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Space Systems — Mechanism design and verification

Systèmes spacieux — Conception et vérification des mécanismes

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Foreword

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This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Mechanisms are important elements of spacecraft and its payloads. A mechanism failure can cause the loss of human lives for manned space systems or jeopardize the intended mission for unmanned space systems.

Currently, there is no international standard that covers all the aspects that can be used for space flight moving mechanisms such as rotating machineries, solar array drive mechanism, paddle hinge mechanism, latch mechanism.

The purpose of this document is to establish general requirements for mechanisms. It provides the uniform requirements necessary to minimize the duplication of effort for resolving technical barrier, considering the differences between approaches taken by the participating nations and their commercial space communities in developing mechanisms. In addition, the use of agreed-upon standards will facilitate cooperation and communication among space programmes.

This document, when implemented for a particular space system, ensures high confidence in achieving safe and dependable operation in all phases of its planned mission.

Space Systems — Mechanism design and verification

1 Scope

This document establishes requirements for the design, material selection and characterization, fabrication, testing and inspection of all space mechanisms on spacecraft and payloads to meet the mission performance requirements. This document does not cover the requirements for mechanisms on expendable and reusable launch vehicles. Applicability of the requirements contained in this document to launch vehicle mechanisms is a decision left to the individual launch vehicle project.

This document applies specifically to all moving mechanisms used in spacecraft during all phases of the mission, with the exception of engines and thermal protection systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10786, *Space systems — Structural components and assemblies*

ISO 14302, *Space systems — Electromagnetic compatibility requirements*

ISO 15864, *Space systems — General test methods for spacecraft, subsystems and units*

ISO 21886, *Space systems — Configuration management*

ISO 23135, *Space systems — Verification program and management process*

ISO 23460, *Space projects — Programme management — Dependability assurance requirements*

ISO 24113, *Space systems — Space debris mitigation requirements*

ISO 27025, *Space systems — Programme management — Quality assurance requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
mechanism
assembly of parts that are linked together to enable a relative motion

3.2
outgassing
evolution of gaseous species from a material, usually in a vacuum

Note 1 to entry: Outgassing also occurs in higher-pressure environments.

[SOURCE: ISO 15388:2012, 3.1.34]

3.3
interface
mechanical, thermal, electrical, or operational common boundary between two elements of a system

[SOURCE: ISO 10795:2019, 3.132]

3.4
acceptance test
required formal test conducted on flight hardware to ascertain that the materials, manufacturing processes, and workmanship meet specifications and that the hardware is acceptable for intended usage

[SOURCE: ISO 10786:2011, 3.2]

3.5
contamination
introduction of any undesirable molecular or particulate matter (including microbiological matter) into an item or into the environment of interest

[SOURCE: ISO 10795:2019, 3.62]

3.6
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

3.7
redundancy
⟨design property of a system⟩ existence of more than one means for performing a function

Note 1 to entry: The additional means of performing the function may be intentionally different (diverse) to reduce the potential for common mode failures.

[SOURCE: ISO 10795:2019, 3.196]

3.8
debris
fragment such as abrasion powders produced by the operation of *mechanism* (3.1) parts

Note 1 to entry: See also *space debris* (3.18).

3.9
tribology
discipline that deals with the design, friction, wear and *lubrication* (3.6) of interacting surfaces in relative motion to each other

3.10
qualification test
required formal contractual test used to demonstrate that the design, manufacturing, and assembly have resulted in hardware designs conforming to specification requirements

[SOURCE: ISO 10795:2019, 3.187]

3.11
maintainability
⟨of an item⟩ ability to be retained in, or restored to a state in which it can perform as required, under given conditions of use and maintenance

Note 1 to entry: Given conditions of use may include storage.

Note 2 to entry: Given conditions of maintenance include the procedures and resources for use.

Note 3 to entry: Maintainability may be quantified using such measures as mean time to restoration, or the probability of restoration within a specified period of time.

[SOURCE: ISO 10795:2019, 3.144]

3.12
misalignment
geometric position error between machine elements and parts

EXAMPLE Translational displacement, inclination, torsion.

3.13
mission
set of tasks, duties or functions to be accomplished by an element

[SOURCE: ISO 10795:2019, 3.154]

3.14
latching
locking
intentional constraining of one or more previously unconstrained degrees of freedom which cannot be released without specific action

3.15
model
physical or abstract representation of relevant aspects of an **item** or **process** that is put forward as a basis for calculations, predictions, or further assessment

Note 1 to entry: The term "model" can also be used to identify particular instances of the **product**, e.g. flight model.

[SOURCE: ISO 10795:2019, 3.155]

3.16
modelling
act of creating a *model* (3.15), i.e. act of creating a representation of a system

3.17
simulation
imitation of the behavioural characteristics of a system, entity, phenomenon, or process

Note 1 to entry: The term "simulation" can be also used for the production of a computer (or physical) *model* (3.15) of something, especially the purpose of study.

3.18
space debris
objects of human origin in Earth orbit or re-entering the atmosphere, including fragments and elements thereof, that no longer serve a useful purpose

[SOURCE: ISO 24113:2019, 3.23, modified — The deprecated term and note 1 to entry have been removed.]

3.19
dependability
<of an item> ability to perform as and when required

Note 1 to entry: Its main components are reliability, availability and *maintainability* (3.11).

Note 2 to entry: The extent to which the fulfilment of a required function can be justifiably trusted.

Note 3 to entry: Dependability shall be considered in conjunction with safety.

Note 4 to entry: Dependability is used as a collective term for the time-related quality characteristics of an item.

[SOURCE: IEC 60050-192:2015, 192-01-22, modified — The original note 1 to entry has been replaced by Notes 1 to 3 to entry.]

3.20
electromagnetic compatibility
EMC
ability of a space equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: ISO 14302:2002, 3.1.4]

4 Fundamental requirements

4.1 System performance

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

4.2 Mission

Design of the mechanism shall meet the requirements applied throughout the entire period of the mission specified in individual programs. Design of the mechanism shall meet all requirements and encountered environmental conditions in each phase of the mission.

4.3 Function

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

NOTE 1 For example, position over time, velocity and acceleration.

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

NOTE 2 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) It shall be ensured that there is no mechanical interference between the movement of each part with any other part of the mechanism, the spacecraft, the payload or the launch vehicle.

5 Design requirements

5.1 Interfaces

a) Structural interfaces

Mechanisms shall conform to the structural interface conditions and requirements defined in the specification.

b) Thermal interfaces

Mechanisms shall conform to the thermal interface conditions and requirements defined in the specification.

c) Thermo-mechanical interfaces

Mechanisms shall be designed in consideration of thermal stress induced between the mechanism and its installation points.

d) Electrical interfaces

Mechanisms shall conform to the electrical interface conditions and requirements defined in the specification.

e) Physical interfaces

The mass of a mechanism shall conform to the requirements defined in the specification.

f) Other interfaces

Mechanisms shall conform to the interface conditions of optical (visual field), mounting alignment, accessibility during operation, envelope area, clearance with other equipment and ground-based equipment defined in the specification.

5.2 Environmental design

5.2.1 General

Mechanisms shall conform to the environmental condition requirements defined in the specification.

5.2.2 Ground environment

a) Mechanisms shall meet the required performance even under ground handling environment conditions such as ground test, assembly, storage and transportation.

b) Mechanisms shall be designed to take into account the ground test environment including temperature, vibration, sound, shock, different atmospheric gases, pressure, humidity, cleanness and corrosive environment.

5.2.3 Launch vehicle flight environment

a) Mechanisms shall meet the required performance after being exposed to launch vehicle flight environment conditions.

b) As to the launching environment, mechanisms shall be designed to take into account changes in the parameters such as temperature, vibration, sound, shock, pressure and humidity.

5.2.4 Orbital environment

a) Mechanisms shall meet the required performance under orbital environment conditions until the end of their required operating life is reached.

b) As to the orbital environment, mechanisms shall be designed to take into account environmental factors such as vacuum, temperature cycle, vibration, shock, radiation, ultraviolet and atomic oxygen. Mechanisms shall be designed to take into account the environmental effects in outer space on the materials used in the mechanism.

5.3 Parts and materials

5.3.1 General

The parts, materials and processes of the mechanism shall be selected to meet the requirements about function, performance, environmental conditions, quality, reliability, and other properties specified in the mechanism specification.

5.3.2 Requirements for parts

a) Parts used in mechanisms shall be selected from customer approved standard parts or registered parts for project use if possible and proper.

2) Parts used in mechanisms shall be selected to conform to the mechanism requirements.

3) Parts used in mechanisms shall be standardized to the possible and proper level.

5.3.3 Requirements for materials

a) Mechanism materials shall be selected to conform to the mechanism requirements specification, referring to material outgassing data, metallic materials mechanical properties data, and non-metallic materials mechanical properties data for aerospace use.

NOTE MMPDS Handbook Metallic Materials Properties Development and Standardization Handbook, MIL-HDBK-17 Composite Materials Handbook, and Aerospace Structure Metals Handbook are known as popular mechanical properties data for metallic or non-metallic materials used in aerospace industries.

b) In addition to physical and mechanical properties, corrosion resistance, galvanic corrosion resistance, susceptibility for stress corrosion cracking, and surface modification treatment (as needed) shall be taken into account in metallic materials selection.

c) Mechanism materials which are to be exposed to the outer space environment shall be selected to conform to the applicable mission requirements, to have durability for radiation, ultraviolet, atomic oxygen, and space debris, and to have low outgassing characteristics.

d) Materials shall be selected so that material property change due to temperature change and temperature cycle conforms to the mechanism requirement specification.

e) If environmental factors such as radiation, ultraviolet, atomic oxygen and temperature environment can have combined effects on the materials, materials shall be selected so that the combined effects on the materials under such complex environment conform to the mechanism requirements specification.

f) When using hygroscopic or swellable materials, materials shall be selected so that the material property change due to moisture absorption and swelling conform to the mechanism requirements specification.

5.4 Mechanism design

5.4.1 Accuracy control design

For mechanisms used in pointing application where accuracy control is necessary, the performance error due to the following factors shall be properly considered in determining the error budget:

a) machining and assembly tolerances, misalignment;

b) bending (deflection), torsion;

c) dynamic loads;

d) thermal distortion;

e) mechanical interference (movable envelope);

f) friction, friction noise (friction or torque variations), and friction hysteresis;

g) variation in driving force (driving motor ripple, spring, electromagnetic solenoid);

h) control system transient (resonance, overshoot);

i) steady-state errors;

j) other error variations (Structural and mechanical hysteresis, backlash, drive motor ripple, quantization errors in command and feedback sensors, and any other defined error source).

5.4.2 Driving capability design

A proper margin (allowance) shall be provided to mechanisms with a driven section. The following items shall be considered at the driving capability design of mechanisms:

a) For frictional forces, not only dynamic friction force during steady drive but also to static friction force and hysteresis during activation and inverse driving shall be considered.

b) For motor driving, each motor shall have a torque (or force) margin which meets the requirements for expected changes in operational temperature and speed. The driving current shall be in agreement with the power resource.

c) In reviewing (calculating) the required driving force (drive resistance), the worst-case combination of operationally expected changes in temperature and speed shall be reviewed with respect to each resistance element (such as bearing, gears, harness cables, latches and dampers). If necessary, the calculated values shall be checked for validity through testing at the element and subassembly level.

d) For drive mechanism elements using a redundant system, a proper torque (or force) margin shall be ensured in case an element fails under the worst-case conditions.

e) For deteriorated drive mechanism elements with a redundant system, the margin of other mechanism elements shall be evaluated in consideration of the possibility that the deteriorated mechanism will develop resistance force.

NOTE See Annex A for additional notes.

5.4.3 Design life

The design life of a mechanism shall correspond to the expected sum total of nominal ground test and orbital operation. Mechanism shall be designed to meet the specified life requirements under the expected environment conditions.

NOTE The specified life requirements include the margins specifically to address assembly, integration, test, and number required cycles in the life cycle of mechanisms.

5.4.4 Tribology

a) Mechanisms shall be designed to allocate dimension and dimensional tolerance to each element properly. Material and lubricant of mechanisms shall be selected to prevent adhesion, seizing, and biting and to reduce wear at the sliding surface and the rolling surface to conform to the mechanism performance requirements throughout the required lifetime.

b) Requirements to the design, storage, handling and operation of the mechanism shall be clarified in order to maintain the integrity such as prevention of the lubricating surface contamination of the mechanism.

c) The outgassing rate of the lubricant used to lubricate the mechanism shall be measured in accordance with a predetermined measurement method. Allowable outgas limit shall be determined by the applied contamination and cleanliness control requirements for space systems.

NOTE 1 See ASTM E 595 - 15.

NOTE 2 Specific requirements for mission involving advanced optical instruments are covered by the specific mechanism specification.