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Space systems — Space environment simulation for material tests — General principles and criteria

Systèmes spatiaux — Simulation de l'environnement spatial pour les essais de matériaux — Principes généraux et critères

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

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Introduction

In outer space environment, spacecraft materials are subjected to various factors that may cause damage and deterioration of their service properties. In addition, there are several objective reasons to require improvements in the forecasting of spacecraft material durability in relation to outer space environment impact. The most important reasons are the following:

— increase of spacecraft lifetime;

— development of new spacecraft designs (non-hermetic spacecraft, microsatellites, etc.);

— application of new materials, including nanomaterials;

— complexity and sensitivity improvement of spacecraft on-board equipment;

— development of new orbits in the near-Earth space;

— implementation of new space projects (manned flight to Mars, building of manned bases on the Moon, etc.).

Material durability forecast in relation to space environment impact is based on results of ground tests and mathematical modelling of processes of space environment effects on materials and on-board experiments. For high-precision forecasts, it is necessary

— to choose correctly the set of space environment components which affect a spacecraft in various space regions, and to define their characteristics authentically,

— to select the principle and minor physical and chemical processes causing the material degradation under the space environment impact, including possible synergistic effects,

— to define the requirements to conditions of the ground-based material tests and to applied physical and mathematical models,

— to define the criteria for structural and functional material durability to the space environment impact, and

— to select the correct methods of material durability forecasting for different spacecraft lifetimes in various space regions.

This International Standard considers the items above as a unified system. It does not detail specific questions but only determines general principles and criteria for space environment simulation during material tests. Thus, this International Standard does not replace existing International Standards on specific types of space material tests. The basic purpose of this International Standard is to describe the general test methodologies using the most correct and full initial data on the space environment. Development of a general methodology will

— determine the role of each existing International Standard on space materials tests more precisely,

— help understand how existing International Standards provide the general system of space materials tests, and

— determine tests types for which development of new International Standards is necessary.

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Space systems — Space environment simulation for material tests — General principles and criteria

1 Scope

This International Standard provides a general description of the whole set of space environment components which affect spacecrafts in various outer space regions, and the physical and chemical processes causing material degradation in a space environment, including synergistic effects. This International Standard defines the most important general principles and criteria of space environment simulation during material tests, and formulates the general requirements to laboratory test facilities and to physical and mathematical models that are applied to the research of the space environment impact on materials. The basic purpose of this International Standard is to

— provide a general description of the methodology in selecting a set of space environment components and their characteristics during spacecraft material tests, and

— determine general principles and criteria for the tests.

Additionally, such methodology will help in the understanding of the degree of coverage of space materials tests with existing International Standards on the specific test types, and help define the actual directions in developing new International Standards.

This International Standard can be applied as a reference document in designing spacecrafts, forecasting spacecraft lifetime, conducting ground-based tests, and analyzing changes in material properties during operation.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11227, *Space systems — Test procedure to evaluate spacecraft material eject upon hypervelocity impact*

ISO 15856, *Space systems — Space environment — Simulation guidelines for radiation exposure of non-metallic materials*

ECSS-Q-ST-70-02C, *Thermal vacuum outgassing test for the screening of space materials*

ECSS-Q-ST-70-04C, *Thermal testing for the evaluation of space materials, processes, mechanical parts and assemblies*

ECSS-Q-ST-70-06C, *Particle and UV radiation testing for space materials*

IEC 60068–2-14, *Environmental testing — Part 2-14: Tests — Test N: Change of temperature*

ASTM E512, *Standard practice for combined, simulated space environment testing of thermal control materials with electromagnetic and particulate radiation*

ASTM E595, *Standard test method for total mass loss and collected volatile condensable materials from outgassing in a vacuum environment*

ASTM E1559, *Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials*

ASTM E2089–00, *Standard practices for ground laboratory atomic oxygen interaction evaluation of materials for space applications*

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JERG-2-143, *Design standard — Space environment effect mitigation*

GOST R 50109, *Nonmetallic materials test method for mass loss and content of volatile condencable substances under vacuum-thermal effect*

MIL-STD-202–107, *Test method standard for electronic and electrical component parts — Test method 107: Thermal shock*

3 Terms and definitions

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

NOTE Common terms are defined according to ISO 10795.

3.1 Terms related to regions in space

3.1.1
near-Earth space
region of space limited by sphere with radius equal to the average distance from the Moon to the Earth (380 000 km)

3.1.2
Earth's magnetosphere
region of the near-Earth space occupied by the Earth's magnetic field where physical conditions are determined by its interaction with solar wind

3.1.3
Earth's ionosphere
region of the Earth's atmosphere at 50 km to 1 500 km height containing partially ionized cold plasma

3.1.4
interplanetary space
region of space limited by sphere with radius equal to average distance of the most remote from the Sun planet

3.2 Terms related to orbits

3.2.1
low Earth Orbits
orbits with altitude up to 2 000 km

3.2.2
low polar (Sun synchronous) orbits
orbits with the altitude of 600 km to 800 km and the inclination of 85° to 97°

3.2.3
mid-Earth orbits
intermediate circular orbits with an altitude h = 2 000 km to 36 000 km:

— GPS orbit h = 20 200 km, inclination (i) = 55°

— GLONASS orbit h = 19 100 km, i = 64,8°

— GALILEO orbit h = 23 222 km, i = 56°

— BeiDou orbit h = 21 528 km, I = 55°

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3.2.4
geosynchronous orbit
orbit around the Earth with an orbital period of one sidereal day, matching the Earth's sidereal rotation period

3.2.5
geostationary orbit
circular orbit with the altitude of ~36 000 km in the Earth's equatorial plane. Geostationary orbit is a special case of a geosynchronous orbit

3.2.6
high elliptical orbits
perigee of approximately 1 000 km and apogee of approximately 36 000 km

3.3 Terms related to space environment factors affecting spacecrafts

3.3.1
primary factors
factors existing in space and affecting spacecraft (i.e. space environment components)

— vacuum

— neutral particles of the Earth's upper atmosphere (including atomic oxygen)

— plasma (cold plasma with particle energy up to 10 eV, hot plasma with particle energy of 10 eV to 10^5 eV)

— solar electromagnetic radiation: X-rays, vacuum ultraviolet radiation, ultraviolet radiation, visible light, infrared radiation

— charged particles of high energy: Earth's radiation belts, solar energetic particles, galactic cosmic rays

— meteoroids (micrometeoroids), ejecta (for Moon), lunar dust

— space debris (microparticles)

3.3.2
secondary (induced) factors
space factors appearing as a result of the impact of primary factors on materials but possessing of their own characteristics and physical mechanisms of the impact on materials

— spacecraft own atmosphere

— surface charging

— internal charging

— thermal cycling

— spacecraft operation factors: plasma sources (plasma contactors), electric propulsion engines and others

3.4 Terms related to penetration depth of affecting space factors

3.4.1
surface impact factors
space factors which impact changes in the characteristics or properties of near-surface layers of materials (with depth of less than ~100 μm)

EXAMPLE Plasma, ultraviolet (UV) and vacuum ultraviolet (VUV), and hard microparticles.

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3.4.2
volume impact factors
space factors causing changes in bulk materials (in depths more than 0,1 mm to 1 mm)

EXAMPLE Particles of Earth's radiation belts, galactic cosmic rays, solar energetic particles, meteoroids and others.

3.5 Terms related to physical and chemical mechanisms of space environment effects on materials

3.5.1
mechanisms of space environment effects on materials
totality of physical and chemical phenomena causing the changes in material properties under the influence of primary and secondary space environment factors

— evaporation, sputtering, surface erosion

— surface contamination

— charge accumulation on the surface (surface charging)

— charge accumulation in the volume of dielectrics (bulk charging)

— formation of structural radiation defects

3.5.2
synergistic effects
effects appearing with the simultaneous or sequential impact of several space environment factors when the final effect is not equal to the sum of the effects from the individual factors

3.5.3
durability criteria
maximum permissible changes in operational parameters of spacecraft materials and equipment causing by the impact of primary and secondary space environment factors when a material or an equipment element can perform the given function

— radiation hardness

— durability to surface and internal charge accumulation

— mass losses and surface erosion

— surface contamination

— thermal stability

Note 1 to entry: In determining durability criteria, mechanical, thermal, electrical and optical properties of materials are to be considered.

4 Abbreviated terms and symbols

4.1 Abbreviated terms

AO	atomic oxygen
ERB	Earth's radiation belts
GCR	galactic cosmic rays
GEO	geostationary Earth orbit

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