by analysis.

b. Dimensioning and sizing methods shall be agreed by the customer.

4.8.2.12 Disturbance generation (emission) and susceptibility

a. The mechanism operation shall be verified by analysis to comply with the specified requirements for induced loads.

NOTE For example, micro-vibrations.

b. The moving parts of the mechanism should be balanced to conform to the specified requirements on disturbances.

4.8.2.13 Analysis of control systems

a. A mathematical model or computer simulation describing the dynamic behaviour of the mechanism and its associated control system shall be established to perform verification by analysis.

b. The functional performance of the control system shall be analysed for

1. stability,
2. bandwidth,
3. dynamic and static accuracy,
4. resolution, and
5. generation of and susceptibility to disturbances at the interfaces of the mechanism.

c. All non-linearities shall be analysed.

d. Non-linearities such as backlash, dead zones, friction, saturation of drive electronics shall be characterized and taken into account in the control system analysis.

e. Characterization of non-linearities shall take place over the full range of displacements and over the full specified qualification temperature range.

f. The worst-case combinations of parameters occurring during the operational lifetime of the equipment shall be taken into account in the analysis of the non-linearities.

g. The robustness of the control against variations in the environment, between models and over the operational lifetime shall be verified by analysis.

4.8.2.14 Lubrication analysis

a. An analysis of the choice of lubrication system and its dimensioning for the proposed application and lifetime shall be provided.

b. The analysis specified in requirement 4.8.2.14a shall be based on similarity to a qualified application with regards to the following parameters:

   1. worst case peak contact hertzian stress;
   2. worst case operational contact hertzian stress;
   3. number and range of cycles;
   4. worst case environmental conditions.

c. For fluid lubrication systems, the analysis specified in requirement 4.8.2.14a shall verify the compatibility of the lubricant with the specified lifetime increased by a factor of 1,5 under the following worst case operational conditions:

   1. qualification temperatures;
   2. operational temperature profile of the mechanism over the full life time.

4.8.2.15 Lifetime analysis

a. Limited-life components shall be identified.

b. Conformance of limited-life components to the lifetime requirements specified in the specific mechanism specification shall be verified by analysis, using as a minimum the lifetime factors specified in clause 4.8.3.3.14 in addition to the fatigue factor specified in clause 4.7.5.2.

4.8.2.16 Hygroscopic effect analysis

a. The design compatibility with the hygroscopic environment during the complete lifetime shall be verified by analysis.

   NOTE The hygroscopic environment is mainly relevant on-ground.

4.8.2.17 Magnetic and electromagnetic analysis

a. The sizing of magnetic or electromagnetic components shall be verified by analysis.

4.8.2.18 Radiation analysis

a. Conformity of the components susceptible to radiation to the (lifetime) performance requirements shall be verified by analysis.

4.8.2.19 Electrical analysis

a. Electrical parts stress analysis shall be performed to demonstrate that the electrical parts conform to the derating requirements.

NOTE For derating see ECSS-Q-ST-30-11.

4.8.3 Verification by test

4.8.3.1 General

a. The tests to be performed to verify that the mechanism fulfils the requirements for use as space hardware shall be:

1. defined in a test plan, and
2. agreed by the customer.

NOTE The aim of testing can be either characterization, development, qualification or acceptance.

b. The permissible operations and the constraints for the operations on ground shall be defined by the supplier and agreed by the customer.

c. The mechanisms test programme shall include the verification that the hardware conforms to the requirements on design specified in clause 4.7, on construction specified in clause 4.9, and on performance specified in the specific mechanism specification.

d. The tests shall verify that the mechanism conforms to the functional dimensioning requirements specified in clause 4.7.5.3.

e. Tests shall be performed to check mechanism performance in both launch and operational configurations.

f. The mechanism shall be subjected to a thermal verification.

g. The mechanism shall be subjected to a structural verification.

NOTE For structural requirements, see ECSS-E-ST-32.

h. Non-linearities shall be measured in order to characterize the dynamic behaviour of the mechanism.

NOTE Examples of non-linearities are hysteresis and backlash.

4.8.3.2 Characterization or development testing

4.8.3.2.1 Model requirements

a. Development tests shall be carried-out on the bread-board models to test the specific aspect agreed by the customer.

NOTE The objective is to use bread-board models of varying levels of sophistication to test specific aspects or assumptions of a design on which the outcome of the design depends.

4.8.3.2.2 Test

a. Except in the case specified in requirement 4.8.3.2.2b, the following verification tests on development model mechanisms shall be performed during phases A or B of the project:

1. functional performance tests in ground ambient environment.

2. vibration and thermal tests.

3. tribological lifetime test on life critical components.

b. Verification test specified in requirement 4.8.3.2.2a need not be performed if the customer agrees that the test available data from previous space application can be used instead.

4.8.3.3 Qualification testing

4.8.3.3.1 General

a. All mechanisms shall be qualified by test for the application in which they are used.

b. The qualification tests shall be performed in a representative sequence and in a representative environment, agreed by the customer.

4.8.3.3.2 Structural qualification testing

a. The mechanisms structure shall be qualified by testing.

4.8.3.3.3 Thermal vacuum qualification testing

a. A thermal qualification of the mechanism shall be performed.

b. Operation of the mechanism in a representative environment under worst-case temperature gradients shall be verified by test at a level agreed by the customer.

4.8.3.3.4 Functional qualification testing

a. Settling and thermal stabilization shall be performed prior to functional performance testing.

b. The conformance of the mechanism to the performance requirements following exposure to environmental conditions (loads, thermal) at qualification level and mechanism qualification duration shall be verified by test.

4.8.3.3.5 Energy or shock

a. Mechanisms shall be verified by test to withstand release and end shocks caused by the motion of the mechanism.

b. Latching shock emissions shall be measured.

4.8.3.3.6 Solid lubricated ball bearing verification

a. Solid lubricated ball bearing material, design and performance (including the cage) shall be verified by testing.

b. The environment for the lubricant life test demonstration shall be agreed by the customer.

4.8.3.3.7 Fluid lubricated ball bearing verification

a. Ball bearing cage material, design, impregnation procedures for cages and reservoirs, and performance shall be verified by testing.

b. Lubricant quantity shall be verified by tests.

c. The compatibility of the fluid lubricant with the mechanism materials and other lubricants used within the mechanism shall be verified.

4.8.3.3.8 EMC or ESD qualification testing

a. The EMC performance (susceptibility and emissivity) of mechanisms shall be verified by testing when:

   1. EMC sensitive components are used on the mechanism, or

   2. spacecraft specific EMC requirements are applicable to the mechanism.

b. ESD testing shall be performed on a complete mechanism including all electrical components and thermal hardware.

   NOTE For EMC and ESD see ECSS-E-ST-20.

4.8.3.3.9 Electrical qualification testing

a. Electrical wires shall be tested to verify their insulation from the structure and from each other by not less than 10 MΩ with a DC voltage of 500 V applied for a duration of 2 min or until a steady state resistance value is measured.

b. Electrical wires shall be tested to withstand a voltage of 500 V AC (50 Hz) applied between each other or between wires and the structure for a duration of 1 min without causing disruptive discharges.

   NOTE For example, flash-over, spark-over and breakdown.

c. Motor windings shall be tested to verify their insulation from the structure and from each other by not less than 100 MΩ with a DC voltage of at least five times the worst-case flight operating voltage applied for a duration of 2 min or until a steady state resistance value is measured.

d. Motor windings shall be tested to withstand the following voltage (50 Hz) applied between each other or between windings and the structure for a duration of 1 min without causing disruptive discharges:

   1. 250 V AC (worst flight operating motor voltage up to 50 V);

   2. 500 V AC (worst flight operating motor voltage up to 100 V).

   NOTE Example of such disruptive discharges are flash-over, spark-over and breakdown.

4.8.3.3.10 Control system qualification testing

a. The mathematical model used to analyse the dynamic behaviour of the control system shall be correlated with measurements performed on representative hardware agreed by the customer.

b. The verification of control system performance by test should be performed using independent measurement devices.

c. The control system transducer shall not be used as a reference during the tests unless the transducer has been calibrated previously in a representative environment.

4.8.3.3.11 Lifetime qualification testing

a. The mechanism design, lubricant lifetime and performance shall be verified by test on a flight representative life test model in the specified environment after exposure to flight representative environmental tests.

NOTE For example, worst-case loads and accumulated vibration durations.

b. Exposure of lifetime model to vibrations prior to life test shall include:

1. exposure to accumulated durations of acceptance tests at acceptance load level and accumulated durations corresponding to the number of vibrations tests expected by the flight hardware, and
2. one time exposure to qualification load level and duration of vibration.

c. The environment for the verification of the lifetime of a lubricant shall be agreed by the customer.

4.8.3.3.12 Life test model requirements

a. The model and lifetime testing shall be representative with respect to the following parameters:

1. Thermal conditions, loading conditions, contact stress, motion profile and speed during testing, representative of the operational conditions.
2. Lubrication regime representative of worst-cases expected operational conditions, and for durations factored as agreed by the customer.

NOTE The duration factors are defined in clause 4.8.3.3.14.

b. Extended life durations to be agreed by the customer shall be implemented for the simulation of realistic conditions during accelerated tests.

NOTE These parameters can influence the life of the mechanism.

4.8.3.3.13 Life test profile

a. The profile and sequence of a life test shall be defined and agreed by the customer.

4.8.3.3.14 Life test duration

a. The lifetime qualification shall be verified using the factored sum of the predicted nominal ground test cycles and the in-orbit operation cycles.

b. For the test verification, the number of expected cycles shall be multiplied by the factors in Table 4-3.

Table 4-3: Life test duration factors

Type	Number of expected cycles	Factor
Ground testing (minimum 10 cycles to be tested)	1 to 1 000 cycles	4
	1 001 to 100 000 cycles	2
	> 100 000 cycles	1,25
In-orbit	1 to 10 cycles	10
	11 to 1 000 cycles	4
	1 001 to 100 000 cycles	2
	> 100 000 cycles	1,25

c. The cycle definition shall be agreed by the customer and take into account at least.

1. the number of motions over the same location, and
2. motion amplitude and number of reversals.

d. In order to determine the lifetime to be demonstrated by test, an accumulation of cycles multiplied by their individual factors shall be used.

NOTE Table 4-4 presents two case examples to calculate the number of cycles to be used in the test.

Table 4-4: Examples of lifetime to be demonstrated by test

Example	Data	Calculations
Example 1	Expected ground test cycles: 15	15×4 = 60
	Expected in-orbit cycles: 100	
	First 10 cycles	10×10 = 100
	Remaining 90 cycles	90×4 = 360
	Total life test number	520
Example 2	Expected ground test cycles: 2	2×4 = 8
	But minimum is 10	10
	Expected in-orbit cycles: 1	1×10 = 10
	Total life test number	20

e. Any element in a chain of actuation shall conform to the maximum number of cycles applicable to any of the other elements in the chain.

NOTE Example of such elements are motors, bearings, and gears.

4.8.3.3.15 Accelerated lifetime testing

a. If accelerated lifetime testing is employed to verify the lifetime performance of the mechanism, the model used for accelerated lifetime testing shall be representative of the worst-case environmental conditions with respect to degradation.

4.8.3.3.16 Post-test inspection

a. After completion of the life test, the mechanisms shall be disassembled into its tribological components and the status of the components verified with respect to the life test success criteria identified in clause 4.8.3.3.17.

4.8.3.3.17 Qualification testing success criteria

a. Qualification testing of the mechanism or of mechanical subsystem shall be considered successful when all the following criteria are demonstrated at the end of the test:

1. No direct contact between metallic elements in relative motion identified in the interface of solid lubricated contact surfaces;
2. Surface properties of contact surfaces not modified beyond the specified limits of their performance properties;
3. No chemical deterioration beyond the specified limits of fluid lubricants is found;
4. The amount and size of wear products conforms to contamination and overall mechanism performance requirements specified in the specific mechanism specification;
5. Worst-case variation or degradation peak torque or force overall throughout qualification (including life) testing is compatible with the functional dimensioning requirements specified in clause 4.7.5.3;
6. Deterioration torque or force performance is less than or equal to 50 % of the values measured at the beginning of qualification tests;
7. Other degradation factors agreed on a case by case basis with the customer are within the specified limits;
8. All measured performances conform to the requirement of the specific mechanism specification.

4.8.3.4 Acceptance testing

4.8.3.4.1 Mechanical settling and thermal stabilization

a. Mechanical settling and thermal stabilization shall be performed prior to acceptance testing.

4.8.3.4.2 Acceptance tests

a. New builds of qualified designs shall be acceptance tested to verify that the actual manufactured hardware is free from manufacturing defects.

b. The acceptance test sequence shall be agreed by the customer.

c. The acceptance level testing shall be carried out at levels, which are higher than expected in flight but less than the qualification levels.

d. After acceptance testing, refurbishment should not be performed.

NOTE This is for the test levels experienced to be at a level, which is not detrimental to the health of the hardware.

4.8.3.4.3 Dielectric test

a. Electrical wires shall be tested to withstand the following voltage (50 Hz) applied between each other or between wires and the structure for a duration of 10 s without causing disruptive discharges:

1. 250 V AC (worst flight operating voltage up to 50 V), or
2. 500 V AC (worst flight operating voltage up to 100 V),
3. 5 times the operating voltage, AC (worst flight operating voltage higher than 100 V).

NOTE For example, flash-over, spark-over and breakdown.

4.8.3.4.4 Acceptance tests criteria

a. Acceptance testing shall be considered successful when all the following criteria are met:

1. The peak torque or force, resulting from the summation of the following, comply with the functional dimensioning requirements specified in clause 4.7.5.3:
   (a) the worst-case variation or degradation of the peak torque or force measured on the qualification model overall throughout life testing, and
   (b) the worst case force or torque measured on the flight unit.
2. Deterioration torque or force performance throughout acceptance tests is less than the values measured on the qualification model.
3. All measured performances conform to the specific mechanism specification (SMS).

4.9 Production and manufacturing

4.9.1 Manufacturing process

a. All processes used in the manufacture of space mechanisms hardware shall be

1. approved by the customer, and
2. part of the overall product assurance system.

NOTE This approval is normally based on their repeatability and proven capability of achieving the specified levels of safety and reliability.

4.9.2 Manufacturing drawings

a. Manufacturing drawings shall be established in conformance with ISO 128.

4.9.3 Assembly

a. The assembly of mechanisms shall be performed in a clean environment specified by the customer.

4.10 Deliverables

a. The supplier shall provide the mechanisms design description in conformance with the DRD in Annex B.

b. The supplier shall provide the mechanisms analytical verification (MAV) in conformance with the DRD in Annex C.

c. The supplier shall provide the mechanism user manual (MUM) in conformance with the DRD in Annex D.

NOTE 1 In accordance with requirement 4.2.2a, a specific mechanism specification is also delivered by the supplier for customer approval.

NOTE 2 Requirements 4.10a to 4.10c covers the deliverable documents specific to the present standard. Table E-1 in Annex E includes the mechanism documentation technical items, and the ECSS documents where they are covered.

Annex A (normative) Specific mechanism specification (SMS) - DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-33-01, requirement 4.2.2a.

A.1.2 Purpose and objective

The purpose of the specific mechanism specification (SMS) is to specify the mechanism requirements specific to the particular application. It is expected that a SMS is developed for each individual mechanism in a project.

The SMS is developed by the supplier, and propose to the customer for approval.

A.2 Expected response

A.2.1 Scope and content

<1> Introduction, references and terminology

a. The SMS shall contain a description of the purpose, objective, content and the reason prompting its preparation.

NOTE For example: "This document describes the application specific requirements of the <name> mechanism for the <name> project".

b. The SMS shall list any applicable and reference documents to support the generation of the document.

c. The SMS shall include any additional definition, abbreviation or symbol used.

<2> Customer specific requirements

a. The SMS shall include all the specific requirements expressed by the customer.

<3> General requirements

a. The SMS shall specify or refer to the qualification procedure for parts and components.

NOTE See 4.2.4.2a.

b. If the mechanism is not maintenance free during storage and ground life, the SMS shall list the maintenance requirements, including for each of them:

1. number of operations,
2. frequency of operations,
3. special tooling and test equipment,
4. calibration and adjustments,
5. fault identification and repair, and
6. environment for maintainability operation.

NOTE See 4.2.4.4b.

c. The SMS shall include or refer to the method to demonstrate the mechanism reliability compliance.

NOTE See 4.2.5.1.

d. The SMS shall describe the redundancy concepts for the mechanism.

NOTE See 4.2.5.2d.

e. The SMS shall include the cleanliness requirements of the inert dry for flushing the critical parts of the mechanisms.

NOTE See 4.2.6a.

f. The SMS shall include the minimum functional performances to be conformed to, over the complete mission (including on-ground).

NOTE This minimum functional performance is used to ensure that the mechanism is not degraded over the mission. In particular, it is used to ensure that there is not unacceptable degradation due to:

- Radiation (see 4.5.2.8);
- Atomic oxygen (see 4.5.2.9);
- Degradation of the lubricant in the on-ground and in-orbit environments (see 4.7.3.1c);
- Migration of fluid lubricants that can cause a change of the lubricant amount on the parts to be lubricated. In this case, anti-creep barriers can be used (see 4.7.3.3.3c).

<4> Constraints

a. The SMS shall include the specific climatic protection and environmental requirements.

b. The SMS shall include the sterilization requirements and the sterilization test procedure requirements.

c. The SMS shall include the stray light and emission requirements.

NOTE These requirements are used to select the materials and coatings (see 4.5.2.7).

<5> Interfaces requirements

a. The SMS shall list the following interface definitions and requirements:

1. Structural
2. Thermal
3. Thermo-mechanical
4. Electrical
5. Data
6. Physical

   NOTE Examples of physical interfaces are: mass, geometry, MOI, COG, and I/F pattern.

7. Optical
8. Alignment
9. Access and stay-out zones
10. GSE

<6> Design requirements

a. The SMS shall list the handling, storage and operational requirements for all lubricated components.

b. The SMS shall include the limits for outgassing, creeping and potential sources of contamination.

NOTE 1 This limits have a strong impact on the design of the fluid lubricated system.

NOTE 2 For generic requirements on outgassing limits, see requirement 4.7.3.3.2.b.

c. The SMS shall define the specific requirements for mission involving advanced optical instruments.

d. The SMS shall include the qualification temperature range under all ground, test, launch and in-orbit conditions.

NOTE This is used for the mechanism thermal design and sizing (see 4.7.4.2a).

e. The SMS shall list the shock load requirements for latches and locks.

NOTE For the derivation of such requirements, see 4.7.5.4.3i.

f. The SMS shall include the specified maximum positions of the mechanism.

NOTE These maximum positions are provided to design end stops in accordance with 4.7.5.4.4a.

g. The SMS shall specify the reliability requirements, to verify the conformity of the design, material and manufacture of elements to be cut used in release and locking.

NOTE See 4.7.5.4.12c.

h. The SMS shall specify the shock loads for release and locking devices.

NOTE For the derivation of such requirements, see 4.7.5.4.12g.

<7> Verification requirements

a. The SMS shall list the requirements for shock generation and susceptibility.

NOTE See 4.8.2.11a.

b. The SMS shall list the limited-life components lifetime requirements.

NOTE See 4.8.2.15b.

A.2.2 Special remarks

None.

Annex B (normative) Mechanism design description (MDD) - DRD

B.1 DRD identification

B.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-33-01, requirement 4.10a.

B.1.2 Purpose and objective

The purpose of the mechanism design description (MDD) is to provide the customer with a comprehensive understanding of the mechanism design and functionality.

B.2 Expected response

B.2.1 Scope and content

<1> Introduction, references and terminology

a. The MDD shall contain a description of the purpose, objective, content and the reason prompting its preparation.

NOTE For example: “This document describes the functionality and design of the <name> mechanism for the <name> project.

b. The MDD shall list:

1. the model standard of the mechanism being described;

   NOTE Examples are DM, EM, QM, and FM for which the definition is provided in ECSS-E-HB-10-02.

2. the list of documents providing additional subsystem design description;
3. any other applicable and reference documents to support the generation of the document.

c. The MDD shall include any additional definition, abbreviation or symbol used.

<2> Mission and mechanism main functions

a. The MDD shall describe the mission and the role of the mechanism in achieving the mission.

b. The primary functions of the mechanism shall be described.

<3> Key requirements

a. The MDD shall include the requirements that drive the selected mechanism concept.

NOTE Examples of such requirements are functional, operational, and imposed design solutions.

<4> Functional principle

a. The MDD shall describe how the mechanism primary functions are broken down into their elementary functions.

NOTE For example, use functional tree.

b. Schematic functional elements should be added to the tree.

<5> Detailed description of the mechanism

a. The MDD shall describe the mechanism detailed design, including the following:

1. product tree (sub assembly break down);
2. physical design of the mechanism in all configurations;
3. how each function is achieved;
4. protection and redundancy implementation;
5. general assembly drawings with cross sections or equivalent;
6. interface descriptions (mechanical, thermal and electrical);
7. static and dynamic envelopes.

<6> Performance and budgets

a. The MDD shall provide informative data with regard to performance, mass and power budgets.

NOTE This is provided for information only. The contractual values are provided in the verification files.

B.2.2 Special remarks

None.

Annex C (normative) Mechanism analytical verification (MAV) - DRD

C.1 DRD identification

C.1.1 Requirement identification and source document

This DRD is called from ECSS-ST-E-33-01, requirement 4.10b.

C.1.2 Purpose and objective

The purpose of the mechanism analytical verification (MAV) is to provide the customer with a comprehensive functional and performance analysis of the mechanism.

C.2 Expected response

C.2.1 Scope and content

<1> Introduction, references and terminology

a. The MAV shall contain a description of the purpose, objective, content and the reason prompting its preparation.

NOTE For example: This document provides all functional and performances analyses of the "name" mechanism for the "name" project. This document is part of the verification files and ensures that the mechanism is sized to meet the related requirements.

b. The MAV shall list:

1. all the applicable documents regarding requirements related to design and performance;
2. the design definition file reference of the mechanism being analysed;
3. the list of documents providing inputs to analyses presented in this document;

NOTE 1 For example, thermal analysis, structural analysis, and test reports.

NOTE 2 Subsystems and components data to be included.

4. any other applicable and reference documents to support the generation of the document.

c. The MAV shall include any additional definition, abbreviation or symbol used.

<2> Mission and mechanism main functions

a. The MAV shall describe the mission and the role of the mechanism in achieving the mission.

b. The primary functions of the mechanism shall be described.

<3> Analytical verification

a. The MAV shall provide all analyses regarding analytical verification as defined in 4.8.2

b. For each of the analyses of C.2.1<3>a, the results shall be summarized in a table and compared to the requirements.

NOTE Each specific analysis can be provided in a separate document or grouped together.

C.2.2 Special remarks

None.

Annex D (normative) Mechanism user manual (MUM) - DRD

D.1 DRD identification

D.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-33-01, requirement 4.10c.

D.1.2 Purpose and objective

The purpose of the mechanism user manual (MUM) is to provide the customer with a comprehensive set of information and instructions for storage, transportation, handling, integration at subsystem or system level, and on ground and in-orbit operation of the mechanism.

NOTE Operational information and instructions provided by the mechanism supplier are limited to mechanism level.

D.2 Expected response

D.2.1 Scope and content

<1> Introduction, references and terminology

a. The user manual shall contain a description of the scope and applicability of the document.

NOTE For example: This document provides all information and instructions for storage, transportation, handling, integration at subsystem or system level, and on ground and in-orbit operation of the "name" mechanism for the "name" project.

b. The user manual shall include:

1. the mechanism requirement specification;
2. the delivered mechanism applicable CIDL;
3. the list of consumables and spares;
4. the list of GSE and special tools;

5. the list of user manuals for GSE and special tools;

6. the calibration data.

c. The user manual shall include any additional definitions, abbreviations or symbols used.

<2> Mission and mechanism main functions

a. The user manual shall describe the mission and the role of the mechanism in achieving the mission.

b. The primary functions of the mechanism shall be described.

<3> Safety instructions

a. The user manual shall present all aspects with regard to personnel safety and shall detail all necessary safety precautions.

<4> Traceability requirements

a. The user manual shall define the information to be recorded after delivery.

NOTE For example: Number of limited operations.

<5> Delivery configuration

a. The user manual shall present the following information regarding the mechanism delivery configuration:

1. short description of the mechanism and all self standing subassemblies;

2. short description of GSE and special tools, including drawings or pictures.

b. The description specified in D.2.1<5>a shall include drawings or pictures.

<6> Storage, transportation and handling

a. The user manual shall describe the following topics:

1. mechanism configuration for storage, transportation and handling;

2. container characteristics and operation instructions;

3. packing, and transportation instructions;

4. unpacking and incoming inspections;

5. handling and storage instructions;

6. environmental conditions for the in D.2.1<6>a.1.to D.2.1<6>a.5. defined phases.

NOTE Examples of such environmental conditions are mechanical, thermal, hygrometry, and pressure, cleanliness.

<7> Interfaces definition

a. The user manual shall provide the following information with regards to interfaces definition:

1. description of mechanical and thermal interfaces (including the list of applicable mechanical and thermal ICD);
2. description of electrical interfaces (including the list of applicable electrical ICD);
3. description of optical interfaces (including the list of applicable optical ICD).

   NOTE In case the ICDs are provided in a specific chapter of the EIDP, the list of applicable ICDs can be limited to the EIDP chapter reference.

<8> Integration instructions

a. The user manual shall provide the following information with regards to integration instructions:

1. integration sequence;
2. preparation prior to integration, including
   (a) mechanism and self standing subassemblies configuration;
   (b) GSE and special tools to be used;
   (c) items to be removed;
   (d) specific precautions and safety instructions;
   (e) cleaning instructions;
   (f) environmental conditions for integration;
   (g) detailed handling instructions for integration.
3. step by step mounting instructions including torque on threaded fasteners, alignment provisions, shims, electrical connections, intermediate inspections and checks;
4. final inspections.

   NOTE For example, visual, electrical checks, clearances, and health checks.

<9> Onground operation instructions

a. The user manual shall describe all activities to operate the mechanism on ground, including:

1. Preparation for start up:
   (a) operational configuration;
   (b) GSE and special tools to be used;
   (c) items to be removed;
   (d) specific precautions and safety instructions including limitations in terms of operation and performances;

(e) cleaning instructions;

(f) environmental conditions for operation.

2. Step by step Start up operation instructions.

3. For each operational mode

(a) operational configuration;

(b) GSE and special tools to be used;

(c) specific precautions and safety instructions including limitations in terms of operation and performances;

(d) environmental conditions for operation;

(e) step by step operation instructions;

(f) telemetry requirements and health monitoring;

(g) recovery contingencies.

NOTE Example of such operational modes are release, calibration, deployment, and pointing, scanning.

<10> Maintenance operations

a. The user manual shall describe all maintenance operations.

NOTE For example:

- Time limited consumables replacement
- Cycles limited consumables replacement
- Periodic health check
- Periodic operations

<11> In-orbit operation instructions

a. The user manual shall describe all activities to operate the mechanism in-orbit.

b. For each operational mode the following topics shall be described:

1. operational configuration;

2. specific precautions including limitations in terms of operation;

3. operation sequence;

4. telemetry requirements and health monitoring;

5. recovery contingencies.

NOTE Examples of such operational modes are release, calibration, deployment, pointing, and scanning.

D.2.2 Special remarks

None.

Annex E (informative) Documentation technical items

Table E-1 includes the mechanism documentation technical items, and the ECSS documents where they are covered.

Table E-1: Documentation technical items

Document	ECSS reference
Configuration item data	ECSS-M-ST-40
Critical items	ECSS-Q-ST-10-04
Declared components	ECSS-Q-ST-60
Declared materials, parts and processes	ECSS-Q-ST-70
Design description	ECSS-E-ST-33-01 Annex B
Design, development and verification approach	ECSS-E-ST-10-02
Failure modes and effects criticality analysis (FMECA)	ECSS-Q-ST-30-02
Fracture control	ECSS-E-ST-32-01
Analytical verification	ECSS-E-ST-33-01 Annex C
Hazard and safety analysis	ECSS-Q-ST-40-02
Interface control	ECSS-E-ST-10
Manufacturing file	-
Manufacturing, assembly, integration and test approach (including Zero G rigs)	ECSS-E-ST-10-02
Mechanism user manual	ECSS-E-ST-33-01 Annex D
Qualification status	ECSS-Q-ST-10
Requirements compliance	ECSS-E-ST-10-02
Thermal analysis	ECSS-E-ST-31
Structural analysis	ECSS-E-ST-32

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ECSS-E-ST-10	Space engineering – System engineering general requirements
ECSS-E-HB-10-02	Space engineering – Verification handbook
ECSS-E-ST-10-04	Space engineering – Space environment
ECSS-E-ST-32-01	Space engineering – Fracture control
ECSS-E-ST-10-04	Space engineering – Space environment
ECSS-E-ST-70-11	Space engineering – Space segment operability
ECSS-M-ST-40	Space project management – Configuration and information management
ECSS-Q-ST-10	Space engineering – Product assurance management
ECSS-Q-ST-10-04	Space product assurance – Critical-item control
ECSS-Q-ST-20	Space product assurance – Quality assurance
ECSS-Q-ST-30-02	Space product assurance – Failure modes, effects (and criticality) analysis (FMEA/FMECA)
ECSS-Q-ST-30-11	Space product assurance – Derating – EEE components
ECSS-Q-ST-40-02	Space product assurance – Hazard analysis
ECSS-Q-ST-60	Space product assurance – Electrical, electronic and electromechanical (EEE) components
ECSS-Q-ST-70-01	Space product assurance – Contamination and cleanliness control
ECSS-Q-ST-70-02	Space product assurance – Thermal vacuum outgassing test for the screening of space materials
ECSS-Q-ST-70-46	Space product assurance – Requirements for manufacturing and procurement of threaded fasteners