

BS EN 16602-70-01:2014



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Space product assurance — Cleanliness and contamination control

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its secretary.

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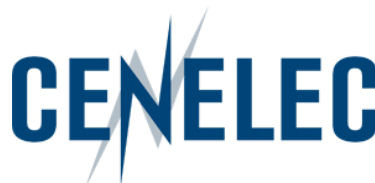
Raumfahrtproduktsicherung - Reinheit und Verunreinigungskontrolle

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Foreword

This document (EN 16602-70-01:2014) has been prepared by Technical Committee CEN/CLC/TC 5 "Space", the secretariat of which is held by DIN.

This standard (EN 16602-70-01:2014) originates from ECSS-Q-ST-70-01C.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2015, and conflicting national standards shall be withdrawn at the latest by April 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document has been developed to cover specifically space systems and has therefore precedence over any EN covering the same scope but with a wider domain of applicability (e.g. : aerospace).

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Introduction

The objective of this Standard is to ensure a successful mission by the definition of acceptable contamination levels for space system elements, their achievement, and maintenance, throughout

- performance assessment versus contamination,
- facilities and tools definition for contamination control and monitoring,
- materials and processes selection, and
- planning of activities.

1

Scope

The purpose of this standard is to define:

- The selection of critical items, the definition of cleanliness requirements to satisfy the mission performance requirements and control the levels to be met by personnel, items, facilities and operations of space projects.
- The management, including organization, reviews and audits, acceptance status and documentation control.

It covers design, development, production, testing, operation of space products, launch and mission.

In this standard are also guidelines given for identification of possible failures and malfunctions due to contamination and guidelines for achieving and maintaining the required cleanliness levels during ground activities, launch and mission.

This Standard applies to all types and combinations of projects, organizations and products, and during all the project phases, except manned missions.

It also applies to those ground systems that have a hardware interface to space systems, such as MGSE integration stands.

This Standard does not address magnetic, electrical or electrostatic cleanliness.

This Standard does not address completely biocontamination aspects. However, references to relevant ECSS standards are provided.

This standard may be tailored for the specific characteristic and constraints of a space project in conformance with ECSS-S-ST-00.

2

Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply. However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

EN reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system — Glossary of terms
EN 16602-10-09	ECSS-Q-ST-10-09	Space product assurance — Nonconformance control system
EN 16602-20	ECSS-Q-ST-20	Space product assurance — Quality assurance
EN 16602-20-07	ECSS-Q-ST-20-07	Space product assurance — Quality assurance for test centres
EN 16602-70	ECSS-Q-ST-70	Space product assurance — Materials, mechanical parts and processes
EN 16602-70-02	ECSS-Q-ST-70-02	Space product assurance — Thermal vacuum outgassing test for the screening of space materials
EN 16602-70-29	ECSS-Q-ST-70-29	Space product assurance — Determination of offgassing products from materials and assembled articles to used in manned space vehicle crew compartment
EN 16602-70-50	ECSS-Q-ST-70-50	Space product assurance — Particle contamination monitoring for spacecraft systems and cleanrooms
EN 16602-70-53	ECSS-Q-ST-70-53	Space product assurance — Material and hardware compatibility test for sterilization processes
EN 16602-70-55	ECSS-Q-ST-70-55	Space product assurance — Microbial examination of flight hardware and cleanrooms
EN 16602-70-58	ECSS-Q-ST-70-58	Space product assurance — Bioburden control of cleanrooms
	ISO 14644	Cleanrooms and associated controlled environments
	IEST-STD-CC1246D	Product cleanliness levels and contamination control program

Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-ST-00-01 and ECSS-Q-ST-70 apply.

3.2 Terms specific to the present standard

3.2.1 airborne particle

particle suspended in air

3.2.2 airborne particle cleanliness class

level of cleanliness specified by the maximum allowable number of particles per cubic metre (or cubic foot) of air

3.2.3 bakeout

activity of increasing the temperature of hardware to accelerate its outgassing rates with the intent of reducing the content of molecular contaminants within the hardware

NOTE Bakeout is usually performed in a vacuum environment, but can be done in a controlled atmosphere.

3.2.4 biocontamination

contamination of materials, devices, individuals, surfaces, liquids, gases or air with viable particles

[ISO 14698-1:2003, 3.1.4] [ISO 14698-2:2003, 3.4]

3.2.5 cleaning

actions to reduce the contamination level

3.2.6 cleanliness (contamination) control

any organized action to control the level of contamination

3.2.7 cleanliness level

quantitative level of contamination

3.2.8 cleanliness verification

activity intended to verify that the actual cleanliness conditions of the space system, the cleanrooms or the vacuum chambers are in conformance with the applicable specifications and other cleanliness requirements

3.2.9 cleanroom

room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room, and in which other relevant parameters, e.g. temperature, humidity and pressure, are controlled as necessary

[ISO 14644-6]

3.2.10 clean zone

dedicated space in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room, and in which other relevant parameters, e.g. temperature, humidity and pressure, are controlled as necessary

[ISO 14644-6]

NOTE This zone can be open or enclosed and can or can not be located within a cleanroom.

3.2.11 contaminant

any unwanted molecular or particulate matter (including microbiological matter) on the surface or in the environment of interest, that can affect or degrade the relevant performance or life time

3.2.12 contaminate, to

act of introducing any contaminant

3.2.13 contamination budget

permissible contamination levels defined at different stages of the life of the instrument and satellite

3.2.14 contamination potential

potential amount of contaminant in the source which can produce contamination

3.2.15 controlled area

environmentally controlled area, operated as a cleanroom, with two pre-filter stages but without the final stage of HEPA (or better) filters used in cleanrooms

3.2.16 fibre

particle with a length to diameter ratio of 10 or more

3.2.17 FTIR spectrometer

analyser (chemical identification) of organic and inorganic contamination using infrared wavelengths

3.2.18 HEPA particle filter

throwaway, extended-medium, dry type filter in a rigid frame that has a minimum particle-collection efficiency of 99,97 % (that is a maximum particle penetration of 0,03 %) for 0,3 µm thermally generated DOP or specified alternative aerosol

3.2.19 induced contaminant environment

environment created by the presence of contaminating items

3.2.20 molecular contamination

airborne or surface contamination (vapour, gas, liquid, or solid) without observable dimensions (i.e. with dimensions at molecular level)

3.2.21 monitoring

to perform routine, quantitative measurements of environmental parameters in and around cleanrooms, clean zones, and other clean areas, including contamination parameters

3.2.22 non-volatile residue (NVR)

quantity of residual soluble, suspended, and particulate matter remaining after the controlled evaporation of a volatile liquid at a specified temperature

3.2.23 obscuration factor (OF)

ratio of the projected area of all particles to the total surface area on which they rest

3.2.24 offgassing

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

3.2.25 outgassed quantity

total quantity of outgassed species expressed as a mass (e.g. gram or percent of the initial specimen) or as pressure × volume (e.g. hPa × m³)

3.2.26 outgassing

evolution of gaseous species from a material, usually in vacuum

NOTE Outgassing also occurs in a higher-pressure environment.

3.2.27 particle

unit of matter with observable length, width and thickness

3.2.28 particle fallout

accumulated deposit of particulate matter on a surface

3.2.29 particle size

apparent maximum linear dimension of a particle in the plane of observation as observed with an optical microscope, or the equivalent diameter of a particle detected by automatic instrumentation

NOTE The equivalent diameter is the diameter of a reference sphere having known properties and producing the same response in the sensing instrument as the particle being measured.

3.2.30 particulate

of or relating to minute separate particles

3.2.31 particulate contamination (PAC)

airborne or surface contamination due to particles

3.2.32 plume

exhaust (molecules or particles) of thrusters and engines

3.2.33 purging

supply of clean gas to protect the critical hardware from contamination

3.2.34 quartz crystal microbalance (QCM)

device for measuring small quantities of mass deposited on a quartz crystal using the properties of a crystal oscillator

3.2.35 ram direction

in the direction of velocity vector

3.2.36 sensitive item

item whose contamination may affect its performance or life time

3.2.37 ULPA particle filter

throwaway, extended-medium, dry-type filter in a rigid frame that has a minimum particle-collection efficiency of 99,999 % (that is, a maximum particle penetration of 0,001 %) for particles in the size range of 0,1 μm to 0,2 μm

3.2.38 venting

conveying unwanted gaseous products through an aperture

3.2.39 visibly clean

absence of surface contamination when examined with a specific light source, angle of incidence and viewing distance using normal or magnified vision

3.2.40 wake direction

direction opposite to the velocity vector

3.2.41 witness sample

sample used to collect contaminants during exposure, usually in an environmentally controlled area, and then analysed or measured

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
ACS	American Chemical Society
AIT	assembly, integration and testing
AIV	assembly, integration and verification
AO	atomic oxygen
BOL	beginning of life
CC	contamination control
C&CCP	cleanliness and contamination control plan
CRS	cleanliness requirement specification
CVCM	collected volatile condensable material
DIW	deionised water
DML	declared materials list
DOP	dioctylphthalate
ECLS	environmental control and life support
EGSE	electrical ground support equipment
EMC	electromagnetic compatibility
EOL	end of life
EVA	extra vehicular activity
FTIR	Fourier transform infrared
GSE	ground support equipment
HEPA	high-efficiency particulate air filter
ICC	internal contamination control
IPA	isopropyl alcohol
IR	infrared
LEO	low Earth orbit
MGSE	mechanical ground support equipment
MLI	multi layer insulation
MOC	molecular contamination
MRR	manufacturing readiness review

NVR	non-volatile residue
OF	obscuration factor
PAC	particulate contamination
PDR	product definition review
PFO	particle fallout
PMP	parts, materials and processes
QCM	quartz crystal microbalance
RH	relative humidity
RT	room temperature
RML	recovered mass loss
SRR	system requirement review
TB	thermal balance
TML	total mass loss
TRR	test readiness review
TV	thermal vacuum
UV	ultra-violet
ULPA	ultra-low-particle air filter
VBQC	vacuum balance quartz crystal
VCM	volatile condensable material

4 Principles

The cleanliness and contamination control process is applied all along the project life cycle, from the definition of the C&CCP programme during the early phases (see clause 5.1) until its implementation during phases B, C, D, E and F (see clause 5.2) through the systematic verification of the cleanliness requirements baseline including: predictions through contamination modelling and the establishment of agreed procedures (see clause 5.3 and 5.4) for: environments control (see clause 5.3) packaging, containerization, transportation and storage of the space system.

NOTE Figure C-1 of Annex C gives an overview of an example of a cleanliness and contamination process.

5

Requirements

5.1 Cleanliness and contamination control programme

5.1.1 General

- a. The supplier shall define and implement a cleanliness and contamination control programme for each level of configuration.

NOTE 1 Surveys can also be made to determine the contamination control requirements, based on mission objectives and scenarios.

NOTE 2 The objective of this programme is, starting from the mission performance requirements, to establish cleanliness and contamination levels to be achieved at different manufacturing, AIT and mission stages.

NOTE 3 In general, the organization of regular workshops dedicated to cleanliness and contamination control for a specific programme is a good practice.

- b. The supplier shall establish measures for the coordination and resolution of cleanliness and contamination control issues among the parties involved in the project.

5.1.2 Documentation

5.1.2.1 Contamination requirements specification

- a. The supplier shall define and document cleanliness requirements in a cleanliness requirement specification (CRS), in conformance with the DRD in Annex A.
- b. The CRS shall be defined as early as possible in the programme, in order to properly address it during the design phase and provided at the latest at SRR, as part of the review data package.

NOTE Cleanliness is of fundamental importance for the space system's performance.

- c. The CRS should be prepared in collaboration with users and engineers from the different disciplines.

NOTE Users can be, for example, experimenters or scientists.

- d. In case the CRS cannot be produced at an early stage of the design, a cleanliness control policy document shall be used.

NOTE 1 The cleanliness control policy document gives the correlation data between acceptable performance losses and the contamination levels from library search or from tests that are performed.

NOTE 2 The cleanliness control policy document can become the CRS during the development of the design.

5.1.2.2 Contamination and Cleanliness Control Plan

- a. In reply to the CRS, the supplier shall establish a cleanliness and contamination control plan (C&CCP) in conformance with the DRD in Annex B (C&CCP DRD), to be provided at the latest at PDR, as part of the review data package.

5.1.3 Contamination budget

- a. As part of the CRS (see Annex A), a contamination budget (allocations) shall be established.

NOTE This budget determines the maximum allowed on ground and in-orbit molecular and particulate contamination levels.

- b. The specified contamination levels shall be derived from the acceptable performance losses simulated through dedicated modelling.

5.1.4 Contamination predictions

- a. As part of the C&CCP (see Annex B), particulate and molecular contamination predictions shall be established.

NOTE Contamination predictions are done in order to estimate the expected on ground and in-orbit molecular and particulate contamination levels.

- b. These predictions shall be updated to evaluate the molecular and particulate contamination levels generated during all on ground activities and during launch and in-orbit phases.

NOTE Ground activities can be MAIT, storage, transportation, launch preparation.

- c. Modelling techniques shall be used to predict “in orbit” contamination levels.

NOTE Examples of modelling techniques are given in Annex F.

- d. For each on ground activity, for launch and in-orbit phases, the following items shall be identified in the contamination prediction:
 - 1. the seen environment,
 - 2. the sensitive surfaces,
 - 3. the duration of the exposure to this environment, and
 - 4. the potential means of protection.
- e. During all on ground activities, the contamination predictions shall be consolidated with the results of molecular and particulate monitoring.

5.1.5 Contamination prediction with respect to budget

- a. The contamination predictions for all the different phases shall be compared to the cleanliness requirements, i.e. contamination budget.

NOTE For example, for of such phases are MAIT, BOL and EOL

- b. If the contamination predictions or when available actual measurements, result in a higher than the specified level, then corrective actions and precautions to reduce contamination shall be investigated and implemented.

NOTE The linear dependency of MOC and PAC as a function of time is not always valid for longer periods.

5.1.6 Cleanliness and contamination process flow chart

- a. The supplier shall establish a contamination and contamination process flow chart.

NOTE An example of cleanliness and contamination process flow chart is given in Figure C-1 of Annex C.

- b. Whenever the CRS requirements are not met, countermeasures should be prioritized from the most to the least preferred.

NOTE The most preferred is categorized as "1" and the least preferred as "4" in the example given in Figure C-1.

5.2 Phases

5.2.1 Design

5.2.1.1 General design aspects

- a. The level of sensitivity to contamination shall be one of the drivers in the initial design.
- b. The design shall be cleanliness oriented.
 - NOTE 1 A way to implement a cleanliness oriented design is given in Annex E.
 - NOTE 2 Such design can contribute to achieve the contamination levels defined by the CRS on ground as well during the launch and mission.
 - NOTE 3 A way to achieve the target contamination levels can be found in Annex D.
- c. When the design baseline is incompatible with cleanliness requirements, the design changes shall be identified and corrective actions shall be taken in close cooperation with all levels involved.

5.2.1.2 Materials selection

- a. When the offgassing effect of a material is a selection criteria, the supplier shall apply ECSS-Q-ST-70-29.
 - NOTE For modelling the molecular contamination during on-ground activities, when outgassing data are too conservative, offgassing data are advisable.
- b. For the particulate contamination, the supplier shall apply ECSS-Q-ST-70-50.
- c. When the microbiological contamination effect is a selection criteria, the supplier shall apply ECSS-Q-ST-70-55.
- d. When sterilization and material compatibility is a selection criteria, the supplier shall apply ECSS-Q-ST-70-53.
- e. For the outgassing screening of materials, the supplier shall apply ECSS-Q-ST-70-02.
- f. The outgassing requirements shall be based on the quantity of material concerned, and the specific environmental conditions.
 - NOTE Specific environmental conditions can be available volumes and temperatures.
- g. When contamination sensitive items are involved or for materials in the vicinity of cryogenic surfaces, more stringent requirements shall apply.
 - NOTE Those more stringent requirements are specified in clauses 5.2.1.2h to 5.2.1.2j.
- h. The outgassing criteria for materials in the vicinity of sensitive items around RT shall conform to Table 5-1.

- i. The outgassing criteria for materials in the vicinity of sensitive items at temperature below RT shall conform to Table 5-2.
- j. The outgassing criteria for materials in the vicinity of cryogenic surfaces shall conform to Table 5-3.
- k. Volatile metals shall not be used.

NOTE 1 This is especially the case when the temperatures are above room temperatures.

NOTE 2 Some metals such as cadmium and zinc have high vapour pressures and deposit metallic films can occur on adjacent surfaces.

Table 5-1: Outgassing criteria for materials in the vicinity of sensitive items around RT

Mass of material concerned (g)	CVCM (%)	RML (%)
>100	< 0,01	< 1
10 - 100	< 0,05	< 1
< 10	< 0,1	< 1

Table 5-2: Outgassing criteria for materials in the vicinity of sensitive items at temperature below RT

Mass of material concerned (g)	CVCM (%)	RML (%)
>100	< 0,01	< 0,1
10 - 100	< 0,05	< 1
< 10	< 0,1	< 1

Table 5-3: Outgassing criteria for materials in the vicinity of cryogenic surfaces

Mass of material concerned (g)	CVCM (%)	TML (%)
>100	< 0,01	< 0,1
10 - 100	< 0,05	< 1
< 10	< 0,1	< 1

5.2.2 MAIT

5.2.2.1 Manufacturing

- a. Personnel involved in the manufacturing of sensitive items shall be trained with respect to the cleanliness control policy.
- b. All elements manufactured in non-controlled areas or under non-clean conditions shall be the object of a cleaning process until the cleanliness requirements are met, before they are packaged for delivery.
- c. Cleaning and packaging operations for all elements shall be processed according to procedures approved by the customer for the specific application/product.
- d. Elements that can be cleaned after manufacturing shall be cleaned till the cleanliness requirements are met.
- e. For elements that cannot be cleaned after manufacturing, then manufacturing and assembling areas shall meet the cleanliness level requirements specification.
- f. The conformity of the manufacturing facilities shall be verified during MRR or TRR.
- g. An audit of the manufacturing facilities shall be performed according to ECSS-Q-ST-10 clause 5.2.3 criteria.
- h. An audits shall be held after problems have already occurred or as part of a plan to establish if facilities and personnel are adequate.

5.2.2.2 Assembly and Integration

- a. Involved personnel shall be trained with respect to the cleanliness policy.
- b. Critical and sensitive elements shall only be exposed when necessary.
 - NOTE Exposition of sensitive and critical elements during optical calibration or alignment cannot be avoided.
- c. When an exposure of sensitive and critical elements cannot be avoided, the exposure time and conditions shall be recorded.
- d. A set of assembly tools and equipment for assembly and integration shall be used and maintained in clean conditions.
- e. Procedures for assembly and integration shall be established for critical item assembly.
- f. For the selection of the cleanroom, the allocated contamination budget and the duration of the integration shall be known.

NOTE The correlation between the airborne contamination and the particle fallout for normal cleanrooms is basically known (see clause 5.3.1), and so a rough estimate can be made of the type of cleanroom required. A practical contamination level for the cleanroom can be measured with representative activities and a representative number of operators. The expected contamination levels depend on the