Technical Report

ISO/TR 23689

First edition
2024-06

Space environment (natural and artificial) — Space weather information for use in space systems operations

Environnement spatial (naturel et artificiel) — Informations météorologiques spatiales pour utilisation dans les opérations des systèmes spatiaux

Reference number
ISO/TR 23689:2024(en)

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Foreword

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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 document 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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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

This document describes the dynamic variability of the environment, i.e. space weather, and identifies the tools and parameters needed for space systems operations. This document is important for satellite operators who are not be familiar with space weather. For example, when Satellite operators arrive on shift, they are often briefed about terrestrial weather, geomagnetic storms, and collision reports. This provides insight into any possible collisions that their system can have with debris or other satellites. In addition, others who participate in space systems operations can benefit from this document. For example, designers, manufacturers, and launchers of space systems require real-time, operational space weather parameters that can be measured, monitored, or built into automated systems. Users of these systems include developers of software systems that provide LEO satellite orbit determination, radio communication availability for scintillation events (GEO-to-ground L- and UHF-bands), GPS uncertainties, and the radiation environment from ground-to-space for commercial space tourism. These groups require recent historical data, current epoch specification, and forecast of space weather phenomena for their automated or manual systems. National government agencies often rely on space weather data provided by their national organizations, such as those represented in the International Space Environment Service (ISES) group of 14 national agencies, and this document identifies key descriptors provided by those agencies.

This document identifies the phenomena of space weather as a dynamic component of the space environment that affects the technology of space systems. Annexes A and B describe expanded material including guidelines on how to use the document, how to obtain specific space weather parameters, and short but detailed descriptions of parameters. Annexes A and B enable easy updates for this document because new advances in scientific and engineering understanding provide new tools for characterizing the domain of space weather. Table 1 gives an overview of existing ISO documents related to the space environment.

Table 1 — Terrestrial and lunar environment documents

	LEO	PEO	MEO	GEO	>GEO
Testing/analysis/ framework	ISO 15856, ISO 17851, ISO 21980, ISO/TS 22295, (AUL)	ISO 15856, ISO 17851, ISO 21980, ISO/TS 22295, (AUL)	ISO 15856, ISO 17851, ISO/TS 22295, (AUL)	ISO 15856, ISO 17851, ISO/TS 22295, (AUL)	ISO 15856, ISO 17851, (AUL)
Cosmic rays	ISO 15390, ISO 17520, ISO/TR 23689	ISO 15390, ISO 17520, ISO/TR 23689	ISO 15390, ISO 17520, ISO/TR 23689	ISO 15390, ISO 17520, ISO/TR 23689	ISO 15390, ISO 17520, ISO/TR 23689
Solar photons	ISO 21348, ISO/TR 23689	ISO 21348, ISO/TR 23689	ISO 21348, ISO/TR 23689	ISO 21348, ISO/TR 23689	ISO 21348, ISO/TR 23689
Solar particles	ISO 16698, ISO 17520, ISO/TR 18147, (solar wind), ISO/TR 23689	ISO 16698, ISO 17520, ISO/TR 18147, (solar wind), ISO/TR 23689	ISO 16698, ISO 17520, ISO/TR 18147, (solar wind), ISO/TR 23689	ISO 12208, ISO 16698, ISO 17520, ISO/TR 18147, (solar wind), ISO/TR 23689	ISO 16698, ISO 17520, ISO/TR 18147, (solar wind), ISO/TR 23689
Solar fields	ISO 16689, (solar wind), ISO/TR 23689	ISO 16689, (solar wind), ISO/TR 23689	ISO 16689, (solar wind), ISO/TR 23689	ISO 16689, (solar wind), ISO/TR 23689	ISO 16689, (solar wind), ISO/TR 23689
Main magnetic field	ISO 16695, ISO 16698, ISO/TR 23689	ISO 16695, ISO 16698, ISO/TR 23689	ISO 16695, ISO 16698, ISO/TR 23689	ISO 16695, ISO 16698, ISO/TR 23689	ISO 16695, ISO 16698, ISO/TR 23689

Key

AUL application utility level

IRENE International Radiation Environment Near Earth

AO atomic oxygen

Table 1 *(continued)*

	LEO	PEO	MEO	GEO	>GEO
Magnetosphere	ISO 16695, ISO 16698, ISO 19923, ISO/TR 23689, (PC-index)	ISO 16695, ISO 16698, ISO 19923, ISO/TR 23689	ISO 16695, ISO 16698, ISO 22009, ISO 19923, ISO/TR 23689	ISO 12208, ISO 16695, ISO 16698, ISO 22009, ISO 19923, ISO/TR 23689	ISO 16695, ISO 16698, ISO 22009, ISO 19923, ISO/TR 23689
Radiation belts	ISO 17761, ISO 17520, ISO/TS 21979, (IRENE, internal charge), ISO/TR 23689	ISO 17761, ISO 17520, ISO/TS 21979, (IRENE, internal charge), ISO/TR 23689	ISO 17520, ISO/TS 21979, (IRENE, internal charge), ISO/TR 23689	ISO 17520, ISO/TS 21979, (IRENE, internal charge), ISO/TR 23689	ISO 17520, ISO/TS 21979, (IRENE, internal charge), ISO/TR 23689
Plasmasphere	ISO 16457, ISO/TR 23689	ISO 16457, ISO 19923, ISO/TR 23689	ISO 16457, ISO 19923, ISO/TR 23689	ISO 16457, ISO 19923, ISO/TR 23689	ISO 16457, ISO 19923, ISO/TR 23689
Ionosphere	ISO 16457, ISO 16698, ISO/TR 23689	ISO 16457, ISO 16698, ISO/TR 23689	(topside)		
Neutral atmosphere	ISO 14222, ISO/TR 11225, ISO 16698, (AO, satellite drag), ISO/TR 23689	ISO 14222, ISO/TR 11225, ISO 16698, (AO, satellite drag), ISO/TR 23689	(He, H)	(He, H)	(He, H)
Micrometeoroids	ISO 14200	ISO 14200	ISO 14200	ISO 14200	ISO 14200
Debris	ISO 14200, (radiation debris)	ISO 14200, (radiation debris)	ISO 14200	ISO 14200	ISO 14200
Lunar					ISO 10788

Key

AUL application utility level

IRENE International Radiation Environment Near Earth

AO atomic oxygen

Space environment (natural and artificial) — Space weather information for use in space systems operations

1 Scope

This document contains internationally accepted descriptions of the main phenomena of space weather, including its sources and effects upon space systems.

This document is applicable for a variety of engineering and scientific domains. It is applicable to space system operations include ground-based, on-orbit, and deep space automated satellite operations. It can be applied by developers of software systems for space systems, designers of space systems, and launchers of space systems.

2 Normative references

There are no normative references in this document.

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
aerodynamic drag
force derived from the kinetic energy of an orbiting object encountering an *atmosphere* (3.2) as a result of the work done against the object by the atmosphere

3.2
atmosphere
layer of gases surrounding a planet, moon, asteroid, or comet with species composition and temperature often described by altitude

3.3
deep space
region of space beyond the Earth's *atmosphere* (3.2) and magnetosphere and especially beyond the Moon's orbit

3.4
geomagnetically induced current
GIC
induced magnetic field variation caused by geomagnetic disturbances such as CMEs upon the Earth's magnetic field

3.5
geostationary Earth orbit
Earth orbit having zero inclination, zero eccentricity, and an orbital period equal to the Earth's sidereal rotation period

Note 1 to entry: This orbit allows a satellite to remain continuously over approximately the same point on the Earth's surface.

[SOURCE: ISO 24113:2023, 3.11, modified — The abbreviated term “GEO” has been removed; note 1 to entry has been added.]

3.6
geosynchronous Earth orbit
orbit with an orbital period equal to the Earth’s sidereal rotation period

3.7
heliosphere
region surrounding the Sun where the emanating solar wind dominates the interstellar medium

Note 1 to entry: It is the magnetosphere and outermost atmospheric layer of the Sun, taking the shape of a vast, bubble-like region of space, i.e. a plasma cavity formed by the Sun in the surrounding interstellar medium where the strength of the solar, interplanetary magnetic field is greater than that of the local galactic magnetic field.

[SOURCE: ISO 15856:2010, 3.1.8, modified — The word "emanating" has been added; the original note 1 to entry has been replaced by a new one.]

3.8
low Earth orbit
Earth orbit with an apogee altitude that does not exceed 2 000 km

3.9
MEO
medium Earth orbit
mid-Earth’s orbit
Earth orbit with apogee an altitude that is greater than 2 000 km but does not exceed 36 000 km

3.10
space environment
surrounding, aggregated conditions and influences of photons, particles, and fields outside of planetary *atmospheres* (3.2)

3.11
space weather
dynamic variability in the transfer of energy via photons, particles, and fields from the Galaxy and Sun to the *heliosphere* (3.7), including planetary bodies, other objects, and their environs

3.12
suborbital flight
flight at an altitude and velocity that would result in a trajectory incapable of circling the Earth at least once

3.13
sunspot number
R
daily index of sunspot activity defined as k (10 g + s) where s is the number of individual spots, g is the number of sunspot groups, and k is an observatory factor

[SOURCE: ISO 16457:2022, 3.6, modified — Notes to entry have been removed.]

4 Space weather

4.1 Origin of space weather concept

The space weather concept originated in the mid-1990’s within the space physics community and their attempt to understand the temporal, non-climatological variations in the space environment along with the effects at Earth.

4.2 Concept of space weather

Space weather primarily includes energetic processes that originate on the Sun but can include energy transfer from galactic sources outside the heliosphere. Space weather can affect natural environments and human technology starting at and below the surface of the Earth through the outer reaches of the Earth's magnetosphere. It can also affect the environments around other bodies in the solar system.

4.3 Space weather factors

Solar wind plasma, cosmic rays, solar energetic particles and solar electromagnetic and particle ionizing radiation are the main space weather factors. All space factors either originate from the Sun or are modulated by solar activity. Variations of space weather factors influence interplanetary space and planetary (terrestrial) environments.

4.4 Space weather impacts on the near-Earth space

Space weather factors influence space and terrestrial environments. The main space weather manifestations occur following solar flares and coronal mass ejections that produce magnetic storms and magnetospheric substorms, solar proton events, ionospheric disturbances, changes in thermosphere densities, variability in the radiation environment at aircraft altitudes, as well as variations of ground currents at and below the Earth's surface.

4.5 Space weather domains

Solar-terrestrial coupling plays the key role in the development of space weather events. Physical conditions in the Sun, in the heliosphere and in the Earth's magnetosphere are susceptible to space weather factors and impact the terrestrial environment. In various space domains different processes are coupled with solar irradiation, both electromagnetic and particulate, and can influence space weather factors. Solar-terrestrial coupling is produced by the chain of the interconnections between processes in the Sun's environment, in the heliosphere and in near-Earth space. Measurements of the physical conditions in different regions of space can be used to estimate the intensity of space weather factors and their possible impact on planetary environments, including the Earth.

4.6 Space weather information

Space weather information is obtained from satellite, air, and ground-based measurements as well as from space weather models, the combination of which can be used to determine the state of the space environment. Information is collected by governmental, academic, and industrial space weather data centres and processed by operational IT-services that can give a reliable release of space weather conditions.

4.7 Space weather operational models

The models of physical parameters for the space environment depend on measurements and often work automatically in real-time mode. Operational models typically originate from scientific models that are modified to run automatically using observational data input. The process of conversion of scientific models to operational ones is called R2O (research to operations). Operational models testing is called V&M (validation and metrics). The process of using the results of operational models to understand shortcomings for further scientific research is called O2R (operations to research).

4.8 Space weather time frames

Space weather information in different time frames can be used to validate space weather models (e.g. historical data), for verification diagnostics of current space environment conditions (current data), and for space weather predictions (forecast data).