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)

© ISO 2024



COPYRIGHT PROTECTED DOCUMENT

© ISO 2024
All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **v**
Introduction ..... **vi**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Space weather **2**
4.1 Origin of space weather concept 2
4.2 Concept of space weather 3
4.3 Space weather factors 3
4.4 Space weather impacts on the near-Earth space 3
4.5 Space weather domains 3
4.6 Space weather information 3
4.7 Space weather operational models 3
4.8 Space weather time frames 3
5 Time frames for space weather information **4**
5.1 Historical 4
5.2 Current epoch (Nowcast) 4
5.3 Forecast 4
6 Galactic cosmic rays **4**
7 Solar environment within the heliosphere **4**
7.1 Solar dynamo 4
7.1.1 Phenomenology 4
7.2 Solar environment 4
7.2.1 Phenomenology 4
7.2.2 Effects 6
7.3 Sunspots 6
7.3.1 Phenomenology 6
7.3.2 History of discovery, long-term record 7
7.3.3 Variability 7
7.3.4 Effects 7
7.4 Solar shorter wavelength electromagnetic radiation 7
7.4.1 Phenomenology 7
7.4.2 Ranges of electromagnetic radiation with the shortest wavelength 8
7.4.3 Effects 8
7.5 Solar longer wavelength electromagnetic radiation 8
7.5.1 Phenomenology 8
7.5.2 Ranges of short-wave electromagnetic radiation in the longer wavelength range 8
7.5.3 Effects 9
7.6 Solar energetic particles 9
7.6.1 Phenomenology 9
7.6.2 Solar particle events 9
7.6.3 Effects 9
8 Solar event effects on the near-Earth environment **9**
8.1 Magnetosphere 9
8.1.1 Phenomenology 9
8.1.2 Magnetospheric magnetic field 10
8.1.3 Trapping 10
8.1.4 Geomagnetic storms 10
8.1.5 Magnetospheric substorms 10
8.1.6 Effects 11
8.2 Plasmasphere 11
8.2.1 Phenomenology 11

© ISO 2024 – All rights reserved

8.2.2 Geo corona 11
8.2.3 Dynamics 11
8.2.4 Effects 11
8.3 Van Allen radiation belts 12
8.3.1 Phenomenology 12
8.3.2 Outer radiation belt 12
8.3.3 Inner radiation belt 12
8.3.4 Ring current 12
8.3.5 Other radiation belt variability 12
8.3.6 South Atlantic Anomaly 13
8.3.7 Effects 13
8.4 Polar region and high-latitude magnetosphere 14
8.4.1 Phenomenology 14
8.4.2 Auroral oval 14
8.4.3 Polar cap 14
8.4.4 Field aligned currents and auroral electrojets 14
8.4.5 Effects 14
8.5 Geomagnetic cut-off 14
8.5.1 Phenomenology 14
8.5.2 Cut-off rigidity 14
8.5.3 Effects 15

9 Terrestrial environment 15
9.1 Neutral atmosphere 15
9.1.1 Phenomenology 15
9.1.2 Atmospheric layers 15
9.1.3 Effects 16
9.2 Ionosphere 16
9.2.1 Phenomenology 16
9.2.2 Ionospheric layers 16
9.2.3 Ionospheric storm 17
9.2.4 Effects 17

10 Micrometeoroid and debris environment 18
10.1 Phenomenology 18
10.2 Natural 18
10.3 Artificial 18

Annex A (informative) **Space weather indices 19**

Annex B (informative) **Online space weather glossaries 27**

Bibliography 28

© ISO 2024 – All rights reserved

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 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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.

© ISO 2024 – All rights reserved

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

© ISO 2024 – All rights reserved

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

© ISO 2024 – All rights reserved

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.

© ISO 2024 – All rights reserved