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Space systems — Explosive systems and devices

Systèmes spaciaux — Dispositifs et equipements explosifs

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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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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 second edition cancels and replaces the first edition (ISO 26871:2012), which has been technically revised.

The main changes compared to the previous edition are as follows:

— simplification for some requirements;

— updating terminology;

— introduction of a paragraph about debris issues.

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

0.1 Background

The evolution of this document is motivated by changes inputted by the last issue of 2 main mother documents[1],[2].

0.2 Tailoring

This document may be tailored, by the contractor, in consultation with the procuring authority, for the specific characteristics and constraints of a space project.

Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some cases, modification and addition (e.g., for manned spaceflight) of requirements in the standards.

However, the tailored requirements may achieve a level of verification equivalent to the baseline described herein. Rationale for each tailored requirement may be established. If the requirements in this document are not tailored by a contract, they stand as written.

This document will be updated and revised periodically, each five years as appropriate to incorporate technological advances and innovations as well as lessons learned.

Space systems — Explosive systems and devices

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document specifies criteria and requirements for the use of explosive systems and explosive devices commonly used on spacecraft and other space products, including launch vehicles and space vehicle systems. It addresses the aspects of design, analysis, verification, manufacturing, operations and safety.

To the greatest extent possible, requirements from past and existing standards have been analyzed, selected and tailored to be incorporated herein. In addition, the requirements herein include those generated as a result of lessons learned from launch and space vehicle programs.

NOTE Specific requirements for man-rating are not addressed.

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 14300-1, *Space systems — Programme management — Part 1: Structuring of a project*

ISO 24113, *Space systems — Space debris mitigation requirements*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
actuator
component (3.1.10) that performs the moving function of a mechanism

Note 1 to entry: An actuator can be either an electric motor, or any other mechanical (e.g. spring) or electric component or part providing the torque or force for the motion of the mechanism.

3.1.2
all-fire level
lowest level of the fire stimulus (including rise time, shape, duration), which results in initiation of a *first element (initiator)* (3.1.36) within a specific reliability and confidence level as determined by test and analysis

Note 1 to entry: The stimulus duration shall be compliant with the system.

Note 2 to entry: The test sequence should be carried out at the lowest temperature of the operating range.

Note 3 to entry: The probability of functioning should be equal to or better than 0,999 at the 95 % confidence level.

3.1.3
armed
status of an explosive subsystem, when all the safety devices have been disabled and which is able to trigger

3.1.4
auto-ignition
spontaneous explosive reaction of *energetic materials* (3.1.19) in an explosively loaded device due to exposure to environments or interfacing materials

3.1.5
bridgewire
resistive element incorporated into the *first element* (3.1.30) that converts electrical energy into heat or shock to cause initiation of an explosive *charge* (3.1.8)

3.1.6
cartridge
explosive device designed to produce pressure for performing a mechanical function or actuate a mechanical device

Note 1 to entry: A cartridge is called an *initiator* (3.1.36) if it is the first or only explosive element in an *explosive train* (3.1.28).

3.1.7
catastrophic failure
failure which results in the loss of human life, mission or a major ground facility, or long-term detrimental environmental effects

3.1.8
charge
explosive (3.1.23) loaded in a *cartridge* (3.1.6), *detonator* (3.1.14) or separate container for use in an explosive device

3.1.9
closed bomb
fixed volume test chamber to measure output characteristics of pressure producing devices

3.1.10
component
set of materials, assembled according to defined and controlled processes, which cannot be disassembled without destroying its capability and which performs a simple function that can be evaluated against expected performance requirements

Note 1 to entry: The term “part” is preferred when referring to purely mechanical or explosive devices.

Note 2 to entry: The term “component” is preferred for EEE devices.

3.1.11
cook-off temperature
maximum temperature to which an explosively loaded device can be exposed for a period of one hour without reaction

Note 1 to entry: The determination of the cook-off temperature is time and application dependent.

3.1.12
deflagration
chemical decomposition propagating through the *explosive* (3.1.23) at a subsonic velocity

3.1.13
detonation
chemical decomposition propagating through the *explosive* (3.1.23) at a supersonic velocity such that a shock wave is generated

3.1.14
detonator
initiator (3.1.36) whose function is to transform external energy (e.g., mechanical, electrical, thermal) directly into a shock wave strong enough to detonate a secondary *high explosive* (3.1.34)

Note 1 to entry: Detonators are generally used to effect *detonation* (3.1.13) transfers within *explosive trains* (3.1.28).

3.1.15
duding
explosive *charge* (3.1.8) or *component* (3.1.10) that fails to fire or function upon receipt of the prescribed initiating stimulus, after an external effect (human failure, manufacturing failure, environmental, chemical, ageing, etc.)

3.1.16
electro-explosive device
EED
first element (3.1.30) of an *explosive train* (3.1.28): *initiator* (3.1.36) electrically actuated, which has a *bridgewire* (3.1.5) to transform electrical energy inputted into a reaction of the mixture used (e.g., *explosive* (3.1.23) or *pyrotechnics* (3.1.47))

Note 1 to entry: The output of the initiation is heat, shock or mechanical action, see 3.1.13.

3.1.17
electrostatic discharge
ESD

transfer of electrostatic *charge* (3.1.8) between objects at different potentials caused by direct contact or induced by an electrostatic field

3.1.18
end user
person who, or organization that, actually uses a product

Note 1 to entry: The end user may not to be the owner or buyer.

3.1.19
energetic material
material containing, an *explosive* (3.1.23), oxidizer, fuel or combination of them, that can undergo, contribute to, or cause rapid exothermic decomposition such as: combustion, *deflagration* (3.1.12) or *detonation* (3.1.13)

3.1.20
expanding tube separation system
separation system that emits no contamination and that includes detonating cord in a ductile metal tube and a structure containing geometrically controlled stress risers

3.1.21
exploding bridgewire device
EBW
high voltage device in which the *bridgewire* (3.1.5) explodes when functioned

3.1.22
exploding foil initiator
EFI
high voltage device that generates a supersonic flyer plate when functioned

3.1.23
explosive
material which is capable of undergoing an explosion when subjected to heat, impact, friction, *detonation* (3.1.13) or other suitable initiation

3.1.24
explosively actuated device
mechanism that converts the products of explosion (combustion, *deflagration* (3.1.12) or *detonation* (3.1.13)) into useful mechanical work

Note 1 to entry: Pyro-mechanisms and linear detonating separation devices are explosively actuated devices.

3.1.25
explosive component
any discrete item containing an explosive substance

3.1.26
explosive function
any function that uses energy released from explosive substances for its operation

3.1.27
explosive system
collection of all the *explosive trains* (3.1.28) on the *spacecraft* (3.1.60) or *launcher* (3.1.38) system, and the interface aspects of any on-board computers, launch operation equipment, ground support and test equipment and all software associated with *explosive functions* (3.1.26)

3.1.28
explosive train
ET
series of *explosive components* (3.1.25) that transfer explosive signal from the *first element* (3.1.30) to the final *explosively actuated device* (3.1.24)

3.1.29
extreme envelope
positive margin over the conditions of the qualification envelope

Note 1 to entry: The device or system design is based on the conditions that define the extreme envelope.

3.1.30
first element
initial element of an *explosive system* (3.1.27) that converts electrical, optical, or mechanical energy to explosive energy

3.1.31
fail operational
mission capable after one failure

3.1.32
fail safe
design property of a system/subsystem (or part of it), which prevents its failures from resulting in critical or catastrophic consequences (i.e. remain *safe* (3.1.50) after one failure)

Note 1 to entry: Maintaining safety following two independent failures is referred to “fail safe – fail safe”.

3.1.33
gas generator
explosive device wherein pyro *charge* (3.1.8), as a result of chemical reaction, is converted in gaseous products of reaction or exothermic output, or both

3.1.34
high explosive
HE
any chemical material in which the fuel and oxidizer are contained in the same molecule, the decomposition of which is a *detonation* (3.1.13)

3.1.35
hot bridgewire device
HBW
low voltage *EED* (3.1.16)

3.1.36
initiator
first explosive element in an *explosive train* (3.1.28) which, upon receipt of the proper mechanical, optical or electrical impulse, produces a deflagrating or detonating action

Note 1 to entry: The initiator is divided into three categories: 1) igniter, a first element whose output is hot gases and hot particles (igniters may be initiators for solid or liquid *propellant* (3.1.45)); 2) squib, a first element whose output is primarily gas and heat (squibs may be initiators for *gas generators* (3.1.33) and igniters or may be *cartridges* (3.1.6) for actuated devices); 3) detonator, a first element whose output is a high-order *detonation* (3.1.13) (*detonators* (3.1.14) are generally used to effect detonation transfers within explosive trains).

Note 2 to entry: The deflagrating or detonating action is transmitted to the elements following in the train.

Note 3 to entry: Initiators can be electrically (*EEDs* (3.1.16)), optically or mechanically actuated.

3.1.37
laser initiated device
LID
first element (3.1.30) containing *explosives* (3.1.23) that is ignited by laser energy

3.1.38
launcher
launch vehicle
vehicle designed to transport payloads to space

3.1.39
lifetime
period over which any properties are required to be within defined limits

3.1.40
lot
batch
group of *components* (3.1.10) produced in continuous, without uninterrupted production run, with no change in process or drawings

3.1.41
lot acceptance
demonstration by measurement or test that a *lot* (3.1.40) of items meet its requirements

3.1.42
no-fire level
maximal level of input energy with an ignition stimulus (including nominal rise time and shape as required by the system, but with a 5 min extended duration), to a *first element (initiator)* (3.1.36) at which initiation will not occur within a specific reliability and confidence level as determined by test and analysis

Note 1 to entry: The test sequence should be carried out at the hottest temperature of the operating range.

Note 2 to entry: The probability of functioning should be less than or equal to 0,001 at the 95 % confidence level.

Note 3 to entry: A first element tested at this level shall remain *safe* (3.1.50) and functional and shall guarantee the level of performances required after the no-fire level test.

3.1.43
packaged charge
explosive material in a closed container

3.1.44
primary explosive
reaction extremely sensitive explosive material that will detonate in response to normal environmental stimuli

Note 1 to entry: In their intended role, these materials are sensitive to a range of thermal, mechanical and electrical stimuli, including exposures during processing.

3.1.45
propellant
deflagrating explosive material whose output is essentially gaseous

3.1.46
pyro-mechanism
device intended to perform one or more mechanical actions, using the energy produced by the reaction of an *energetic material* (3.1.19)

3.1.47
pyrotechnics
mixture of fuels and oxidizers that can deflagrate

3.1.48
pyrotechnic device
basic pyrotechnic object (from *explosive train* (3.1.28) or explosive device) containing explosive substances and intended to perform an initiation (e.g. ignition, priming), a pyrotechnic effect transmission, amplification effect, or generation of a function

3.1.49
refurbish
replace *components* (3.1.10) or elements in an explosive device or system to maintain reliability or extend *service life* (3.1.58)

3.1.50
safe
property of an item and its environment that limits its potential for damage to an acceptable risk

3.1.51
safe and arm device
S&A
mechanical or electromechanical device that provides a moveable barrier within the *explosive train* (3.1.28) downstream of the *first element* (3.1.30)

3.1.52
scoop-proof connector
connector shell design in which the male contacts are recessed into the connector body to prevent mismating damage to pins (especially in blind mating applications)

3.1.53
secondary characteristic
any characteristic other than the function

3.1.54
secondary explosive
explosive material that is insensitive to heat or handling impact but will detonate under strong shock impulse

3.1.55
semiconductor bridge initiator
SCB
EED (3.1.16) that uses a semiconductor as the bridge element

3.1.56
sensitivity
characteristic of an *explosive* (3.1.23) that expresses its susceptibility to initiation by externally applied energy such as heat, mechanical shock, or other stimuli

3.1.57
sequential firing
application of the firing pulses to *initiators* (3.1.36) separated in time

3.1.58
service life
life that is established by testing or analysis during qualification or acceptance testing and is periodically extended by testing

3.1.59
sneak circuit
undesired function or function that inhibits a desired function

Note 1 to entry: The path may consist of hardware, software, operator actions, or combinations of these elements. Sneak circuits are not the result of hardware failure but are latent conditions, inadvertently designed into the system, coded into the software program, or triggered by human error.

3.1.60
spacecraft
manned or unmanned vehicle purposely delivered by the upper stage of a *launch vehicle* (3.1.38) or transfer vehicle, and designed to orbit or travel in space

Note 1 to entry: A spacecraft is a space segment element.

EXAMPLE Satellite, ballistic probe, re-entry vehicle, space probes and space stations.

3.1.61
space vehicle
manned or unmanned vehicle constructed or assembled for the purpose of manœuvring, moving, operating, or being placed in outer space

Note 1 to entry: A space vehicle can be a *launcher* (3.1.38), a rocket, a payload, a space capsule, a space shuttle, a space plane, a space station, etc., or any assembled combination thereof.

3.1.62
success
simultaneous achievement by all characteristics of required performance

3.1.63
sympathetic firing
firing of other explosive devices due to the output of any other

3.1.64
transfer line
linear explosive assembly in which the explosive material is confined in a metallic sheath plus various layers of over-wrap materials intended to limit radial expulsion of *detonation* (3.1.13) products, but sustain linear propagation of detonation waves

3.1.65
through-bulkhead initiator
TBI
relay which provides transition between the *detonation* (3.1.13) from a transmission line inputted, into combustion of the explosive material located output, through a sealed bulkhead metallic *component* (3.1.10)

Note 1 to entry: The bulkhead remains tight after functioning under the specified environment, e.g., pressure and temperature.

3.1.66
ultimate design factor of safety
FOSU
multiplying factor applied to the design load in order to calculate the design ultimate load

3.1.67
yield design factor of safety
FOSY
multiplying factor applied to the design limit load in order to calculate the design yield load

3.1.68
user manual
document provided by the supplier to describe all the appropriate rules of operations

Note 1 to entry: A content description is given in Annex E.

3.2 Abbreviated terms

AIT	assembly integration and tests
AIV	assembly integration and verification
AL	acceptance test load
CDR	critical design review
DC	direct current
DLL	design limit load
DMPL	declared materials and processes list
DRB	delivery review board
DRD	document requirements definition
DSC	differential scanning calorimetric
DTA	differential thermal analysis
DUL	design ultimate load
DYL	design yield load
EMC	electromagnetic compatibility
EMI	electromagnetic interference
FMECA	failure modes, effects and criticality analysis
FRP	fibre reinforced polymer

FTA	fault tree analysis
GSE	ground support equipment
ICD	interface control document
KA	acceptance test factor
KQ	qualification test factor
LEO	low earth orbit
MEOP	maximum expected operating pressure
MRR	manufacturing readiness review
MSDS	material safety data sheet
N/A	not applicable
NC	normally closed
NO	normally open
PDR	preliminary design review
QL	qualification test load
RAMS	reliability, availability, maintainability, safety
RF	radio frequency
RFI	radio frequency interference
RFP	request for proposal
S/C	spacecraft
SDS	safety data sheet
SRS	shock response spectrum
TBPC	to be provided by customer
TBPM	to be provided by manufacturer
TBPU	to be provided by user
TGA	thermo-gravimetric analysis
UM	user manual
UNO	United Nations Organization
UNECE	United Nations Economic Commission for Euriope
VTS	vacuum thermal stability