



BSI Standards Publication

Space engineering - Mechanisms

National foreword

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English version

Space engineering - Mechanisms

Ingénierie spatiale - Mécanismes

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European Foreword

This document (EN 16603-33-01:2019) has been prepared by Technical Committee CEN-CENELEC/TC 5 "Space", the secretariat of which is held by DIN.

This standard (EN 16603-33-01:2019) originates from ECSS-E-ST-33-01C Rev.1.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2019, and conflicting national standards shall be withdrawn at the latest by October 2019.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a standardization request given to CEN by the European Commission and the European Free Trade Association.

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

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

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

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

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

1

Scope

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

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

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

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

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS standard. For dated references, subsequent amendments to or revisions of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system — Glossary of terms
EN 16603-10-02	ECSS-E-ST-10-02	Space engineering – Verification
EN 16603-20	ECSS-E-ST-20	Space engineering – Electrical and electronic
EN 16603-06	ECSS-E-ST-20-06	Space engineering – Spacecraft charging
EN 16603-07	ECSS-E-ST-20-07	Space engineering – Electromagnetic compatibility
EN 16603-31	ECSS-E-ST-31	Space engineering – Thermal control general requirements
EN 16603-32	ECSS-E-ST-32	Space engineering – Structural
EN 16603-32-01	ECSS-E-ST-32-01	Space engineering – Fracture control
EN 16603-32-10	ECSS-E-ST-32-10	Space engineering – Structural factors of safety for spaceflight hardware
EN 16603-33-11	ECSS-E-ST-33-11	Space engineering – Explosive systems and devices
EN 16602-30	ECSS-Q-ST-30	Space product assurance - Dependability
EN 16602-40	ECSS-Q-ST-40	Space product assurance – Safety
EN 16602-70	ECSS-Q-ST-70	Space product assurance – material, mechanical part and process
EN 16602-70-36	ECSS-Q-ST-70-36	Space product assurance – Material selection for controlling stress corrosion cracking
EN 16602-70-37	ECSS-Q-ST-70-37	Space product assurance – Determination of the susceptibility of metals to stress corrosion cracking
EN 16602-70-71	ECSS-Q-ST-70-71	Space product assurance – Data for selection of space materials and processes
	ISO 76 (2006)	Rolling bearings – Static load rating
	ISO 128 (1996)	Technical drawings

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

Terms, definitions and abbreviated terms

3.1 Terms from other standards

- a. For the purpose of this Standard, the term and definition from ECSS-S-ST-00-01 apply, and in particular the following:
 - 1. cleanliness
 - 2. component
 - 3. interface
 - 4. product
- b. For the purpose of this Standard, the term and definition from ECSS-S-ST-32-10 apply, and in particular the following:
 - 1. fail-safe
 - 2. model factor (KM)
 - 3. project factor (KP)

3.2 Terms specific to the present standard

3.2.1 actuator

component that performs the moving function of a mechanism

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

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

3.2.2 control system

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

3.2.3 deliverable output torque (T_L)

torque at the mechanism or actuator output

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

NOTE 2 For example: A theoretical torque or force of a robotic mechanism (service tool) for which no specific function except torque or force provision can be specified at an early stage in the project development.

3.2.4 deliverable output force (F_L)

force at the mechanism or actuator output

3.2.5 elementary function

lowest level function

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

3.2.6 inertial resistance force (F_D)

force to accelerate the mass

3.2.7 inertial resistance torque (T_D)

torque to accelerate the inertia

3.2.8 fastener

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

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

3.2.9 flushing or purging

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

3.2.10 latching or locking

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

3.2.11 lubrication

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

3.2.12 mechanism

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

3.2.13 off-loading

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

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

3.2.14 phase margin

indicator for the stability of dynamic control systems

3.2.15 positively locked

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

3.2.16 positive indication of status

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

3.2.17 primary function

high level function

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

3.2.18 safety critical mechanism

mechanical product having a critical or catastrophic hazard potential

3.2.19 threaded fastener

fastener with a threaded portion

NOTE For example: Screws, bolts and studs.

3.2.20 tribology

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

3.2.21 venting

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

NOTE For example: Use of dedicated venting holes or passages

3.3 Abbreviated terms

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

Abbreviation	Meaning
A/D	analogue to digital
AC	alternating current
COG	centre of gravity
CVCM	collected volatile condensable material
D/A	digital to analogue
DC	direct current
DFMR	design for minimum risk
DLL	design limits loads
EMC	electromagnetic compatibility
ESD	electrostatic discharge
F	actuation force
F_D	inertial resistance force
F_L	deliverable output force
FMECA	failure mode effects and criticality analysis
F_{min}	minimum actuator force required
FOS	factor of safety
F_R	friction torque or force
GSE	ground support equipment
H_A	harness and other torque or force resistances
H_D	adhesion torque or force
HV	hardness Vickers
H_Y	hysteresis torque or force
I	inertia resistance (linear or angular)
I/F	Interface
LEO	low Earth orbit
M	mass
MAV	mechanism analytical verification
MDD	mechanism design description
MUM	mechanism user manual
MLI	multi-layer insulation
MOI	moment of inertia
MOS	margin of safety

Abbreviation	Meaning
MS	strength safety margin
MSVP	safety critical mechanisms verification plan
MSVR	safety critical mechanisms verification report
n.a.	not applicable
SMS	specific mechanism specification
RML	recovered mass loss
S	spring force
SI	international system of units
S/C	spacecraft
SMS	specific mechanism specification
T	actuation torque
T_D	inertial resistance torque
T_L	deliverable output torque
T_{min}	minimum actuator torque required
TML	total mass loss
UV	ultraviolet
VCD	verification control document

3.4 Nomenclature

The following nomenclature applies throughout this document:

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

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

- c. The words “may” and “need not” are used in this Standard to express positive and negative permissions, respectively. All the positive permissions are expressed with the word “may”. All the negative permissions are expressed with the words “need not”.
- d. The word “can” is used in this Standard to express capabilities or possibilities, and therefore, if not accompanied by one of the previous words, it implies descriptive text.

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

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

4

Requirements

4.1 Overview

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

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

4.2 General requirements

4.2.1 Overview

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

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

4.2.2 Mission specific requirements

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

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

4.2.3 Units

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

4.2.4 Product characteristics

4.2.4.1 Marking and labelling

4.2.4.1.1 Specific identification

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

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

NOTE 2 The identification can be removable.

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

4.2.4.1.2 Marking

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

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

4.2.4.2 Parts and components

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

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

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

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

4.2.4.3 Interchangeability

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

4.2.4.4 Maintainability

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

4.2.5 Reliability and redundancy

4.2.5.1 Reliability

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

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

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

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

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

4.2.5.2 Redundancy

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

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

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

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

4.2.6 Flushing and purging

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

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

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

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.

NOTE Mechanical interfaces include assembly and test rigging and other installation and integration conditions.

- 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

Requirements of clause 4.5 cover 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.
- 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 to conform to the requirements of induced emissions.

NOTE An example of induced emission is stray light.

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 parts should be exercised over a complete revolution at regular intervals, according to an operational procedure agreed by the customer.

NOTE Examples of oscillatory rolling parts 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

Requirements of clause 4.6 cover 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.