INTERNATIONAL STANDARD

ISO 15388

Third edition
2022-10

Space systems — Contamination and cleanliness control

Systèmes spatiaux — Contrôle de la contamination et de la propreté

Reference number
ISO 15388:2022(E)

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Published in Switzerland

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Contents

Page

Foreword ..... **v**

Introduction ..... **vi**

1 Scope **1**

2 Normative references **1**

3 Terms, definitions and abbreviated terms **1**
3.1 Terms and definitions 1
3.2 Abbreviated terms 7

4 Management **8**
4.1 Organization 8
4.2 Cleanliness requirement specification (CRS) 8
4.3 Contamination and cleanliness control plan (CCCP) 8
4.4 Interface control document (ICD) 9
4.5 Project reviews 9

5 Design activities **9**
5.1 Identification of sensitive hardware 9
5.2 Nature of contaminants, their profile and their effects 9
5.2.1 General 9
5.2.2 Typical contaminants 9
5.2.3 Contamination profile 10
5.2.4 Effects of contamination on performance 10
5.3 Contamination prediction 10
5.4 Contamination budget 10
5.5 Cleanliness-oriented design 10
5.6 Selection of materials and processes 11
5.6.1 General 11
5.6.2 Outgassing 11
5.6.3 Absorbed water vapour 11
5.6.4 Offgassing 12
5.6.5 Quality control 12

6 Biocontamination **12**
6.1 General 12
6.2 Contamination of hardware by microorganisms 12
6.3 Sterile hardware 12
6.4 Habitable space systems 13
6.4.1 Habitable spacecraft 13
6.4.2 Offgassing 13
6.5 Planetary protection 13
6.6 Sample protection 13

7 Contamination and cleanliness control for ground operations **13**
7.1 Training of personnel 13
7.2 Cleanroom selection and cleanliness control 14
7.2.1 General 14
7.2.2 Failure of facilities 14
7.2.3 Facility operating procedures 14
7.2.4 Additional information 14
7.3 Cleanroom garments 15
7.3.1 General 15
7.3.2 Considerations for garment selection 15
7.3.3 Additional information 15
7.4 Ground support equipment (GSE) 15
7.5 Monitoring cleanliness of flight hardware and its near surroundings 15
7.6 Packaging, storage and transport 16

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7.6.1 Packaging 16
7.6.2 Storage 16
7.6.3 Transport 16
7.7 Cleaning of flight hardware 16
7.7.1 General 16
7.7.2 Cleaning procedures 16
7.7.3 Bakeout 16
7.7.4 Contaminant source containment 17
7.7.5 Purging 17
Annex A (informative) **Material properties — Electronic databases** **18**
Annex B (informative) **Contamination analysis** **19**
Annex C (informative) **Factors of combined uncertainty** **30**
Bibliography **31**

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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*.

This third edition cancels and replaces the second edition (ISO 15388:2012), which has been technically revised.

The main changes are as follows:

— Annex B, which details guidelines for contamination analysis procedures, is added;

— Annex C, which indicates factors of combined uncertainty, is added;

— the latest international and national documents for planetary protection are referenced in 6.5.

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.

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Introduction

This document addresses the preferred programme elements recommended for contamination and cleanliness control of space systems. This document is written in general terms as a baseline for developing and implementing the control programme. It can be cited as a baseline within a statement of work and/or used for assuring proposal precision and contractor performance. The users are responsible for integrating the elements of this document appropriately to their programme needs.

The purpose of contamination and cleanliness control is to prevent the degradation of the performance of space systems due to particulate and molecular contamination (including biocontamination), and to ensure that the mission objectives are achieved.

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Space systems — Contamination and cleanliness control

1 Scope

This document establishes general requirements for contamination and cleanliness control that are applicable, at all tiers of supply, to the development of space systems, including ground processing facilities, ground support equipment, launch vehicles, spacecraft, payloads, and ground processing and on-orbit operations. It also provides guidelines for the establishment of a contamination and cleanliness control programme.

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 14624-3, *Space systems — Safety and compatibility of materials — Part 3: Determination of offgassed products from materials and assembled articles*

ISO 14644-1, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration*

ISO 14698-1, *Cleanrooms and associated controlled environments — Biocontamination control — Part 1: General principles and methods*

ISO 14698-2, *Cleanrooms and associated controlled environments — Biocontamination control — Part 2: Evaluation and interpretation of biocontamination data*

ISO 14952-2, *Space systems — Surface cleanliness of fluid systems — Part 2: Cleanliness levels*

ISO 14952-3, *Space systems — Surface cleanliness of fluid systems — Part 3: Analytical procedures for the determination of nonvolatile residues and particulate contamination*

ASTM E595, *Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment*

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

3 Terms, definitions and abbreviated terms

3.1 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/

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3.1.1
bakeout
activity of increasing the temperature of hardware to accelerate its *outgassing* (3.1.28) rates with the intent of reducing the content of molecular *contaminants* (3.1.11) within the hardware

Note 1 to entry: Bakeout is usually performed in a vacuum environment but may be done in a controlled atmosphere.

3.1.2
bioaerosol
dispersed biological agents [e.g. viable *particles* (3.1.29), allergens, toxins or biologically active compounds of microbial origin] in a gaseous environment

3.1.3
biocontamination
contamination of materials, devices, individuals, surfaces, liquids, gases or air with viable *particles* (3.1.29)

3.1.4
clean bench
table or bench-top working surface where a filtered airflow is concentrated across the bench top

Note 1 to entry: These bench tops have an established classification of maximum allowable airborne *contaminants* (3.1.11).

3.1.5
cleanliness level
established maximum allowable amount of contamination in a given area or volume, or on a component

Note 1 to entry: The term may also apply to the predicted or measured extent of contamination.

3.1.6
cleanliness requirement specification
CRS
document that defines and identifies the spacecraft items and the environmental areas which are sensitive to contamination, the acceptable contamination levels at beginning and end of life and the applicable contamination environment

3.1.7
cleanroom
room within which the number concentration of airborne *particles* (3.1.29) is controlled and classified, and which is designed, constructed and operated in a manner to control the introduction, generation and retention of particles inside the room

Note 1 to entry: The class of airborne *particle concentration* (3.1.30 and 3.1.31) is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also *surface cleanliness* (3.1.39) in terms of particle, nanoscale, chemical and viable concentrations might also be specified and controlled.

Note 3 to entry: Other relevant physical parameters might also be controlled as required, e.g. temperature, humidity, pressure, vibration and electrostatic.

[SOURCE: ISO 14644-1:2015, 3.1.1]

3.1.8
cleanroom garment
clothing designed, manufactured and worn specifically to prevent contamination of hardware by personnel working in the *cleanroom* (3.1.7)

Note 1 to entry: Cleanroom garments include all items worn by personnel, such as coveralls, frocks, gloves, boots, finger cots and beard covers.

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3.1.9
clean zone
defined space within which the number concentration of airborne *particles* (3.1.29) is controlled and classified, and which is constructed and operated in a manner to control the introduction, generation and retention of *contaminants* (3.1.11) inside the space

Note 1 to entry: The class of airborne *particle concentration* (3.1.30 and 3.1.31) is specified.

Note 2 to entry: Levels of other cleanliness attributes such as chemical, viable or nanoscale concentrations in the air, and also *surface cleanliness* (3.1.39) in terms of particle, nanoscale, chemical and viable concentrations might also be specified and controlled.

Note 3 to entry: A clean zone(s) can be a defined space within a *cleanroom* (3.1.7) or might be achieved by a separative device. Such a device can be located inside or outside a cleanroom.

Note 4 to entry: Other relevant physical parameters might also be controlled as required, e.g. temperature, humidity, pressure, vibration and electrostatic.

[SOURCE: ISO 14644-1:2015, 3.1.2]

3.1.10
collected volatile condensable material
CVCM
mass that outgasses from a material and subsequently condenses on a collector, expressed as a percentage of the initial specimen mass

3.1.11
contaminant
unwanted molecular or particulate matter that can affect or degrade the relevant performance or lifetime of the hardware to which it is attached

3.1.12
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]

3.1.13
contamination and cleanliness control programme
organized effort to establish and achieve acceptable cleanliness and contamination levels during all phases of the space system project

3.1.14
contamination and cleanliness control plan
CCCP
document that describes how to implement a *contamination and cleanliness control programme* (3.1.13), as either an independent document or a part of the consolidated project plan

3.1.15
contamination budget
allowable levels of contamination of hardware at each phase of ground and flight operations

3.1.16
contamination profile
contamination-related conditions in each phase of ground and flight operations

Note 1 to entry: Conditions include airborne particulate cleanliness classes, pressure, humidity, temperature, number of personnel engaged in operations, cleaning activities, outlines of facilities and so on.

Note 2 to entry: The contamination profile is part of the *contamination and cleanliness control plan (CCCP)* (3.1.14).

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3.1.17
cross-contamination
transfer of *contaminants* (3.1.11) from one surface or component to another

Note 1 to entry: Transfer can occur by migration along a surface, by physical contact, airborne as an aerosol, or as a gas or molecular matter.

3.1.18
debris
solid objects with their largest dimension greater than approximately 1 mm (1 000 µm) in size

3.1.19
electrostatic discharge
ESD
electrical breakdown of dielectric or gas or vacuum gaps, and also of surface interface of dissimilar materials, caused by differential charging of parts of dielectric materials and their interfaces

[SOURCE: ISO 11221:2011, 2.10, modified — The abbreviated term "ESD" has been added.]

3.1.20
generally clean
free from manufacturing residue, dirt, oil, grease, processing *debris* (3.1.18), or other extraneous contamination based on visual examination

Note 1 to entry: This level does not apply to hardware that is sensitive to contamination.

[SOURCE: ISO 14952-1:2003, 2.12, modified — The abbreviated term "GC" has been removed.]

3.1.21
ground support equipment
GSE
non-flight systems, equipment or devices necessary to support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, servicing, launch and recovery of a space system at launch, landing or retrieval sites

[SOURCE: ISO 14625:2007, 3.1.5]

3.1.22
interface control document
ICD
specification that describes the characteristics that must be controlled at the boundaries between systems, subsystems and other elements

3.1.23
microorganism
microscopical individual constituted to carry out life functions

Note 1 to entry: Microorganisms include organisms such as bacteria, protozoa, yeasts, moulds, fungi, algae and organisms that depend upon other life forms for reproduction such as viruses and parasites.

Note 2 to entry: Multicellular organisms and agglomerations of microorganisms may be visible to the unaided eye.

3.1.24
molecular contamination
contamination due to deposition of molecules on surfaces or their presence in gases or liquids

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3.1.25
at-rest
condition where the *cleanroom* (3.1.7) or *clean zone* (3.1.9) is complete with equipment installed and operating in a manner agreed upon, but with no personnel present

[SOURCE: ISO 14644-1:2015, 3.3.2]

3.1.26
operational
agreed condition where the *cleanroom* (3.1.7) or *clean zone* (3.1.9) is functioning in the specified manner, with equipment operating and with the specified number of personnel present

[SOURCE: ISO 14644-1:2015, 3.3.3]

3.1.27
offgassing
evolution of gaseous products from a liquid or solid material into an atmosphere

Note 1 to entry: This is for the application in habitable volume considering medical impact on human health.

3.1.28
outgassing
evolution of gaseous species from a material, usually in a vacuum

3.1.29
particle
unit of solid or liquid matter with observable size

[SOURCE: ISO 14952-1:2003, 2.20]

3.1.30
particle concentration
⟨on surface⟩ number of *particles* (3.1.29) per unit area

3.1.31
particle concentration
⟨by volume⟩ number of *particles* (3.1.29) per unit volume of fluid

3.1.32
responsible organization
organization that is responsible for the *contamination and cleanliness control programme* (3.1.13) and which is provided with the authority and resources needed to carry out the programme

3.1.33
recovered mass loss
RML
ratio of the *total mass loss* (3.1.40) of the specimen without the sorbed water to the initial mass:

$$w_{\mathrm{RML}} = w_{\mathrm{TML}} - w_{\mathrm{WVR}}$$

where

w_{RML} is the recovered mass loss, in per cent;

w_{TML} is the ratio of the total mass loss to the initial mass, in per cent;

w_{WVR} is the ratio of the *water vapour regained* (3.1.42) to the initial mass, in per cent.

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Note 1 to entry: The quantity RML is introduced because water is not a critical *contaminant* (3.1.11) for some space systems (see 5.6.3). In most cases, the value of WVR is similar to that of the mass of outgassed water. However, WVR is not exactly the same as the water mass effused from the specimen. Therefore, RML is not equal to the real value of the mass loss other than water.

3.1.34
sensitive hardware
hardware that can be degraded by contamination

3.1.35
significant surface
surface of an item or product that is required to meet established *cleanliness level* (3.1.5) requirements

3.1.36
spacecraft charging
increase in electrostatic potential on spacecraft surfaces resulting from low-energy electron flux impinging on the surface

3.1.37
sterility
absence of viable *microorganisms* (3.1.23)

Note 1 to entry: Inactivated microbes can still represent an important form of *biocontamination* (3.1.3).

3.1.38
supplier
provider
organization that provides a product or a service

EXAMPLE Producer, distributor, retailer or vendor of a product or a service.

Note 1 to entry: A provider can be internal or external to the organization.

Note 2 to entry: In a contractual situation, a provider is sometimes called “contractor”.

[SOURCE: ISO 9000:2015, 3.2.5, modified —"provider" has been changed to an admitted term.]

3.1.39
surface cleanliness
level of contamination on a *significant surface* (3.1.35)

3.1.40
total mass loss
TML
total mass of material outgassed from a test specimen that is maintained at a specified constant temperature and operating pressure for a specified time and measured within the test chamber

Note 1 to entry: TML is expressed as a percentage of the initial specimen mass.

3.1.41
visibly clean
absence of surface contamination when examined using a specified light source and angle of incidence, viewing distance and angle, and normal or magnified vision

Note 1 to entry: This level requires precision-cleaning methods but a *particle* (3.1.30) count may be optional.

Note 2 to entry: Fluorescence indicates possible contamination by, for example, a hydrocarbon.

Note 3 to entry: If recleaning fails to remove fluorescent indications, an investigation should be made to determine if the item material is naturally fluorescent or if the cleaning method is adequate.

[SOURCE: ISO 14952-1:2003, 2.35, modified — The abbreviated term "VC" has been removed.]

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3.1.42
water vapour regained
WVR
mass of water vapour absorbed by a test specimen, after determination of *total mass loss (TML)* (3.1.40) and *collected volatile condensable material (CVCM)* (3.1.10), on exposure to a specified relative humidity atmosphere (usually 50 % at 23 °C or 65 % at 20 °C) for 24 h

Note 1 to entry: Some types of materials continue to absorb water for longer than 24 h. Repeated mass measurements after various time periods (e.g. 24 h, 48 h and 72 h) give a better understanding of the material's water absorbency.

3.2 Abbreviated terms

AIT	assembly, integration and test
AO	atomic oxygen
BOL	beginning of (operational or mission) life
CCCP	contamination and cleanliness control plan
CRS	cleanliness requirement specification
CVCM	collected volatile condensable material
ECSS	European Cooperation for Space Standardization
EOL	end of (operational or mission) life
ESA	European Space Agency
ESA	exposed surface area
ESD	electrostatic discharge
GSE	ground support equipment
GSFC	Goddard Space Flight Center (NASA)
ICD	interface control document
IEST	Institute of Environmental Sciences and Technology (USA)
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration (USA)
NPD	NASA policy directive
NPG	NASA procedures and guidelines
RML	recovered mass loss
TML	total mass loss
UV	ultra violet
WVR	water vapour regained

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