INTERNATIONAL STANDARD

ISO 26871

Second edition
2020-10

Space systems — Explosive systems and devices

Systèmes spaciaux — Dispositifs et equipements explosifs

Reference number
ISO 26871:2020(E)

Contents

Page

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 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

3.3 Symbols

@	At
g	standard surface gravity (9,806 65 m/s^2)
h	drop height (m)
He	helium
M	mass of drop weight (kg)
σ	standard deviation

4 Requirements

4.1 General

4.1.1 Background information

Since an explosive item used for flight can function only once, it can never be fully tested before its crucial mission operation. The required confidence can only be established indirectly by testing identical items, within destructive tests on samples from common production lots. Test results and theoretical justification are essential to demonstrate fulfilment of the requirements. The requirement for repeatability shows that product assurance plays a crucial role in support of technical aspects.

The need for statistics requires that the explosive components used in an explosive system be tested and characterized extensively. The variability in components means it is essential that manufacturers provide customers with proof that the delivered items are identical to those qualified.

Failure or unintentional operation of an explosive item can be catastrophic for the whole mission and life-threatening. Specific requirements can exist for the items associated with it. As all explosives, whatever their use, are to be treated similarly, the same requirements, regulations, practices and standards need to be applied to help avoiding human error.

If there is sufficient data to establish the reliability and confidence level for any given performance against any given condition, this should be done. Subsequently, all margins should be converted into standard deviations (σ) and be incorporated into the reliability and confidence analysis.

When viewed from the perspective of a specific project context, the requirements defined in this document should be tailored to match the genuine requirements of the particular profile and circumstances of a project.

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific project by selection and, in some exceptional cases, modification of existing or addition of new requirements.

The requirements of this document are drawn from the more detailed specifications of AIAA S-113A and ECSS-E-ST-33-11C.

4.1.2 Overview

Being generally applicable, the requirements stated in this clause apply throughout and are not repeated in the clauses relating to specific topics.

As describe in Figure 1, explosive systems and devices use energetic materials in the explosive train (explosives, propellants, powder) initiated by the firing system: mechanical, electrical, thermal, or optical stimuli, for unique (single-shot) functions, e.g. solid booster initiation, structure cutting, stage distancing, pressurized venting, stage neutralization, pyro-valve opening or closing, release of solar arrays, antennas, booms, covers and instruments.

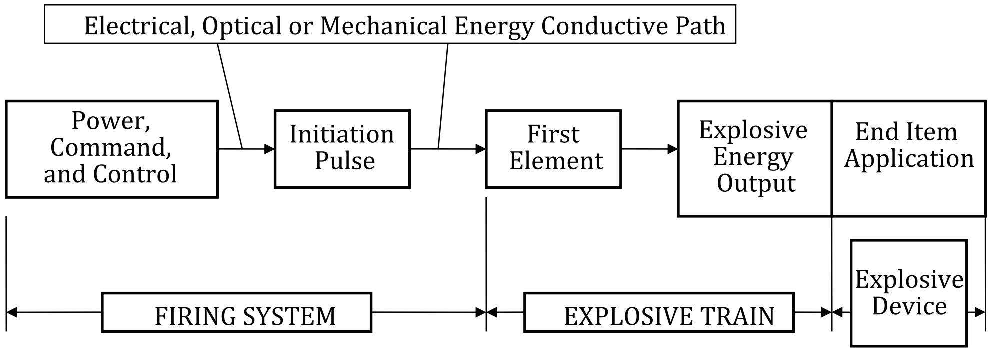


Figure 1 — Explosive system flow diagram

The properties of the initiator govern the major part of the behaviour of the system.

The requirements for initiators and their derivatives, such as cartridges and detonators, are defined in specific requirements related to the specific types.

Properties of explosive components and systems, which cannot be covered by requirements for the initiators alone, are defined in specific requirements relating to the types of explosively actuated device or pyro-mechanisms.

Other components of the explosive system, which can be tested and do not need specific requirements, are subject to the general technical and product assurance requirements. Detailed aspects of these components are included where they have a significant influence on the success of the system.

Single-shot items can never be tested in advance. Particular care shall be taken in their development, qualification, procurement and use, in accordance with the development phases specified in ISO 14300-1.

Safe handling and usage of explosive components are not governed by individual users or the suppliers.

4.1.3 Applicability

This document applies in addition to any existing standards and requirements applicable to spacecraft or launchers considered.

4.1.4 Properties

a) The two states of the properties of the explosive system (before firing and after firing) shall be identified and listed in a specific document for shipper and user.

b) For every explosive component, the function, primary stimulus, unwanted stimuli and secondary characteristics shall be identified and quantified.

c) Only qualified and lot-accepted items shall be used in flight systems.

d) The properties for the two states of the explosive system (before firing and after firing) referred to in item a) of this list shall remain stable over time when subjected to external loads or environmental conditions, within the qualification values.

4.2 Design

4.2.1 General

a) Redundant trains shall be designed such that no component shall adversely affect its substitute.

b) The system layout should facilitate the replacement of subsystems or components.

c) Parts of the explosive system and devices identified as critical on the basis of a RAMS analysis shall be replaceable.

d) Replaceable parts and substitutes shall be listed in the user manual (content description in Annex E) of the explosive system and devices.

e) The initiation system addressing first elements (initiators) shall be designed such that the minimum stimulus applied to each device in the system is equal to or greater than 2 times the statistical all-fire level, defined on the main parameter of the device, (e.g., current for EED, power density for LID, all fire voltage for EBW, etc.)

f) Tests and/or analyses shall be used to validate that a positive margin exists between the first element minimum output energy and the minimum input energy requirements of the interfacing explosive device. Tests shall also verify that a margin exists between the first element maximum output energy and the upper limit of acceptable input energy of the interfacing explosive device. Explosive charge weight alone cannot be used to predict energy output.

g) Safety system shall be used to guarantee any explosive device unwanted unlocking from other explosive devices in interfaces.

4.2.2 Debris requirements

There is international consensus formalized into ISO 24113 that space activities (including launch vehicle orbital stages, operating spacecraft and satellites) shall manage and minimize debris generation and associated risks.

Explosive devices shall not emit any products that will be detrimental to the integrity, the safety and performance of the vehicle.

In addition, considering that not any long-term orbital debris [orbital velocity higher than 8 km/s in A Zone (LEO: 0 km to 2 000 km); see ISO 24113 for the definition of the LEO protected region] shall remain in space, avionics equipment shall be designed and organized to operate the pyro sequences of orbital stages in a way to avoid debris production during flight and end of mission. Pyrotechnic devices on orbital stages shall be designed so as to comply with the requirements in ISO 24113 regarding the release of space debris into Earth orbit (i.e. no space debris larger than 1 mm in their largest dimension into Earth orbit).

To avoid orbit and ground debris from orbital stages, the architecture, design and dimensioning of explosive train shall take into account:

— mission profile (flight parameters, orbital speed, etc.);

— environment induced;

— characteristics reached by the space system (thermal impact, hazardous on-board remaining materials, etc.);

— stage passivation sequence;

— conditions of the break up process & sequence;

— national authority requirements concerning debris;

— requirements related to ground safety against re-entry;

— impact of debris dispersion on the on-ground footprint;

— …

4.2.3 Reliability and confidence levels

a) For the reliability demonstration, the customer shall agree which performance parameters are declared as mean values with associated standard deviation.

NOTE 1 The reliability demonstration is used to justify design margins including the influence of ageing, temperature, and explosive batch.

b) The explosive system shall achieve the specified properties within reliability and confidence level defined at system level.

NOTE 2 All components are contributors.

NOTE 3 This document specifies critical safety and performance properties.

c) The reliability of components shall be equal to or better than 0,999 with a confidence level equal to or better than 95 %.

d) The probability of unwanted functioning of components shall be less than or equal to 0,001 with a confidence level equal to or better than 95 %.

e) The selection of the statistical methods and functional parameters, used to determine the product performances, shall be justified and approved by the customer.

4.2.4 Performance

a) Performances shall be quantified by measurement versus time of initial, transitional, and final values of the specified properties.

NOTE Specified properties are listed in 4.11 and 4.12.

b) The specified time intervals [defined in a)] shall be identified and measured between either

1) a clear reproducible initiation event and the attainment of the performance value, or

2) an initiation event and 90 % of the measured performance value (e.g., initiation event in a closed bomb).

c) The basis of the time shall be specified and justified.

4.2.5 Wanted and unwanted response

a) For wanted response, the response of any component, when subjected to the specified minimum probable stimulus, shall be demonstrated to be more than the specified lower limit agreed between the customer and the supplier.

b) For unwanted response, the response of any component, when subjected to the specified maximum possible disturbance, shall be demonstrated to be less than the specified upper limit agreed between the customer and the supplier.

NOTE This applies to safety and failure.

4.2.6 Dimensioning

4.2.6.1 Strength

The explosive system shall sustain, before, during and after firing:

a) the internal loads due to operation, and

b) the external loads defined by the user.

NOTE These loads represent the sum of pre-load, static, dynamic, thermal and any other load seen in service.

4.2.6.2 Integrity

a) The explosive system shall maintain its integrity and position during its lifetime.

b) A “margin policy” shall be defined, justified and applied in accordance with the methodology given in Annex A.

c) Components that are intended not to rupture during operation, when installed into their explosive system interfaces, shall be able to withstand the maximum expected operational loads times an FOSU factor.

d) The factors FOSY and FOSU shall be consistent with the values given in Annex B depending on the materials used.

e) The deformation of a component shall not

1) reduce its specified performance,

2) affect any part of the system,

3) cause leakage more than the specified limit,

4) cause debris more than the specified limit.

4.2.6.3 Explosive charge sizing

a) The methodology for dimensioning the charge of the explosive devices shall be justified and be done by testing or modelling the worst-case conditions.

NOTE 1 Worst-case conditions include temperature, ageing, radiation effects.

b) A “margin policy factor", K_{MP}; shall be defined, justified and applied in accordance with the methodology given in Annex A.

NOTE 2 This factor, used to give confidence to the design, covers (non-exhaustive list):

— the lack of knowledge on the failure modes and associated criteria,

— the lack of knowledge on the effect of interaction of loadings, and

— the non-tested zones.

NOTE 3 Justification can be performed based on relevant historical practice and analytical or experimental means.

NOTE 4 K_{MP} can have different values according to the explosive materials or device behaviour in the mission profile (e.g. expanding tube, cutter, pyrotechnic actuator).

c) When modelling is performed, K_{MP}, shall include the uncertainties of the model:

1) defined,

2) justified,

3) applied during simulations and analysis.

d) Depending of the development phase, K_{MP} shall include a “project factor”, according to the uncertainty in the program level requirement.

NOTE 5 The project factor applies during the B Phase of the development can become equal to 1 after the PDR with the updated technical specification.

e) K_{MP} shall include an “explosive factor”, for uncertainties on the behaviour of explosive materials in the mission profile and its use configuration.

NOTE 6 The uncertainties can be related to ageing, radiations, temperature influences, batch influence, and chemical compatibility (material, gases, humidity, etc.).

NOTE 7 Use configuration can be, for example, loading density, confinement, thermal exchanges, etc.

4.2.6.4 Motorization

When a mechanical force or torque is complementary to the explosive energy to achieve a motion in an explosive device, the following motorization factor requirements shall apply to dimension the actuation force or torque

a) to provide throughout the operational lifetime and over the full range of travel actuation torques (or forces) according to provision d) or e);

b) to derive the factored worst-case resistive torques (or forces), the components of resistance, considering in-orbit worst-case conditions (environmental effects, e.g. vacuum, temperature, zero G) shall be multiplied by the minimum uncertainty factors specified in Table 1;

Table 1 — Minimum uncertainty factors

Component of resistance	Symbol	Theoretical factor	Measured factor
Inertia	I_T (or I_F)	1,1	1,1
Spring	S	1,2	1,2
Motor magnetic losses	H_M	1,5	1,2
Friction	F_R	3	1,5
Hysteresis	H_Y	3	1,5
Other (harness)	H_A	3	1,5
Adhesion	H_D	3	3

c) The theoretical uncertainty factors in Table 1 may be reduced to the measured factors providing the worst-case measured torque or force-resistive components are determined by measurement according to a test procedure approved by the customer and demonstrate the adequacy of the uncertainty factor with respect to the dispersions of the resistive component functional performances.

d) The minimum actuation torque (T_{min}) shall be derived from the following formula:

$$T_{min} = 2{,}0 \times (1{,}1I_T + 1{,}2S + 1{,}5H_M + 3F_R + 3H_Y + 3H_A + 3H_D) + 1{,}25T_D + T_L$$

where

I_T is the inertial torque applied to a device subjected to acceleration in an inertial frame of reference (e.g. spinning spacecraft, payload or other);

T_D is the inertial resistance torque caused by the worst-case acceleration function specified by the customer at the device level;

T_L is the deliverable output torque, when specified by the customer.

e) The minimum actuation force (F_{min}) shall be derived using the following formula:

$$F_{min} = 2{,}0 \times (1{,}1I_F + 1{,}2S + 1{,}5H_M + 3\,F_R + 3\,H_Y + 3\,H_A + 3\,H_D) + 1{,}25\,F_D + F_L$$

where

I_F is the inertial force applied to a device subjected to acceleration in an inertial frame of reference (e.g. spinning spacecraft, payload or other);

F_D F_D is the inertial resistance force caused by the worst-case acceleration function specified by the customer at the device level;

F_L is the deliverable output force, when specified by the customer.

f) The kinetic energy of the moving components shall not be taken into account to meet the specified motorization factor.

4.2.6.5 Sealing

Explosive devices shall be hermetically sealed or contained in an assembly that is hermetically sealed with a maximum allowable leak rate defined in the requirements tables in 4.12 and 4.13. Assemblies that are not hermetically sealed shall ensure the explosives within them are hermetically sealed. Assemblies that are hermetically sealed shall ensure energetic materials installed in them are protected from elements or contaminants in the assembly. Performance and safety of explosive devices shall not be adversely affected by contamination from the environment.

Use of organic materials to enhance seal effectiveness is acceptable provided they are compatible with the explosive materials used.

Seal effectiveness shall be verifiable before and after exposure to thermal and dynamic environments.

All interfaces in the explosive system shall provide adequate protection to preclude intrusion of water, salt, and other contaminants when exposed to worst-case predicted environments. The designer should consider that a launch or space vehicle may remain on the launch pad through very extreme environments and for a prolonged period (to be decided).

4.3 Mission

a) The use of explosive functions, including those for flight termination and range safety, during all phases of the mission, shall be specified.

b) The environmental conditions, life cycle and functions being activated shall be specified.

EXAMPLE Ground storage, transport, launcher ignition, staging and safety functions, payload and spacecraft separation, motor ignition, solar array, antenna, boom or cover release, propulsion system branch opening or closing, de-orbiting.

c) Mission-related requirements placed on the explosive system shall be specified.

4.4 Functionality

a) The firing sequence of each function of the explosive system shall be specified.

b) The explosive system shall react only to a specified stimulus (e.g. nature, range of values) and shall be insensitive to all others.

c) The explosive system shall ensure that the correct stimulus arrives at the specified place at the specified time.

d) The explosive system shall prevent the stimulus from reaching the initiator at any other time.

e) Unwanted functions or malfunctions shall be prevented.

f) The firing sequence (simultaneous or sequential firing) shall cause no anomaly.

NOTE 1 This applies to secondary characteristics as well as to explosive functions.

g) Explosive systems shall be single-fault tolerant.

h) Explosive systems shall be two-fault tolerant, if premature initiation causes a catastrophic failure.

i) If loss of function is safety-critical or catastrophic, the explosive system shall avoid single-point failures and include at least two initiators.

NOTE 2 Dual bridgewire EEDs are not considered to be redundant within themselves and do not obviate the need for a redundant EED.

j) Provision shall be made within the explosive system to protect its components against unwanted operation or degradation.

4.5 Safety

4.5.1 General

a) The system, including software and procedures, shall be fail safe.

b) For a catastrophic risk, the explosive system shall be fail safe/fail safe or fail operational/fail safe.

c) The response of any explosive device to conditions outside the conditions specified shall be reported by the manufacturer to the user.

d) An explosive subsystem shall only respond to commands intended for that explosive subsystem.

e) Explosive systems and components shall be designed to minimize risk to personnel, equipment, facilities, and environment.

4.5.2 Prevention of unintentional function

4.5.2.1 General

a) The firing pulse (e.g. detonating shock, electrical pulse, light pulse) shall be prevented from reaching any explosive initiator at any time except the correct instant by means of switchable barriers (e.g. electrical, mechanical, plugs, pins).

b) In accordance with the safety “fail safe – fail safe” or “fail operational – fail safe” and the reliability requirements, provision shall be made to prevent firing or degradation in response to radio frequency, direct and indirect effect of lightning, magnetic field and electrostatic discharge. In addition a sneak circuit analysis shall support the safety justification.

c) Explosive system shall demonstrate that not any unwanted sympathetic firing will occur.

d) If the explosive system contains two or more barriers, then at least two of these barriers

   1) shall be independent,

   2) shall not be subject to common cause failure, and

   3) shall each provide disconnection of the firing circuit.

e) For explosive systems involving a potential catastrophic risk, the barrier close to the source of the risk shall be a mechanical barrier.

f) The primary and redundant EEDs shall not be activated through the same electrical firing circuit.

g) Stray circuits or coupling, which can result in unintentional firing, shall be avoided.

4.5.2.2 Safe and arm device pre-arm function

a) The pre-arm function shall be the fourth last in a sequence of functions.

b) The pre-arm function shall be independent and respond only to a unique action.

c) The pre-arm function shall remain in its switched state after operation until the fire function has reverted to its initial state.

d) The pre-arm function can include the select function.

NOTE A safe and arm device is not always included.

4.5.2.3 Select function

a) The select function shall be the third last in a sequence of functions.

b) The select function shall select the explosive devices.

c) The select function shall be independent and respond only to a unique command.

d) The select function shall be used to control only one explosive function.

e) The select function shall revert to its initial state after the fire command within an interval agreed with the customer.

4.5.2.4 Arm function

a) The arm function shall be the second-last action in the sequence.

b) The arm function shall be independent and respond only to a unique command.

c) The arm function shall be used to control only one explosive function.

d) It shall be possible to restore its initial (disarmed) state after the arm command within an interval agreed with the customer.

4.5.2.5 Fire function

a) The fire function shall be the last action in the sequence.

b) The fire function may be used to activate a number of explosive devices.

c) The fire function shall be independent and respond only to a unique command.

d) The fire function shall revert to its initial state after the firing command within an interval agreed with the customer.

4.6 Survival and operational conditions

a) The explosive system shall survive during and after the specified sequence of conditions, encountered during transportation, storage, handling and flight, without malfunctioning or degrading performances beyond the specified limits.

b) The explosive system shall operate between the extremes of the ranges and combinations of specified conditions.

c) The limits used for the qualification of elements and interfaces shall comply with the specified reliability and confidence.

d) End users shall specify the characteristics of the expected environment.

e) The end user shall specify the explosive system constraints.

f) The explosive system shall limit the mechanical, electrical and thermal effects of its operation within limits agreed with the user to avoid disturbance (e.g. shock, electrical short circuits, magnetic fields) or damage to other sensitive elements on the space vehicle.

NOTE For verification tests, see 4.15.

4.7 Interface requirements

4.7.1 General

The natures of the interfaces are

a) geometry, including the analysis of the dimensions for all phases of life (e.g. assembly, transport, flight);

b) mechanical, including induced loads, static and dynamic;

c) fluids, including venting;

d) thermal loads;

e) electrical, including ensuring electrical continuity and EMC;

f) materials, including ensuring compatibility.

4.7.2 Functional

a) Each interface shall

   1) ensure no assembly errors can be made, and

   2) prevent damage during assembly or dismantling.

b) While separated, protection shall be provided to each interface.

   NOTE 1 This is to prevent activation or damage by external loads and environmental conditions.

c) When closed, each interface shall establish stable continuity of properties between the joined elements.

   NOTE 2 This is to prevent disturbance of, or being disturbed by, external loads and environmental conditions.

d) Each interface shall sustain, without degradation in both coupled and separated states,

   1) the assembly and dismantling duty-cycle, and

   2) the operational and environmental conditions of the application.

4.7.3 Internal

a) Each element in the explosive system shall be compatible with its neighbour.

b) Each element shall provide outputs (e.g. electrical, mechanical, thermal, optical) at each interface with margins over the input requirements of the next element or the explosive system output requirements.

4.7.4 External

a) The explosive system shall be compatible with the requirements of all other subsystems on board, external loading and environmental conditions.

b) If case a) of this list cannot be met, it shall be agreed with the user that either

   1) the on-board system requirements be changed, or

   2) protection against the environmental conditions be provided or the external loads on the explosive system be reduced.

4.8 Mechanical, electrical, and thermal requirements

4.8.1 Mechanical

4.8.1.1 Inertial properties

The supplier, in accordance with the reference axis system provided by the customer, shall provide the customer, before and after firing, component information related to:

a) the mass,

b) the centre of mass,

c) the inertial properties, and

d) the numerical model with interfaces, upon request of the user.

4.8.1.2 Main fixings

Each element of the explosive system shall be provided with an interface compatible with the methods of attachment to the structure or appendage agreed with the customer.

4.8.1.3 Modularity of the system

a) The explosive system shall be assembled from modular components.

b) It shall be possible to test the components separately.

c) It shall be ensured that attachment, installation, repair and replacement can be done without affecting the surrounding equipment.

4.8.1.4 Avoidance of confusion (only applicable for launch segment)

a) For launch segment, it shall be ensured, using dedicated marking, that components intended for different applications cannot be confused.

   EXAMPLE Inert components (dummies, etc.) versus live items (test models, flight models, qualification models, etc.).

   Items not suitable for flight use, which could be substituted for flight or flight spare hardware, shall be permanently identified as NOT FOR FLIGHT, or QUARANTINE e.g. colour coded with a unique colour.

b) For launchers, the colour code (see Annex C) can be applied.

   NOTE This is to prevent confusion and to ensure incorrect items are not used for flight or qualification.

4.8.1.5 Accessibility

a) Access shall be provided, throughout the space vehicle integration,

   1) to the initiators, safe, test, and arm plugs for connection,

   2) for measurements of properties, and

   3) to all elements for inspection.

b) Access shall be safe and convenient, as agreed with the customer.

4.8.1.6 Mechanical input to ICD

Complementary mechanical requirements before and after firing the explosive device or system shall be specified by the customer.

4.8.2 Electrical

4.8.2.1 General

a) All explosive devices firing lines shall be initiated via a dedicated module which incorporate the safety inhibits and is mechanically segregated, electrically independent and screened.

   NOTE Example of an initiation module is a firing unit. Examples of safety inhibits are command inhibit, barriers and switches. Examples of a segregation are different electronic boards for prime and redundant initiation, different routing of harnesses (electrical, optical and explosive).

b) The explosive system shall provide power pulses to initiators at the times required by the application.

c) The power pulse, shape, amplitude and duration shall be as specified in the ICD of the initiator manufacturer.

d) It shall be demonstrated by test that case c) in this list is met.

4.8.2.2 Circuit independence

a) Each electrical or optical initiator shall be connected to a dedicated electrical or optical firing line.

b) A separate command shall activate each explosive device for launch vehicles.

c) If case a) in this list cannot be met, the alternative circuit shall be justified and agreed between the customer and the supplier.

d) It shall be verified by test or analysis that the circuits meet the requirements on reliability and on the prevention of unintentional function.

NOTE See 4.2.2 and 4.5.2.

4.8.2.3 Power system overload

The power supply shall ensure that the power subsystem is not overloaded before, during or after the actuation of any explosive device, even in the case of a single-point failure together with a short-circuit (both pin-to-pin and pin-to-ground).

4.8.2.4 Electromagnetic compatibility (EMC)

a) The explosive system power, command and control electrical circuitry shall limit the generation of electromagnetic fields or conducted noise to a level at least 20 dB below the no-fire power rating.

b) The explosive system shall provide shielding to the same levels specified in a) when exposed to conducted and radiated susceptibility tests.

c) Control circuits shall limit the power level at any barrier to at least 20 dB below the no-fire power.

4.8.2.5 Electrostatic discharge (ESD)

a) The explosive system's power, command and control electrical circuitry shall

   1) survive,

   2) not be degraded by specified electrostatic discharges,

   3) be testable to verify survivability.

b) Protective features shall be provided to:

   1) prevent initiation,

   2) prevent change of state of the safety barriers,

   3) prevent parasitic paths,

   4) be tested to verify effectiveness.

c) Electrostatic discharge to ground through the explosive elements shall be prevented.

d) Build-up of electrostatic charges shall be prevented.

e) Measures to satisfy requirement d) of this list shall respect single-point grounding requirements.

f) All ESD-sensitive components shall be shielded or otherwise protected from the environment and identified and listed.

g) Unplanned electrostatic discharges shall be avoided.

4.8.2.6 Voltage drop

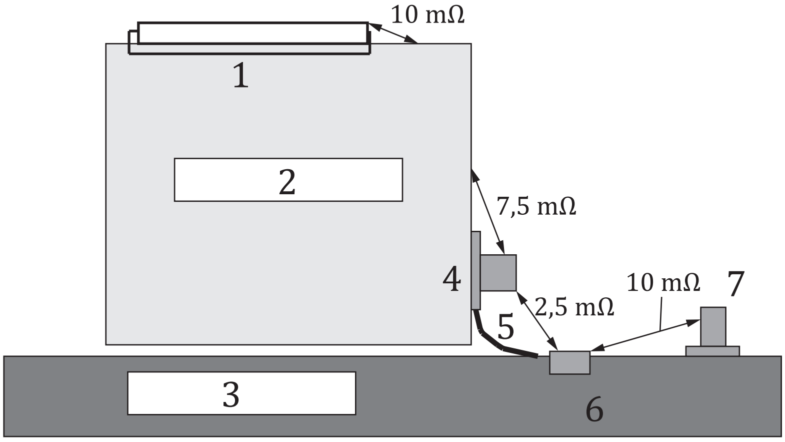
The voltage drop in the electrical circuit shall be taken into account when providing the required firing pulse.

4.8.2.7 Electrical bonding

a) The resistance between the case of the electro-explosive device and the electrical ground shall not exceed the specified value according to the bonding requirements given in Figure 2.

b) The metallic parts of the explosive devices shall be bonded by direct contact.

c) The shielding of the electrical pigtailed explosive devices shall be bonded at both ends of connector and its explosive device.



Key

1 connector
2 equipment
3 main frame
4 equipment bonding stud
5 bonding strap
6 structure
7 vehicle-bonding stud ground reference

Figure 2 — Bonding requirements

4.8.2.8 Isolation

a) Every electrical firing circuit and monitoring circuit shall be electrically independent from each other.

b) The explosive system shall isolate the explosive device to prevent power drain or parasitic paths before and after firing.

c) Provision shall be made to isolate power lines of the explosive system from electrical ground.

NOTE This is to prevent continued drain on the power system after firing, when, for example, a short circuit to ground can occur. A current can be drained by the structure instead of the electrical harness.

d) Provisions for redundancy shall not prevent fulfilment of requirement a) of this list.

e) Safe and arm device control and check-out circuits shall

1) be independent of the firing circuits, and

2) use separate non-interchangeable connectors.

f) For launchers only, provision shall be made to isolate power lines and return lines of the explosive system from electrical ground.

4.8.2.9 Insulation

The explosive system shall neither function nor degrade as a result of the voltage difference between the firing circuits and the shielding or the ground within specified limits.

4.8.2.10 Leakage

The explosive system shall neither function nor degrade as a result of leakage current of electrical firing circuits to ground.

4.8.2.11 Sensitivity to RFI

a) When exposed to RFI, the induced current shall not exceed the greater of the following:

   1) 20 dB below the no-fire current;

   2) 20 dB below the RF sensitivity threshold (any reaction of the component, even a non-nominal one — reliability and confidence levels are given in Table 1).

   NOTE If no RF limit is known, the DC limit can be used.

b) When exposed to RFI, the explosive system shall not be degraded.

4.8.2.12 Magnetic cleanliness

a) The maximum level of residual magnetism shall be agreed with the end user.

   NOTE Reduced levels can be achieved by the choice of suitable materials.

b) The supplier shall provide the customer with the magnetic properties of the explosive device.

c) The explosive system shall not generate magnetic fields exceeding the electromagnetic interference safety margins level required (TBPU).

4.8.2.13 Lightning

a) For launch segments, in accordance with the direct and indirect lightning environment provided by the customer, the explosive systems shall preclude unwanted firing due to electrical potential differences, or current generated within the explosive system by exposure to lightning.

b) Explosive systems should preclude degradation by exposure to lightning.

NOTE Assessment of survivability can be accomplished by inspection and analysis of the explosive system and components design.

4.8.3 Thermal

4.8.3.1 Sensitivity

a) Explosive systems and components shall

   1) survive,

   2) not be degraded by defined thermal loads in terms of intensity, duration and cycling, and

   3) be tested to verify survivability.

b) Protective features shall

   1) be provided to prevent unintended initiation,

   2) be provided to prevent loss of performance, and

   3) be tested to verify effectiveness.

c) Build-up of heat shall be prevented.

d) All thermally sensitive explosive devices shall be shielded or otherwise protected from the environment.

e) Explosive devices shall not decompose when exposed to thermal environments that are 30 °C above the maximum predicted temperature during worst-case service life.

NOTE This is to ensure no self-ignition under "cook-off" test.

4.8.3.2 Heat generation

The explosive system shall not generate heat causing temperatures which exceed the specified limits.

4.8.3.3 Thermal input to ICD

Complementary thermal requirements before and after firing the explosive device or system may be specified by customer.

4.8.4 Status check

4.8.4.1 General

a) The explosive system shall provide for

   1) measurements of electrical or optical properties during the integration of any circuit before and after firing, without inducing firing, unintentional status changes or degradation, and

   2) the indication of at least the status of the safe and arm device during the mission.

b) It shall be possible to check the safe status of the barriers protecting the initiator before its mounting.

c) Check-out circuits shall not allow current flow or electrostatic discharge causing unintentional effects in the explosive system.

   NOTE This applies also after any single failure.

d) Any checking out of the status of electrical initiators shall limit the check-out current to 10^{-2} times the “no-fire” current on the bridge wire.

e) Any checking-out of the status of optical initiators shall limit check-out power to 10^{-4} times (TBPU) the “no-fire” power at the fire wavelength on the optical interface if the fire wavelength is used.

   A different wavelength than that used by the firing laser is recommended for check out.

f) The checking-out power or current or optical wavelength or frequency shall cause no unintentional effects or hazards, even after any single failure.

g) Any checking-out of the insulation resistance of the explosive system shall limit the voltage to 50 V DC to prevent performance degradation (e.g. duding).

h) Provision shall be made for an immediate warning signal to be given for any unplanned change of status of any explosive system control or check-out device.

EXAMPLE Thermal control requirements or material temperature limits.

4.8.4.2 Initiator status

a) Provision shall be made for on-ground checking of the initiator status.

b) Provision shall be made for accessing the arm plug receptacle during AIT phases.

c) Requirements for access shall be communicated to the user and facilities authorities.

NOTE Range safety sometimes prohibits the use of these features.

4.9 Materials

a) The parts, materials, and processes shall be selected to maximize commonality and thereby minimize the variety of parts, related tools, and test equipment required in the fabrication, installation, and maintenance of the vehicle.

b) The parts, materials, and processes shall be selected to meet the functional, performance, safety, reliability, contamination, and strength requirements of the end item during its design life, including all environmental degradation effects.

c) All materials, including explosive substances, shall be compatible with those materials with which they can come into contact.

NOTE 1 Outgassing can occur during, for example, polymerization or degradation of polymers.

NOTE 2 Explosive systems use materials (e.g. explosives, propellants, powder, binders, cleaning agents, cements) that can be toxic, corrosive, highly reactive, flammable, and dangerous with direct contact.

Adhesives, sealants, and solvents used in explosive devices shall be compatible with the explosives contained therein.

d) Inherently fungus-inert materials shall be used.

e) Continued exposure to the expected environmental conditions (including vehicle propellants, fluids, and gases) shall not cause degradation or increased sensitivity in excess of agreed limits.

f) Envelopes and Metals shall be corrosion resistant, or shall be suitably treated to resist corrosion when subjected to the specified environments including mechanical (stress corrosion, etc.), climatic (humidity, salt fog, etc.), materials, fluids and lubricants (corrosive contacts, etc.) during manufacture, installation, storage, handling and operation.

g) Any sealing system used to prevent degradation shall be demonstrated to be effective.

h) No cracking shall be allowed due to shock loads or shock loads combined with low temperatures.

NOTE 3 Materials can become brittle at low temperatures.

i) Age-sensitive materials shall only be used where degradation causes no loss of explosive system performance beyond the limits agreed with the end user.

j) The nature and condition of age-sensitive materials shall be identified and documented in the DMPL.

k) The nature and condition of explosive materials shall be identified and documented in the DMPL.

l) The use of primary explosives should be minimized and shall be evaluated and approved by the user.

m) The decomposition, cook-off, auto-ignition, and melting temperatures of all explosives shall be at least 30 °C higher than the maximum predicted environmental temperature to which the material will be exposed during storage, handling, installation, transportation, launch, flight, and orbit. Explosives that can react in response to normal environmental stimuli shall only be used in agreement with the user.

n) The properties of the explosives shall be reported and shall be compared with the mission requirements.

o) Degradation of the explosives shall not exceed agreed limits.

p) Degradation of explosive characteristics shall be determined by testing.

NOTE 4 Test methods can be DTA, DSC, TGA, VTS.

4.10 Production lot

Explosive items shall be manufactured and tested in individual production lots during the various stages of manufacturing to assure that all items in a production lot are assembled to the approved configuration:

— during the same time period,

— using the same production process, materials, tools, methods, personnel, and controls.

Any interruption of a continuous manufacturing process shall be identified by the supplier. Units on either side of the interruption shall be considered to belong to sub-lots. In-process inspections and tests, and acceptance testing shall verify that all sub-lots demonstrate homogeneous attributes and performance. If this is verified, the subgroups could be suggested to customer, to be considered to belong to a unique lot.

Each production lot shall be loaded with explosive materials manufactured, handled, stored, processed, and tested as a single lot. Critical non-explosive materials such as safety caps, closures, and heat-treated materials shall also be lot controlled. Materials and parts that must be single lot controlled shall be identified for each design and properly controlled during lot manufacturing.

Explosive components shall be considered one-shot items. They shall not be refurbished for flight use after firing.

4.11 Non-explosive components and equipment

4.11.1 Connectors

a) There shall be only one connection per pin.

b) The requirements of 4.7.2 shall apply to connectors of non-explosive components and equipment.

c) Mismating of connectors shall be impossible (e.g., geometry, layout, dimensions, harness length).

d) The insert polarization and contact arrangement of the connectors used in the explosive system shall not be used elsewhere on the space vehicle.

e) Initiator connector shall be terminated by male contacts.

f) Spare or un-terminated contacts shall not be allowed.

g) Prime and redundant circuits for the same function shall not pass through the same connector.

h) Electrical connectors shall provide continuous shielding in all directions.

i) Electrical connectors shall provide continuous shielding during

   1) engagement before the pins connect,

   2) disengagement after the pins disconnect.

j) Connector savers should be used in agreement with AIT requirements.

   NOTE This is to prevent the receptacle and contacts from wear and damage.

4.11.2 Wiring

a) Electrical supply for each initiator, optical source and safe and arm device shall be by a separate shielded, twisted-pair, line or coaxial cable (with double braid).

b) All connections between conductors shall be made by

   1) soldering,

   2) crimping,

   3) connectors.

   NOTE See 4.11.1 for connectors.

c) Wiring used for explosives should be visibly and uniquely identifiable.

4.11.3 Shielding

a) The firing circuit, including the initiator, shall be shielded.

b) The shield, isolators, shall provide 20 dB attenuation at the specified electromagnetic frequencies.

c) Cable shielding shall provide ≥90 % optical coverage.

d) Double-layer cable shielding should be used.

e) For all other element shielding, there should be shielding at 100 % optical coverage (e.g., no gaps or discontinuities, full shielding at the back faces of the connectors, no apertures in any container housing elements of the firing circuit), in order to be compliant with the electromagnetic environment severity.

f) Shields shall not be used for current carrying.

   NOTE Shields can be multiple points grounded to the structure.

4.11.4 Faraday cap

a) Faraday caps shall be used at the input interface of the explosive devices.

b) The Faraday cap shall prevent EEDs from being initiated or damaged by electromagnetic interferences.

4.11.5 Safety cap

a) Safety caps shall be used.

b) The safety cap shall contain the products of initiation of an explosive device.

c) It shall not be possible to install an explosive device with the safety cap mounted.

4.11.6 Power

a) The explosive system shall make use of the available voltage and current supplies from the power subsystem to produce power pulses of suitable size, duration and firing sequence for each of the functions.

b) The firing pulse requirements in Table 4, row 5, and Table 6 shall apply for EEDs and laser initiators respectively.

c) The power provided at the power distribution points shall be adequate to fulfil the requirements of 4.8.2.6, allowing for losses.

4.11.7 Arm plug receptacle

a) A connector shall be provided on the exterior surface of the space vehicle for use with manually inserted plugs to enable

   1) isolation,

   2) coupling of any explosive system, and

   3) testing of any explosive system.

   NOTE 1 This connector is referred to as arm plug receptacle.

b) Provision shall be made for access to the interface.

c) Requirements for access shall be communicated to the user, the customer and facilities authorities.

d) The arm plug receptacle shall be visibly identifiable.

e) The arm plug receptacle shall be qualified for the number of required connection cycles (e.g. to cover integration, testing and use).

f) The receptacle shall meet the requirements of 4.11.1.

   NOTE 2 A sub-D connector, self-locking bayonet or triple-start thread type can be used.

g) A connector saver shall be used.

   NOTE 3 This is to prevent the receptacle and contacts from wear and damage.

4.11.8 Safe plug

a) For electrical initiators, the safe plug shall

   1) short-circuit each initiator,

   2) ground each shorted initiator circuit,

   3) short-circuit each firing circuit, and

   4) ground each firing circuit.

b) For optical initiators, the safe plug shall be capable of absorbing or redirecting *n* times the maximum power the laser can generate, where *n* is defined by the user.

c) The safe plug shall be

   1) compatible with the safe and arm connector receptacle,

   2) suitable for use with flight hardware,

   3) suitable for the number of connection cycles necessary to cover integration, testing and use,

   4) scoop-proof,

   5) lockable (e.g. sub-D connector, bayonet or triple-start thread type),

   6) visibly identified, and

   7) carrying a “Remove before Flight” banner.

4.11.9 Arm plug

The arm plug shall

a) provide electrical continuity between the supply and firing circuits with electrical properties (including resistance, isolation, bonding, and Faraday protection) in any line, and be compliant with the requirements,

b) be compatible with the safe and arm connector,

c) be scoop-proof,

d) be lockable (e.g. sub-D connector, bayonet or triple-start thread type), and

e) be visibly identified.

4.11.10 Test plug

The test plug shall

a) provide electrical access to the firing circuits with electrical properties (including resistance, isolation, bonding measurements, Faraday protection and firing current pulse verification, including its correct distribution) in any line agreed with the end user,

b) be compatible with the safe and arm connector,

c) not carry any potential or current at the time of insertion or removal,

d) be suitable for the number of connection cycles necessary to cover integration, test and use,

e) be suitable for use with flight hardware,

f) be scoop-proof, and

g) be lockable (e.g. sub-D connector, bayonet or triple-start thread type).

4.11.11 Safe and arm device

4.11.11.1 General

a) Electrically actuated safe and arm devices should be used.

b) A safe and arm device shall

   1) be used in applications where unplanned initiation of the explosive system can cause injury, death, or severe damage to property,

   2) prevent the mounting of initiators in the armed position,

   3) provide means of remote arming,

   4) provide means of remote safing,

   5) provide safing without passing through the armed position,

   6) prevent manual arming,

   7) provide manual safing and prevent unwanted return to arm,

   8) remain in the selected position under all conditions except when intentionally activated,

   9) prevent the device from remaining in any state between "safe" and "arm",

10) arm within a time interval agreed with the user,

11) not require a force or torque to safe, exceeding the specified value, and

12) if actuated remotely, shall be safe within the specified time interval.

c) It shall not be possible to arm the safe and arm device if an initiator has been activated with the safe and arm device in safe position.

d) The safe and arm device shall be capable of being manually positioned to “safe” during any phase of this cyclic life.

e) The barrier shall be removable, or a reconnection shall allow propagation when required (“armed” condition).

f) Remote operation and status indication shall be provided.

g) Local visible unambiguous status indication shall be provided.

h) All additional blocks shall be flagged “Remove before flight”.

NOTE Safe and arm devices can use initiator-simulator resistors.

4.11.11.2 Electrically actuated

The electrically actuated safe and arm device

a) shall be designed to withstand repeated cycling from arm to safe for at least five times the expected number of cycles, without any malfunction, failure or degradation in performance,

b) shall have a demonstrated cyclic life of 1 000 safe-to-arm-to-safe transitions, or five times the number of transitions predicted during its lifetime, whichever is greater, without failure or degraded performance.

4.11.11.3 Mechanically actuated

The mechanically actuated safe and arm device shall be designed to withstand repeated cycling from arm to safe for at least five times the expected number of cycles, without any malfunction, failure or degradation in performance.

4.11.11.4 Safing

Safing shall prevent detonation or initiation transfer by

a) the placement of a barrier between the initiator and next explosive element, or

b) misalignment of the initiator and the next explosive element.

4.11.11.5 Arming

a) Arming shall enable detonation or initiation transfer by

1) the removal of a barrier between the initiator and next explosive element, or

2) alignment of the initiator and the next explosive element.

b) During transition from “safe” to “arm”, each electrical switch shall disconnect before connecting to the next circuit.

4.11.11.6 Status indicators

a) The device shall

1) provide remote status indications,

2) provide local status indications,

3) indicate an “Arm” status with a black “A” on a red background or a red “A”,

4) indicate a “Safe” status with a white “S” on a green background or a green “S”.

b) The status indications shall be unambiguous.

c) Visibility of the status indicators when installed on the spacecraft or launcher shall be ensured.

4.11.12 Initiator harness connector

The initiator harness connector

a) shall comply with the interface requirements of the integral connector of the initiator, and

b) shall not be used for other purposes on the space vehicle.

4.11.13 Initiator test substitute

Any initiator test substitute shall be representative with respect to properties which affect the results of the test.

4.12 Explosive components

4.12.1 General

4.12.1.1 Applicability

4.11 applies to explosive components that cannot be fully tested before flight.

For other elements of the system, which can be fully tested before flight, the equipment environmental test conditions of the user shall apply.

The requirements for explosive components are given below as measurements to be made after specific preconditioning and under survival and operational conditions identified in 4.6.

4.12.1.2 Identification

a) Each part, material or product shall be identified by a unique and permanent part or type number.

b) In addition, parts, materials and products shall be identified as individual entities or groups by means of one or more of the following methods:

1) date codes indicating date of manufacture, to identify items made by a continuous process or subject to degradation with age;

2) lot or batch numbers, to identify items produced in homogeneous groups and under uniform conditions; this identification applies when the items need not be individually distinguishable;

3) serial numbers, to identify individual items for which unique data shall be maintained.

c) The method of marking shall be compatible with the nature of the item and indicate its behaviour.

d) Identification should include

   1) manufacturer,

   2) part number, lot number,

   3) serial number,

   4) manufacturing date stating month and year.

e) For launchers, colour coding shall be used on components to indicate behaviour.

f) Colour coding should be in accordance with Annex C.

4.12.1.3 Contamination

a) Contamination shall be prevented during all the phases of the product life.

   EXAMPLE By the use of approved materials and by design to contain products of the operation of explosive components.

b) If requirement a) of this list cannot be met, a component shall not be accepted unless the limits of the amount and type of contamination are identified by the manufacturer and agreed with the end user.

   NOTE The contamination to be analysed is:

   — from the environment to the components,

   — from the components to the environment, and

   — related to the failure of innocuousness of the component during and after functioning.

4.12.1.4 After functioning

After functioning, no explosive component shall cause

a) any disturbance beyond specified limits agreed with the end-user,

b) contamination beyond specified limits, agreed with the end-user,

4.12.2 Initiators, cartridges, detonators and packaged charges

4.12.2.1 General

Properties of initiators shall be in accordance with Table 3, shall be quantified and conform to the figures where shown.

Under the conditions given in column E of Table 3, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 3 — Common requirements for initiator [igniter, squib, through bulkhead, detonator (hot bridgewire device, SCB, high voltage, laser, exploding foil, mechanical) cartridge, packaged charge] properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	AC leakage current	mA	TBPM	TBPM		
2	Bonding resistance	mΩ	10	N/A	To next-level assembly	

Table 3 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
3	Thermal response	V/t	TBPM	TBPM		
4	Leak rate	scc He/s	10^{-6}	N/A	@ Δp = 0,1 MPa before and after firing	
5	Structural integrity	MPa		TBPM		Applies to MEOP according to 4.2.6.2
6	Temperatures/Humidity					
a)	Auto-ignition	°C	N/A	TBPM		
b)	Non-operating	°C/HR%	TBPM	TBPM		
c)	Operating	°C/HR%	TBPM	TBPM	Duration TBPM	
d)	Storage	°C/HR%	TBPM	TBPM	Duration TBPM	
e)	Transport	°C/HR%	TBPM	TBPM	Duration TBPM	
f)	Verification Tests	°C/HR%	TBPM	TBPM	Number TBPM	
7	Generated in a closed bomb					
a)	Pressure	MPa	TBPM	TBPM	TBPM	Only the known and relevant output parameter are provided.
b)	Heat	J	TBPM	TBPM	TBPM	Only the known and relevant output parameter are provided.
c)	Light	lm	TBPM	TBPM	TBPM	Only the known and relevant output parameter are provided.
d)	Shock pressure	GPa	TBPM	TBPM	TBPM	Only the known and relevant output parameter are provided.
8	Probability of ignition of a reference charge			99,9 %	95 % confidence.	
9	Detonating devices					
a)	Shock transmission capability	GPa	TBPM	TBPM	Standard material	
b)	Flyer characteristics	mm	TBPM	TBPM	Flyer thickness, diameter, material, and jitter	
c)	Flyer velocity	m/s	TBPM	TBPM	Best estimate	
d)	Ignition gap	mm	TBPM	TBPM	By initiator type: TBPM	
11	End-to-end transmission gap	mm	TBPM	TBPM		
12	No. of mating/ de-mating cycles		TBPM	TBPU	With/without change of seals.	

Table 3 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
13	Lifetime	Year	TBPM	N/A	For transport, storage and operation.	

4.12.2.2 1 W/1 A no-fire initiators

a) The minimum no-fire rating shall be 1 A (current) or 1 W (power) for 5 min.

b) The firing probability when subjected to the no-fire current or no-fire power for 5 min shall be less than 0,001 at a 95 % confidence level.

c) After exposure to the no-fire current or no-fire power, the EED shall be capable of functioning according to its requirements.

d) The properties of the 1 W/1 A no-fire initiator given in Table 4 shall be quantified and conform to the figures where shown.

e) Under the conditions in column E of Table 4 the properties in column A, expressed in the units specified in column B, shall be between the values in column C (maximum) and column D (minimum).

Table 4 — Requirements for low-voltage initiator properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	DC insulation resistance	M Ω	N/A	2	@ ≥250 V (DC) or 500 V (DC), ≥60 s	Applicable to manufacturer only during manufacturing
2	Breakdown voltage	kV	11	N/A		
3	ESD survival	kV	N/A	25	@ 500 pF and 5 000 Ω for pin to pin test @ 500 pF and 0 Ω for pin to case test	
4	Dielectric strength	μA	500	N/A	@ 200 V (AC) ≥60 s	Applicable to manufacturer only during manufacturing
5	All-fire level	A	TBPM	TBPM	≥99,9 % of the units function with a confidence level of 95 % @ specified conditions	
6	All-fire power	W	TBPM	TBPM	≥99,9 % of the units function with a confidence level of 95 % @ specified conditions	
7	Response time	ms	TBPM	N/A	for all-fire current or power	

Table 4 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
8	No-fire level	A	N/A	1	≤0,1 % of the units function with a confidence level of 95 % @ 5 min, at specified conditions.	
9	No-fire power	W	N/A	1	≤0,1 % of the units function with a confidence level of 95 % @ 5 min, at specified conditions.	
10	Bridgewire resistance	Ω	TBPM	TBPM	@10 mA, ≤60 s, number of applications TBPM	

4.12.2.3 High-voltage initiators

a) Properties of high-voltage initiators shall be in accordance with Table 5 and shall be quantified.

b) Under the conditions given in column E of Table 5, the properties given in column A, expressed in the unit specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 5 — Requirements for high-voltage initiator properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	All-fire voltage	V	TBPM	TBPM	≥99,9 % of the units function with a confidence level of 95 %	
2	No-fire voltage	V	TBPM	TBPM	≤0,1 % of the units function with a confidence level of 95 % @ 5 min, test temperature TBPM	
3	Operating voltage	V		>500		

4.12.2.4 Laser initiators

a) Properties of laser initiators shall be in accordance with Table 6 and shall be quantified and conform to the figure where shown.

b) Under the conditions given in column E of Table 6, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 6 — Requirements for laser initiator properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	All-fire power density	W/mm^2	TBPM	TBPM	≥99,9 % of the units function with a confidence level of 95 %	
2	No-fire power density	W/mm^2	TBPM	TBPU	≤0,1 % of the units function with a confidence level of 95 % @ 5 min, at specified conditions (wavelength TBPM)	Factor of safety for spurious lights (TBPU).
3	Pulse width	ms	N/A	TBPM		Precise pulse width used for firing signal and monitoring one
4	Wavelength	nm	TBPM	TBPM		Depending on optical source: solid laser, laser diode. Precise wavelength used for firing signal and monitoring one

4.12.2.5 Mechanical initiators

a) Properties of mechanical initiators shall be in accordance with Table 7 and shall be quantified.

b) Under the conditions given in column E of Table 7, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 7 — Requirements for mechanical initiator properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	All-fire energy	J	TBPM	TBPM	≥99,9 % of the units function with a confidence level of 95 %	
2	No-fire energy	J	≤0,1 × minimum all-fire energy	TBPM	≤0,1 % of the units function with a confidence level of 95 %	
3	Test energy	J	N/A	TBPM		

4.12.2.6 Packaged charges

a) Properties of packaged charges shall be in accordance with Table 8 and shall be quantified, except for structural integrity and those of Table 3.

b) Under the conditions given in column E of Table 8, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 8 — Requirements for packaged charge properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Structural integrity		N/A	N/A	Handling and transport loads	
2	Detonation? Yes/No		TBPM	N/A	Intended operational mode	
3	Deflagration? Yes/No		TBPM	N/A	Intended operational mode	

4.12.3 Through-Bulkhead initiators

a) The properties of through-bulkhead initiators given in Table 9 shall be quantified and conform to the figures where shown.

b) Under the conditions in column E of Table 9, the properties in column A, expressed in the units specified in column B, shall be between the values in column C (maximum) and column D (minimum).

Table 9 — Requirements for through-bulkhead initiators properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Notes**
1	Output					
(a)	Pressure	MPa	TBPM	TBPM	In TBPM cm^3 at 20 °C	
(b)	Energy	J	TBPM	TBPM	TBPM	
(c)	Leak rate	scc He/s	10^{-6}	N/A	@ Δp = 0,1 MPa before firing	
2	Barrier tightness leak rate	scc He/s	10^{-5}	N/A	@ Δp = 0,1 MPa before firing	
3	Barrier tightness leak rate	scc He/s	10^{-3}	N/A	@ Δp = 0,1 MPa after firing	
4	Structural integrity	MPa	TBPM	TBPM		(barrier resistance after firing).

4.12.4 Integral initiator connectors

4.12.4.1 General

a) The configuration of the connector shall be used only for initiators.

NOTE This is the integral (upper) part of the initiator.

b) The interface shall allow for sealing.

4.12.4.2 Electrical initiator connector

a) The connector thread or closing mechanism shall be self-locking.

b) The connection shall have electrical continuity with a resistance <10 mΩ.

c) The connector shall be able to undergo 50 mating/de-mating cycles without degradation.

d) The connection shall be able to undergo specified thermal and mechanical environments without degradation.

e) Connection requirement shall precise if the connector shall be a scoop-proof connector.

4.12.4.3 Laser initiator connector

a) The initiator shall incorporate an interface to match the interfaces on the fibre-optic connector and the adaptor used to join the two items.

b) The connector interface shall not be used for any purpose other than explosive devices.

c) The connector thread or closing mechanism shall be self-locking.

d) The connection shall have electrical continuity with a resistance <10 mΩ.

e) The connector shall be able to undergo 50 mating/de-mating cycles while meeting its requirements.

4.12.5 Transfer devices

4.12.5.1 General

Properties of transfer devices shall be in accordance with Table 10 and shall be quantified.

Under the conditions given in column E of Table 10, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 10 — General requirements for transfer device properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Critical diameter	mm	N/A	TBPM		Information about explosive to be provided.
2	Temperature/ Humidity:					
a)	Auto-ignition	°C/ HR%	N/A	TBPM		
b)	Non-operating	°C/ HR%	TBPM	TBPM		
c)	Operating	°C/ HR%	TBPM	TBPM	Duration TBPM	
d)	Storage	°C/ HR%	TBPM	TBPM	Duration TBPM	
e)	Transport	°C/ HR%	TBPM	TBPM	Duration TBPM	
3	Probability of ignition of a reference charge			99,9 %	95 % confidence	
4	No. of mating/ de-mating cycles		TPBM	TBPU	With/without change of seals	
5	Life time	Year	N/A	TBPU	For transport, storage and operation	

4.12.5.2 Transfer line assemblies

a) The properties of transfer line assemblies shall be in accordance with Table 11 and shall be quantified.

b) Under the conditions given in column E of Table 11, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 11 — Requirements for transfer line assembly properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Propagation velocity	m/s	TBPM	TBPM		
2	Deflagrating lines					
a)	Pressure	MPa	TBPM	TBPM		
b)	Heat	J	TBPM	TBPM		
3	Detonating lines					
a)	Shock transmission capability	GPa	TBPM	TBPM	Standard material	
b)	Flyer characteristics	mm	TBPM	TBPM	Flyer thickness, diameter, material, and jitter	
c)	Flyer velocity	m/s	TBPM	TBPM	Best estimate	
d)	Ignition gap	mm	TBPM	TBPM	By initiator type: TBPM	
4	End-to-end transmission gap	mm	TBPM	TBPM		
5	Electrical continuity	mΩ	TBPM	N/A	From end to end	
6	Leak rate (together with interfaces)	scc He/s	10^{-6}	N/A	@ Δp = 0,1 MPa before firing	
7	Leak-tightness (together with interfaces)	scc He/s	10^{-3}	N/A	@ Δp = 0,1 MPa after firing (ends implemented in the specified interface) + no debris	
8	Organic contamination of surfaces	mg/m^2	2	N/A	TBPU	
9	Radius of curvature	m	N/A	TBPM	Bending	
10	No. of times can bend		TBPM	TBPU	Bending	
11	Twist angle	rad/m	TBPM	N/A		
12	Tension	daN	TBPM	N/A		
13	Overall mass	g/m	TBPM	N/A	Linear mass of flexible part (g/m) + ends (g)	
14	Explosive mass	g/m	TBPM	N/A	Linear mass of flexible part (g/m) + ends (g)	

4.12.6 Safe and arm devices containing explosive

a) 4.11.11 applies.

b) Only secondary explosives with less or equal sensitivity to hexogen shall be used.

4.12.7 Gas generators

a) Properties of gas generators shall be in accordance with Table 12 and shall be quantified.

b) Under the conditions given in column E of Table 12, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 12 — Common requirements for gas generator properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Bonding resistance	mΩ	10	N/A	To next level assembly	
2	Leak rate	scc He/s	10^{-6}	N/A	@ Δp = 0,1 MPa before and after firing at initiator interface	
3	Structural integrity	MPa		TBPM	Applies on MEOP according to 4.2.6.2	
4	Temperature/Humidity					
a)	Auto-ignition	°C	N/A	TBPM		
b)	Non-operating	°C/HR%	TBPM	TBPM		
c)	Operating	°C/HR%	TBPM	TBPM	Duration TBPM	
d)	Storage	°C/HR%	TBPM	TBPM	Duration TBPM	
e)	Transport	°C/HR%	TBPM	TBPM	Duration TBPM	
5	Generated					
a)	pressure	MPa	TBPM	TBPM		Only the known and relevant output parameters is provided.
b)	heat	J	TBPM	TBPM		Only the known and relevant output parameters is provided.
c)	no. of mating/ de-mating cycles		TBPM	TBPU	With/without change of seals	
d)	shock	g/ms	TBPM	N/A	Time history and TBPU sampling rate. Test configuration TBPU.	
6	lifetime	Year	TBPM	N/A	For transport, storage and operation	

4.12.8 Shaped charges

a) Charge holders, or locating devices as appropriate, shall be used for all shaped charge functions to ensure proper charge orientation and standoff.

b) Charge holders and other attachment fittings to position shaped charges shall be designed to survive the same environmental exposures as the devices themselves, and also survive to any redundant shaped charge fired previously

c) Linear shaped charge assemblies shall be designed to accommodate any dimensional change in structural interfaces due to thermal expansion/contraction or expansion due to flight conditions.

d) Properties of shaped charges shall be in accordance with Table 13 and shall be quantified.

e) Under the conditions given in column E of Table 13, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 13 — Requirements for shaped charge properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Cutting capabilities					
a)	Structure thickness	mm	TBPM	N/A	Associated with material properties	
b)	Structure loads	MPa	TBPM	TBPM		
c)	Cutting delay	ms	TBPM	TBPM		
d)	Type of impulse	N s	TBPM			
e)	Generated shock	“g”/ms	TBPM	N/A	Time history and TBPC sampling rate. Test configuration TBPC	
2	Redundancy				TBPM	
3	Debris/ contamination/ induced					
4	Temperature/ Humidity					
a)	Auto-ignition	°C				
b)	Survival non-operating	°C/HR%	TBPM	TBPM		
c)	Operating	°C/HR%	TBPM	TBPM		
d)	Storage	°C/HR%	TBPM	TBPM		
e)	Transport	°C/HR%	TBPM	TBPM		
5	Lifetime	Year	TBPM	N/A	During transport, storage and mission	
6	Explosive charge Nature Linear mass	TBPM g/m				
7	Initiation mode	TBPM				Axial or radial

4.12.9 Expanding tube separation system

a) Properties of expanding tube separation system shall be in accordance with Table 14 and shall be quantified and conform to the figures where shown.

NOTE These devices include separation systems based on:

— detonation (shock and deformation),

— inflation (pressure-generated),

— combination of these above.

b) Under the conditions given in column E of Table 14, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 14 — Requirements for expanding tube separation system properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Cutting capabilities					
a)	Structure thicknesses, position of the cutting area	TBPM	TBPM	TBPM	Associated with material properties (e.g. ductility, elongation, strain rate)	
b)	Structure loads	MPa	TBPM	TBPM		
c)	Cut structure loads during cutting	kN	TBPC	TBPC	Associated with material properties (e.g. ductility, elongation, strain rate, plasticity)	
d)	Type of impulse	N s	TBPM	TBPU	Radial or axial	
2	Explosives: quantity and type	g	TBPM	TBPM	Associated with tube materials properties	
3	Redundancy				TBPM	
4	Expanding tube unsupported length	m	TBPM	N/A	Number and size of windows for the expanding tube separation system	
5	Cutting conditions					
a)	Response time	ms	TBPM	TBPM	Between first input and completion of cutting	
b)	Generated shock	g/ms	TBPM	N/A	Time history and TBPC sampling rate. Test configuration TBPC	
6	Device leak rate	scc He/s	10^{-6}	N/A	@ Δp = 0,1 MPa before firing	
7	Device leak rate	scc He/s	10^{-3}	N/A	@ Δp = 0,1 MPa after firing	
8	Particle generation		TBPU	N/A	Test method TBPC	
9	Temperatures					
a)	Auto-ignition	°C	N/A	TBPM		
b)	Non-operating	°C	TBPM	TBPM		
c)	Operational	°C	TBPM	TBPM		
d)	Storage	°C	TBPM	TBPM		
e)	Transport	°C	TBPM	TBPM		
10	Lifetime	Year	TBPM	N/A		

4.12.10 Distribution boxes

a) Properties of distribution boxes shall be in accordance with Table 15 and shall be quantified.

b) Under the conditions given in column E of Table 15, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 15 — Requirements for distribution box properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Input/output					
a)	Number		TBPM	TBPM		
b)	Interface type		TBPM	TBPM	Design TBPM	
2	Explosives					
a)	Quantity and type	g	TBPM	TBPM		
b)	Response		TBPM	TBPM	e.g. detonating, deflagrating	
3	Redundancy				TBPM	
4	Response time	ms	TBPM	TBPM	Between first input and all outputs	
a)	Generated shock	g/ms	TBPM	N/A	Time history and TBPC sampling rate. Test configuration TBPC	
b)	Device leak rate	scc He/s	10^{-6}	N/A	@ Δp = 0,1 MPa before firing	
c)	Device leak rate	scc He/s	10^{-3}	N/A	@ Δp = 0,1 MPa after firing	
5	Temperature/Humidity					
a)	Auto-ignition	°C	TBPM	TBPM		
b)	Non-operating	°C/HR%	TBPM	TBPM		
c)	Operating	°C/HR%	TBPM	TBPM		
d)	Storage	°C/HR%	TBPM	TBPM		
e)	Transport	°C/HR%	TBPM	TBPM		
6	Lifetime	Year	TBPM	N/A	During transport, storage and mission	

4.12.11 Explosive delays

a) Properties of explosive delays shall be in accordance with Table 16 and shall be quantified.

b) Under the conditions given in column E of Table 16, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 16 — Requirements for explosive delay properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Delay type		TBPM	TBPM		With or without gas generation.

Table 16 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
2	Delay time	ms	TBPM	TBPM	Mean value, standard deviation at temperatures	
3	Temperature sensitivity	%/°C	TBPM	TBPM	Temperature range to be provided	
4	Initiation		TBPM	TBPM	To be provided: mechanical (e.g. percussion), electrical, thermal, detonation	
5	Output		TBPM	TBPM	To be provided: pressure versus time, calorific energy, detonation	
6	Leak rate	scc He/s	10^{-6}	TBPM	@ Δp = 0,1 MPa before firing	
7	Leak rate	scc He/s	TBPM	N/A	@ Δp = 0,1 MPa after firing	
8	Temperature/Humidity					
a)	Auto-ignition	°C	TBPM	TBPM		
b)	Non-operating	°C/HR%	TBPM	TBPM		
c)	Operating	°C/HR%	TBPM	TBPM		
d)	Storage	°C/HR%	TBPM	TBPM		
e)	Transport	°C/HR%	TBPM	TBPM		
9	Lifetime	Year	TBPM	N/A	During transport, storage and mission	

4.13 Explosively actuated devices

4.13.1 General

a) For any explosively actuated devices which incorporate initiation and explosive charges, the requirements of 4.12 shall apply.

b) No released part shall cause damage.

c) The requirements of Table 17 shall apply.

d) Under the conditions given in column E of Table 17, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 17 — General requirements for explosively actuated device properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Leak rate	scc He/s	TBPU	N/A	@ Δp = 0,1 MPa before firing	

Table 17 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
2	Leak rate for spacecraft in a vacuum chamber	Number of moles of pyrotechnic leaking gases	2,5.10-5 moles		@10^{-2} Pa minimum during firing	When firing tests are performed in closed thermal (temperature *T*) vacuum chambers of volume *V*, measure of the pressure increase ΔP for a sufficient duration to get an asymptotic pressure curve (e.g. 80 s). The Number of moles of leaking gases is given by: $n_{leaking\ gases} = \frac{V\Delta P}{RT}$ R=8,314 J×mol^{-1} ×K^{-1}
3	Leak rate	scc He/s	TBPU	N/A	@ Δp = 0,1 MPa after firing	
4	Temperature/ Humidity					
a)	Non-operating	°C/HR%				
b)	Operating	°C/HR%	TBPM	TBPM	Duration TBPM	
c)	Storage	°C/HR%	TBPM	TBPM	Duration TBPM	
d)	Transport	°C/HR%	TBPM	TBPM	Duration TBPM	
5	Functional delay	ms	TBPM	TBPM		
6	No. of assemblies/ disassemblies		TBPM TBPM	TBPU TBPU	To the maximum load of the device attachments	
7	Generated shock	g/ms	TBPM	N/A	Time history and TBPU sampling rate. Test configuration TBPU.	
8	Lifetime	Year	TBPM	N/A	During, transport, storage and mission	

4.13.2 Separation nuts and separation bolts

a) The properties of separation nuts and bolts shall be in accordance with Table 18 shall be quantified and conform to the figures where shown.

b) Resettable separation nuts shall include a means of verifying that the nut is properly reset before and after its mating bolt or stud installation and preloading.

c) The pre-load shall be specified.

d) The pre-load shall be measurable at a value exceeding the maximum expected amplitude of the dynamic tension in the bolt and effects of thermal variations.

NOTE The safety margin on the pre-load is positive under mechanical and thermal environment.

e) If separation nut, stud or bolt capture devices are used, they shall be designed and tested to ensure that free components do not degrade any adjacent structure, system, or component.

f) Under the conditions given in column E of Table 18, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 18 — Requirements for separation nut and bolt properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Screw pre-load tension				Screw properties to be provided	
a)	By pure tension	kN	TBPM	TBPM		
b)	By torque	kN	TBPM	TBPM		
2	Load capabilities				Worst-case temperatures	
a)	Axial load	kN	TBPM	TBPM		
b)	Transverse load	kN	TBPM	TBPM		
c)	Bending moment	Nm	TBPM	TBPM		
d)	Torsion	Nm	TBPM	TBPM		
3	Stiffness				Worst-case temperatures	
a)	Axial	N/m	TBPM	TBPM		
b)	Transverse	N/m	TBPM	TBPM		
c)	Bending moment	Nm/rad	TBPM	TBPM		
d)	Torsion	Nm/rad		TBPM		

4.13.3 Pullers

a) The properties of pullers given in Table 19 and shall be quantified and conform to the figures where shown.

b) The puller shall be capable of withdrawing the pin under maximum shear and bending loads.

c) The retractable pin shall not rebound after its stroke.

d) Sufficient stroke must be provided so that complete release is attained under worst-case dimensional tolerances and environmental conditions.

e) Under the conditions given in column E of Table 19, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 19 — Requirements for puller properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Pin pre-loads			N/A		
a)	Axial	N	TBPM	N/A		
b)	Shear	N	TBPM	N/A		
c)	Bending moment	Nm	TBPM	N/A		
2	Traction force	N	TBPM	TBPM	Minimum at end of stroke	

Table 19 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
3	Pulling stroke	mm	TBPM	TBPM		

4.13.4 Pushers (Thrusters)

a) Properties of pushers given in Table 20 shall be quantified and conform to the figures where shown.

b) Pushers shall be able to withstand the expected loads during operation.

NOTE These loads comprise e.g. compression, shear and bending moment.

c) Sufficient stroke shall be provided so that complete release is attained under worst-case dimensional tolerances and environmental conditions.

d) Under the conditions given in column E of Table 20, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 20 — Requirements for pusher properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Rod axial load	kN	TBPM	N/A		
2	Push force	N	TBPM	TBPM	Minimum at end of stroke	
3	Pushing stroke	mm	TBPM	TBPM		

4.13.5 Cutters

a) Properties of cutters given in Table 21 and shall be quantified and conform to the figures where shown.

b) Cutter target material used in testing shall be certified and controlled.

c) Cutters shall be designed, and testing shall consider, all operational factors including loads, oblique cutting angles, and environments.

d) Under the conditions given in column E of Table 21, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 21 — Requirements for cutter properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Cutting capabilities				At worst-case temperatures	
a)	Dimensions	mm	TBPM	N/A	Associated with material properties	
b)	Ultimate strength	MPa	TBPM	TBPM		
c)	Tension load	kN	N/A	TBPM		

Table 21 *(continued)*

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
2	Mass of generated particles	mg	TBPM	N/A		Total mass associated with load and load carrier properties.
3	Dimensions of generated particles	mm	TBPM	TBPM		Range of size associated with load and load carrier properties.

4.13.6 Pyro-valves

a) The properties of pyro-valves given in Table 22 shall be quantified and conform to the figures where shown.

b) After firing, the pyro-valve piston shall remain in its actuated position.

c) The pyro-valve piston shall remain in its actuated position when subjected to a back pressure of at least twice the peak fluid operating pressure.

d) The type of pyro-valve, NO or NC, shall be marked on the device.

e) The flow direction shall be marked on the device.

f) Under the conditions given in column E of Table 22, the properties given in column A, expressed in the units specified in column B, shall be between the values of column C (maximum) and those of column D (minimum).

Table 22 — Requirements for pyro-valve properties

	A	B	C	D	E	F
	Property	**Unit**	**Maximum value**	**Minimum value**	**Condition**	**Other**
1	Valve capabilities				Associated with fluid properties	
a)	MEOP	MPa	TBPM	TBPM	In fluid circuit	
b)	Pressure drop	MPa	TBPM	TBPM	In fluid circuit	
c)	Pyrovalve passage diameter	mm	TBPM		In fluid circuit, nominal	
d)	Fluid circuit leak rate	scc He/s	10^{-6}	TBPM	@ Δp = 0,1 MPa before and after firing	Before and after functioning.
e)	Internal leak rate (blow by)	scc He/s	TBPU	TBPM	TBPM	During functioning.
2	Mass of generated particles	mg	TBPM	N/A	In fluid circuit	
3	Dimensions of generated particles	mm	TBPM	TBPM	In fluid circuit	

4.14 Items external to the flight equipment

4.14.1 GSE

Verification of GSE (ground support equipment) used to support assembly, integration, test, handling, transport and launch campaign activities shall be conform with the following requirements:

a) GSE validation:

   1) The GSE shall be validated based on expected environmental conditions and operational constraints.

   2) Hazards to personnel, flight hardware, facilities and environments shall be processed.

b) Only approved equipment and procedures shall be used.

c) GSE shall provide support and protection within specified limits, including ESD and EMI.

d) Test equipment shall be energy-limited (e.g. electrical, optical) in accordance with 4.8.4.

e) The status indication of the explosive system shall be provided.

f) Changes in the status indications shall be provided.

g) Status and status changes shall be recorded.

4.14.2 Test equipment

a) Only approved equipment and procedures shall be used.

b) Uncontrolled modifications to equipment or procedures shall be prohibited.

4.14.3 Launch site

a) The launch site shall provide specified transport, handling and storage facilities for explosive components and systems.

b) The status of explosive safety barriers shall be monitored when the space vehicle (e.g. launcher, satellite, spacecraft) induces a catastrophic risk.

c) Provisions shall be made to make visible the status of explosive safety barriers.

d) Any indicators used to show the status of the explosive devices and the barriers shall be clear and unambiguous.

e) Periods of sensitivity to external environment (e.g. EMI) shall be notified to the authorities.

f) Provisions shall be made for access to safe and arm devices for manual disarming.

4.15 Verification

4.15.1 General

Following exposure to the conditions specified in 4.15.3, explosive devices and systems shall meet the performance requirements specified in the appropriate subclauses of 4.11, 4.12 and 4.13 when measured according to 4.15.3.

4.15.2 Inspection

a) Inspection stages and procedures shall be compliant with the product assurance plan agreed with the customer.

b) Non-destructive inspection is required to demonstrate specified assembly and condition of every explosive component (e.g. X-Ray or N-Ray).

c) Resolution shall be better than the dimension of the smallest feature to be checked (e.g. micro-cracks).

d) It shall be demonstrated by inspection of all fired components that the internal dimensions, surfaces and material properties have not been degraded beyond specified limits.

NOTE Erosion, corrosion and burning due to the functioning can cause failure or leakage.

4.15.3 Tests

4.15.3.1 Test specification

The test specification describes in detail the test requirements applicable to any major test activity included in the AIV plan. In particular, it defines the purpose of the test, test approach, test article and set-up, the required GSE, test equipment and instrumentation, test conditions, test sequence, test facility, pass/fail criteria, required documentation, participants and test schedule.

The document is used as an input to the test procedures, as a requirements document for booking the environmental test facility and to provide evidence to the customer on certain details of the test activity in advance of the activity itself.

a) The test specification shall be detailed and agreed with the customer in advance.

b) The test conditions for explosive components and systems shall be derived from the operational conditions and constraints (e.g. ground, flight, in orbit).

c) Qualification and lot acceptance tests shall be in accordance with 4.15.4.

d) Acceptance tests shall be done at identical limit conditions and levels, whatever the application, to ensure valid reference to previous results and to reduce the numbers of tested items.

4.15.3.2 Test procedures

The test procedure gives directions for conducting a test activity in terms of description, resources, constraints and step-by-step procedure. The document is used and filled-in as appropriate during the execution and becomes the as-run procedure.

a) The test specification shall be detailed and agreed with the customer in advance.

b) The test procedure shall be written to comply with the test specification.

4.15.3.3 Test report

The test report describes the execution of a particular test and the results obtained. It contains the as-run procedure with supporting data, the anomalies and the evaluation of the test data in comparison with the requirements. Its principal use is to provide the customer with the evidence of the performed test activity in verification close-out of the relevant requirements.

Test results shall:

— describe the execution and results of the test activity;

— be detailed according to the content and format agreed with the customer in advance.

4.15.3.4 Essential confirmation

For every test, connection to the correct initiator shall be checked and recorded.

4.15.3.5 Routing tests

a) It shall be verified by test that the correct stimulus arrives at the correct initiator and no other.

b) Records shall be kept of the routing test.

4.15.3.6 End-to-end tests

a) End-to-end test shall be performed on monitorable items of the train, to ensure system capability within the reliability and safety limits agreed with the end user, during which

   1) a verification that the correct ignition energy levels are present at each pyrotechnic device shall be performed prior to final connection of the firing circuit to the device,

   2) a simulator of the pyrotechnic device characteristics shall be used during these tests,

   3) circuit continuity and stray energy checks shall be made prior to connection of any firing circuit to any pyrotechnic device, and

   4) circuit continuity checks shall be repeated whenever that connection is opened and prior to re-connection.

b) Only planned and approved activities shall be performed, according to approved procedures.

c) Firing tests shall not be performed until a successful rehearsal has been completed.

4.15.3.7 Safety tests

Refer to Table 23 for safety tests to be performed on unpacked articles.

Table 23 — Safety tests

Reference test	Test method	Recommended sequence	
		L	**S/C**
Slow cook-off	See *UNO Manual of Tests and Criteria*, test 7 (h)	R	N/A
External fire	See *UNO Manual of Tests and Criteria*, test 7 (g)	R	N/A
Handling drop test (e.g. 2 m height)	TBPU	R	O
12 m drop test	See *UNO Manual of Tests and Criteria*, test 4 (b)	R	N/A
Mechanical shock	TBPU	O	N/A
Radiated field	See MIL-STD 1576	R	R
Lightning	TBPU: pyro device level shall be calculated from launcher level (e.g. peak current 5 000 A, average rise time 4 µs, fall time 100 µs)	O	N/A

Key
L: launcher
S/C: spacecraft
R: required
O: optional
N/A: not applicable

4.15.3.8 Lifetime demonstration

a) Lifetime tests or analysis shall be done to establish changes over time in performance and susceptibility.

b) If accelerated ageing is used, it shall be justified.

4.15.3.9 Reliability tests

a) For any component, performances shall be declared in terms of reliability, confidence level, test and analysis methods.

b) The supplier shall justify the selected method used for the reliability demonstration.

NOTE The methods in Table 24 are given for information.

Table 24 — Reliability methods

Component	Method
Initiator	Bruceton or One Shot or Neyer
Cutter/release nut/pyro-valve/pusher/puller	Severe method
TBI	Severe method
Shaped charge	Probit or severe method
Expanding tube	Probit or severe method
Transmission lines	Bruceton or One Shot or Neyer or severe method

4.15.4 Qualification and lot acceptance

4.15.4.1 General

a) Qualification and acceptance of explosive components and systems shall be in accordance with quality assurance requirements TBPU.

b) For qualification, each device shall meet the requirements corresponding to that device specified in 4.11 or 4.12 after exposure to the complete sequence of conditions specified in Table 25.

c) For lot acceptance, each device shall meet the requirements corresponding to that device specified in 4.11 or 4.12 after exposure to the selected conditions specified in Table 26.

d) For lifetime, each device shall the requirements corresponding to that device specified in 4.11 or 4.12 after exposure to the complete sequence of conditions specified in Table 25.

e) Dynamic leak measurement shall be made under vacuum.

4.15.4.2 Qualification tests

4.15.4.2.1 General

Qualification tests shall be performed in accordance with Table 25.

NOTE Typical values are given in Annex D.

Table 25 — Qualification tests

Qualification test	Spacecraft component	Launcher component
No-fire stimulus	R	R
Physical properties (measurement)	R	R
Secondary characteristics measurement	R	R
Functional and performance (measurement)	N/A	N/A
No-damage drop	O	R
Salt fog	N/A	R
Rain	N/A	R
Humidity	O	R
Leakage test	O	O
Generated shock	R	O
Pressure	N/A	N/A
Acceleration	O	R
Sinusoidal vibration	R	R
Random vibration	R	R
Acoustic	N/A	R
Shock	R	R
Corona and arcing	N/A	N/A
Thermal vacuum	O	O
Thermal cycling	R	R
EMC/ESD (for initiator only)	R	R
Life	O	
Microgravity	N/A	N/A
Audible noise	N/A	N/A
Radiation	O	N/A
Functional and performance (measurement)	R	R
Destructive physical analysis	R	R

Key

R: required

O: optional

N/A: not applicable

NOTE 1 Only possible at the end of the qualification sequence.

NOTE 2 See 4.15.4.1 e).

4.15.4.2.2 Re-qualification

A device or system shall be re-qualified if there is a change in any of the following:

a) design;

b) more extreme environmental levels to which it will be exposed;

c) manufacturer or manufacturer facility location;

d) parts, materials, and processes;

e) energetic material or energetic material manufacturer;

f) designs that have been out of production for 5 years or more shall be subjected to margin and qualification testing.

4.15.4.2.3 Delta-qualification

A reduced scope qualification program may be used to accomplish the following:

a) supplement missing data in the qualification by similarity assessment above;

b) re-qualify a device or system for increased environmental or performance levels;

c) re-qualify a device or system that has undergone changes in design or manufacturing parts, materials, or processes that have been determined to negatively impact the qualification status.

The scope of the delta qualification program shall be reviewed and approved by the procuring authority.

4.15.4.3 Acceptance tests

a) Lot acceptance tests shall be performed on each production lot. They consist on non-destructive and destructive acceptance tests.

b) The test article configuration applicable to these tests follow the Test Like You Fly philosophy in which fully assembled devices are tested. Test definitions as well as fixtures to be used for testing of devices or systems shall be designed to simulate the intended flight applications to the greatest extent practical.

c) Failure of the test unit during acceptance is considered a failure of the lot.

d) Acceptance tests shall be in accordance with Table 26.

e) Lot acceptance tests results shall confirm that the hardware replicates the qualified product.

Table 26 — Acceptance tests

Acceptance test	Spacecraft component	Launcher component
Physical properties	R	R
Secondary characteristics	R	R
Functional and performance	N/A	N/A
Leak	R	R
Pressure	N/A	N/A
Random vibration	O	O
Acoustic	N/A	N/A
Generated shock	N/A	N/A
Thermal vacuum	O	N/A

Key

R: required

O: optional

N/A: not applicable

NOTE 1 Only possible at the end of the acceptance sequence.

NOTE 2 See 4.15.4.1 e).

Recommended values on the number of specimen submitted to destructive acceptance tests:

— for lot up to 50 devices: 10 % of devices submitted to destructive tests;

— for lot upper than 50 devices: 5 % or a maxi of 20 devices submitted to destructive tests.

Table 26 *(continued)*

Acceptance test	Spacecraft component	Launcher component
Thermal cycling	O	N/A
Burn-in	N/A	N/A
Microgravity	N/A	N/A
Audible noise	N/A	N/A
Functional and performance	O	O
Destructive physical analysis	O	O

Key

R: required

O: optional

N/A: not applicable

NOTE 1 Only possible at the end of the acceptance sequence.

NOTE 2 See 4.15.4.1 e).

Recommended values on the number of specimen submitted to destructive acceptance tests:

— for lot up to 50 devices: 10 % of devices submitted to destructive tests;

— for lot upper than 50 devices: 5 % or a maxi of 20 devices submitted to destructive tests.

4.16 Transport, facilities, handling and storage

4.16.1 General

a) Specified transport, handling and facilities for explosive subsystems and devices shall be provided.

b) Explosive system and devices shall be manufactured, packaged, handled, stored and installed in such a manner that supports contamination requirements for the launch vehicle or spacecraft.

4.16.2 Transport

a) It is presupposed that explosives devices are transported in conformance with applicable regulations, such as the latest version of UNECE regulations ST/SG/AC.10/1 and that containers comply with the applicable national and international transportation regulations.

b) If it is not possible to exclude explosive devices considered of Class 1, the explosive device is assigned to Class 1 and the required transport classification should be 1.4.S (see transport of dangerous goods: UNECE regulations: ST/SG/AC.10/1 Chapter 2.1 par 2.1.3.6).

c) The containers shall protect the component from the transport and storage mission profile.

d) It is presupposed that the definition of containers is in accordance with applicable regulations, such as the latest version of UNECE regulations (ST/SG/AC.10/1).

NOTE 1 It is good practice to pack explosive components individually to prevent changes in humidity and electrostatic charge.

e) Containers shall not be exposed to environments exceeding those specified.

NOTE 2 It is good practice to use thermal and shock sensors.

f) Identification label shall be marked before delivery in a permanent way on each deliverable.

g) Containers shall be marked with the following information:

1) equipment name and part number;

2) contents and quantity;

3) mass (gross and net explosive weight) in kilograms;

4) contract number;

5) supplier name and address;

6) explosive label with hazard and compatibility classifications;

7) the following label: “Open only in clean-room area by qualified operators”, if necessary.

h) Containers shall indicate the orientation to be kept maintained.

i) Application of the applicable directives (e.g. for European use, CE93/15/EEC, 2008/43/EC and 2012/4/EU) shall be analysed by the manufacturer and applied if relevant.

j) A material safety data sheet (MSDS) or safety data sheet (SDS) of the explosive device shall be provided in English and also in the Language used for Operations and by the end user.

NOTE 3 A template of SDS is provided in Annex F.

4.16.3 Facilities

a) It is presupposed that explosive devices are stored in dedicated storages according to the national regulations applicable for safety and security.

b) The nature of, and precautions required for, all explosive devices and systems shall be communicated to the facility designer.

c) All explosive devices shall be stored in places with controlled temperature and humidity and in secure storage areas, except when required for controlled spacecraft activities.

d) Records of all environmental conditions in locations where explosive components or systems are stored or handled shall be maintained and be available for review.

NOTE For example, environmental conditions such as thermal, humidity.

e) The location of every live or fired explosive component or subsystem shall be known and identifiable at any time.

4.16.4 Handling and storage

It is presupposed that all handling is done by qualified personnel according to the national regulations.

NOTE Handling includes testing, measuring, and installing.

a) It is presupposed that all handling is done in conformance with specified procedures and the specified Personal Protective Equipment, to comply with all appropriate regulations of countries, in which items will be transported, stored, used, and operated at spaceport.

b) Personnel and equipment shall be grounded to a common ground.

c) Only approved tools, aids and test equipment shall be used for explosive devices.

d) Consistent, coherent and complete records shall be maintained of components or systems which have a direct effect upon the system, including test activities and measurements during any break-in activities.

e) Restoration of the original accepted condition shall be required.

f) The correctness of all connections shall be confirmed and a record of all connections maintained.

g) Site safety regulations, provisions and procedures shall be checked for adequacy for explosive activities.

4.17 In-service

4.17.1 Information feedback

a) Checks shall be made to ensure consistency of information between different equipment at different stages in the launch preparation.

b) Results shall be recorded.

c) Information shall be provided of hardware and software provisions for the monitoring and command of explosive functions and shall show changes from one stage to the next.

d) RF links, wiring, connectors and pin functions shall be specified for checking of the source and destination.

e) Diagrams or photographs of consoles and installations shall be provided.

f) Confirmation shall be provided that no unwanted responses or drifts have occurred.

4.17.2 Launch site procedures

a) Only planned and approved activities which follow approved procedures shall be undertaken.

b) These shall include contingency actions.

c) Rehearsals shall be performed.

4.17.3 Monitoring

Confirmation of operation shall be made available immediately.

4.18 Product assurance

4.18.1 General

a) The explosive functions on a vehicle shall be treated together as a single subsystem.

b) All explosive devices shall be treated as critical items.

4.18.2 Dependability

a) The explosive system shall comply with all dependability requirements to meet the reliability and confidence requirements.

b) Age-sensitive parts and materials shall be identified.

4.18.3 Assembly integration and tests

a) Properties of the subsystem and all activities shall comply with the safety requirements to meet the reliability and confidence requirements.

b) Immediately before every electrical or optical connection and disconnection, it shall be confirmed that no conductor is live and that no power can flow or be interrupted across the interfaces.

c) Immediately before every connection and disconnection, it shall be confirmed that the operator and parts are grounded to a common ground.

4.19 Deliverables

Documentation in accordance with Table 27, coordinated and tailored with the customer contract agreement, shall be delivered.

NOTE Additional specific documents can be established at the customer's request.

Table 27 — Documentation to be delivered

Document	Response to RFP	KO	PDR & CDR	MRR & TRR	DRB	A/N	Reference standard
DRD for management							
Management and development plan	X		X				
Risk assessment report Risk management plan						X	
Progress reports						X	
Audit reports						X	
Inspection reports						X	
Non-conformance reports (minor)						X	
Non-conformance reports (major)					X		
DRD for product assurance							
Verification matrix	Xd	X	X				
Declared materials list Declared mechanical part list Declared processes list			Xd	X			
Qualification status list				X			
FMECA			X	X			
Request for deviation				X			
Request for waiver				X			
DRD for engineering and verification							
Functional and technical specifications	x	x	x	x	x		
Mechanical, thermal, electrical ICD's			X	X	X		
Design justification file	X	X	X	X	X		
Verification matrix	X	X	X	X	X		
Verification control document (design, reliability, qualification plan)	X	X	X	X	X		

Key

RFP: to be included in the request for proposal documentation

KO: to be included in the kick-off meeting documentation

MRR: to be included in the manufacturing readiness review data package

TRR: to be included in the test readiness review data package

DRB: to be included in the delivery review board data package (including Qualification data package)

A/N: as necessary or as required

Xd: draft document.

Table 27 *(continued)*

Document	Response to RFP	KO	PDR & CDR	MRR & TRR	DRB	A/N	Reference standard
Verification report (design, reliability, qualification justification reports)			X	X	X		
User manual			X	X	X		
Manufacturing and test documents							
Test procedure			Xd	X			
Production documentation tree	Xd		X	X			
Acceptance test plan			Xd	X			
Configuration item data list				X	X		
As-built configuration list				X	X		
Test reports					X		
Logbook					X		
End item data package (EIDP)					X		
Certificate of conformance					X		

Key

RFP: to be included in the request for proposal documentation

KO: to be included in the kick-off meeting documentation

MRR: to be included in the manufacturing readiness review data package

TRR: to be included in the test readiness review data package

DRB: to be included in the delivery review board data package (including Qualification data package)

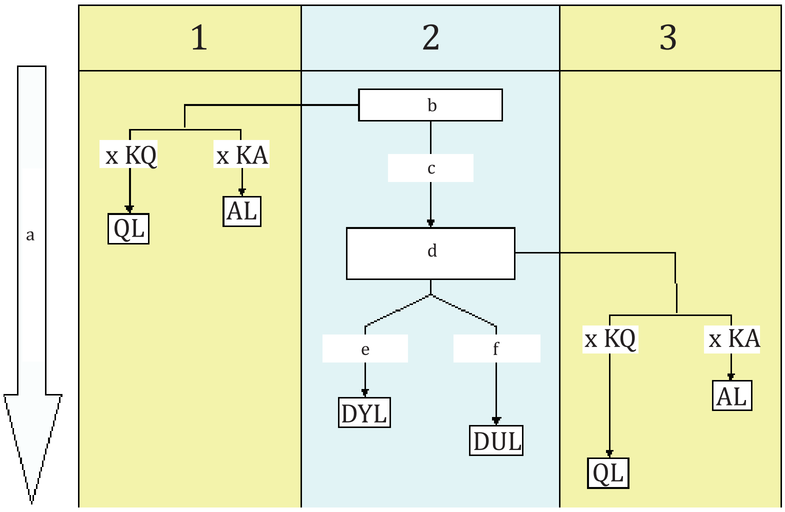
A/N: as necessary or as required

Xd: draft document.

Annex A
(normative)

Loads and factors of safety relationship

QL, AL, DLL, DYL and DUL, for the rest of the design of spacecraft, expendable launch vehicles, pressurized hardware, shall be calculated from the LL in accordance with Figure A.1 and Table A.1.



Key

1 satellites test logic
2 common design logic
3 expendable launch vehicles, pressurized hardware and manned system test logic
a increasing load level
b limit loads (LL)
c x Coef. A
d design limit loads (DLL)
e x Coef. B
f x Coef. C

Figure A.1 — Logic for factors of safety applications

Table A.1 — Relationship among structural factors of safety, design factors and additional factors

Coefficient	Satellite	Launch vehicles and pressurized hardware
Coef. A or Design factor	KQ × KP × KM	KP × KM
Coef. B	FOSY × KLD	FOSY × KMP × KLD
Coef. C	FOSU × KLD	FOSU × KMP × KLD
NOTE The yield factor (FOSY) ensures a low probability of yielding during loading at DLL level.		

Annex B
(normative)

Factors of safety

The factor of safety for metallic and FRP structures shall be selected from Table B.1.

The factor of safety for sandwich, glass and ceramic structures, joints, inserts and connections shall be selected from Table B.2.

Table B.1 — Factors of safety for metallic and FRP structures

Structure type	Vehicle	Requirement			
		FOSY	FOSU	FOSY verification by analysis only	FOSU verification by analysis only
Metallic parts	Spacecraft	1,1	1,25	1,25	2,0
	Launcher	1,1	1,25	[b]	2,0
FRP structures (uniform material)	Satellite	N/A	1,25	N/A	2,0
	Launcher	N/A	1,25	N/A	2,0
FRP structures (discontinuities)[a]	Satellite	N/A	1,25	N/A	2,0
	Launcher	N/A	1,25	N/A	2,0

[a] For example, holes, frames, reinforcements, abrupt change in thickness.

[b] No commonly agreed value within the space community can be provided.

Table B.2 — Factors of safety for sandwich, glass and ceramic structures, joints, inserts and connections

Structure type	Vehicle	Requirement			
		FOSY	FOSU	FOSY verification by analysis only	FOSU verification by analysis only
Sandwich structures: — face wrinkling — intracell buckling — honeycomb shear	Satellite	N/A	1,25	N/A	2,0
	Launch vehicle	N/A	1,25	N/A	2,0
Glass and ceramic structural structures	Satellite	N/A	2,5	N/A	5,0
	Launch vehicle	N/A	[c]	N/A	[c]
Joints and inserts[a]: — failure — gapping — sliding	Satellite	N/A N/A N/A	1,25 N/A N/A	N/A 1,25 1,25	2,0 N/A N/A
	Launch vehicle	N/A 1,1 1,1	1,25 N/A N/A	N/A	N/A
Elastomer system and elastomer to structure connection[b]	Satellite	[c]	2,0	[c]	[c]
	Launch vehicle	[c]	2,0	[c]	[c]

[a] These factors are generally not applied on the bolts pre-load.

[b] Analysis and testing are performed to show that the possible non-linear dynamic behaviour of the elastomer does not jeopardize the satellite strength and alignment.

[c] No commonly agreed value within the space community can be provided.

Annex C
(informative)

Explosive component colour code

See Table C.1.

Table C.1 — Explosive component colour code

Colours related to component behaviour		
Detonation		yellow-orange
Combustion-Deflagration		light brown
Inert		bright red-orange
Colours related to the state or purpose of the component		
Arm		bright red
Safe		green

Annex D
(informative)

Component qualification test levels to be customized to the space system considered

See Tables D.1 and D.2.

Table D.1 — Component qualification informative test levels

Environment	Launcher	Satellite
Cold	−80 °C / 10 h	−120 °C/48 h
Dry heat	+110 °C / 5 h	+120 °C/48 h
Damp heat	2 × 24 h 20 °C to 35 °C; 100 % RH	N/A
Thermal cycles in damp air	40 × [21 °C (1 h) to 33 °C (1 h)] 100 % RH	N/A
Thermal vacuum	0,1 MPa to 10^{-6} MPa in 30 s at −80 °C	N/A
Rain	Equipment sprinkled 50 mm/h, 30'/face	N/A
Salt fog	24 h with salt fog + 24 h without	N/A
Sine vibrations	4 min/axis Per axis 5 Hz–16 Hz: 10 mm peak to peak 16 Hz–30 Hz: 10 g per peak (1/3 oct/min) 30 Hz–70 Hz: 22,5 g peak 70 Hz–200 Hz: 50 g peak (2 oct/min) 200 Hz–2 000 Hz: 22,5 g peak Test temperature: −80 °C/+110 °C	3 axes–1 sweep Per axis 5 Hz–25 Hz: ±11 mm 25 Hz–100 Hz: 25 g peak (2 oct/min) Test temperature: ambient
Random vibrations	4 min/axis 20 Hz: 0,091 3 g^2/Hz 20 Hz –150 Hz: +6 dB/oct 150 Hz: 4 g^2/Hz 350 Hz: 4 g^2/Hz 350 Hz–700 Hz: [TBD] dB/oct 700 Hz: 3 g^2/Hz 700 Hz–2 000 z: −10,7 dB/oct 2 000 Hz: 0,1 g^2/Hz Test temperature: −80 °C / +110 °C	6 min/axis–3 axes 20 Hz–50 Hz: +3 dB/oct 50 Hz–600 Hz: 2 g^2/Hz 600 Hz–2 000 Hz: −3 dB Test temperature: ambient
Medium shocks	½ sinus 50 g, 11 ms Test temperature: ambient	½ sinus 50 g, 11 ms Test temperature: ambient
Pyroshocks	SRS _ Z1 level: Appendix Test temperature: ambient	SRS _ Z4 level: Test temperature: ambient
Radiations	N/A	30 krad Test temperature: ambient
Firing test conditions	−80 °C and + 110 °C	±120 °C

NOTE Customer can decide to input extreme envelope within these levels.

Key

N/A: not applicable

TBD: to be decided

Table D.2 — Pyroshocks for launcher and satellites

Severity code	Z1	Z4
Amplitude at 1 000 Hz	9 000	300
Amplitude at 2 000 Hz	17 500	1 000
Amplitude at 3 000 Hz	35 000	1 750
Amplitude at 3 500 Hz	35 000	2 300
Amplitude at 4 000 Hz	35 000	3 000
Amplitude at 25 000 Hz	35 000	3 000
NOTE Tolerances for the amplitudes are: +40 % and –50 %.		

Annex E
(informative)

Product user manual (PUM/UM) — DRD

E.1 DRD identification

E.1.1 Purpose and objective

The objective of the product user manual (PUM) or user manual (UM) is to provide information on design, operations and data of the product required by the user to handle, install, operate, maintain and dispose of the product during its lifetime.

This description of DRD contents is very general and could be applied to all components, devices and systems used in several fields (mechanical, electrical, etc.).

E.2 Expected response

E.2.1 Scope and content

	<1>	**Introduction**
		The Introduction describes the purpose and objective of the PUM.
	<2>	**Applicable and reference documents**
		The PUM lists the applicable and reference documents in support of the generation of the document.
	<3>	**Product function definition**
	<3.1>	**Product expected functions**
		The PUM provides a general description of the expected functions of the product during its lifetime in the expected operational context and environment.
	<3.2>	**Product functional constraints**
		The PUM describes all product functional constraints.
	<3.3>	**Lifetime phases and purposes**
		a) The PUM addresses the whole product life cycle and all its modes:
		1. handling;
		2. storage;
		3. installation;
		4. operations (nominal and contingency);
		5. maintenance;
		6. disposal.
		b) The PUM considers potential consequences of the environment on those sequences.
	<4>	**Product description**
	<4.1>	**Design summary**
		The PUM includes the following:
		a) a summary of the product design, showing the definition of the product, its constituents, the distribution of functions and the major interfaces;

		b) a block diagram of the product;
		c) a top-level description of the product software architecture;
		d) a description of nominal product operations scenarios and constraints, e.g. mutually exclusive modes of operation, power or resource sharing.
	<4.2>	**Product level autonomy**
		The PUM includes the following:
		a) a description of product-level autonomy provisions in the area of fault management (FDIR);
		b) a definition, for each autonomous function, of the logic or rules used and of its internal (product constituents) and external interfaces.
	<4.3>	**Product configurations**
		The PUM includes the following:
		a) drawings of the overall product configuration in all product modes;
		b) a definition of the product reference axes system(s);
		c) drawings of the product layouts.
	<4.4>	**Product budgets**
		The PUM provides the distribution (or allocation) of the following budgets, per product constituent, or per operating mode, as appropriate:
		a) mass properties;
		b) alignment;
		c) power consumption for all operational modes;
		d) thermal budget and constraints and predictions;
		e) description of interfaces and related budgets. (e.g. RF links);
		f) telemetry and telecommand date rates;
		g) memory;
		h) timing.
	<4.5>	**Interface specifications**
		The PUM provides a cross-reference to the applicable version of the ICD.
	<4.6>	**Handling**
		a) The PUM describes the conditions and procedures for the handling of the product, be it integrated or stand-alone.
		b) The PUM describes the specific design features, transport and environmental conditions, required GSE, and limitations for the handling of the product.
	<4.7>	**Storage**
		a) The PUM describes the conditions and procedures for the storage of the product, be it integrated or stand-alone.
		b) The PUM describes the specific design features, environmental conditions, required GSE, monitoring requirements, life-limited items, health maintenance procedures (activation, monitoring) and limitations for the storage of the product.
	<4.8>	**Installation**
		a) The PUM describes the conditions and procedures for the installation of the product, be it integrated or stand-alone.
		b) The PUM describes the specific design features, required GSE, modes, environmental conditions, and limitations for the installation of the product.

	<4.9>	**Product operations**
	<4.9.1>	**General**
		The PUM includes timelines, modes and procedures, constraints to operate the product during its life cycle, in nominal and contingency conditions, and to highlight critical operations.
		NOTE 1 When the product is a space segment, the product operations aspects are included in a specific part of the UM called the flight operations manual (FOM).
		NOTE 2 The implementation of the FOM by the ground segment responsible organization is contained in the mission operations plan.
	<4.9.2>	**Timelines**
		a) The PUM includes the following:
		1. baseline event timelines for all nominal and contingency modes and phases;
		2. related constraints.
		b) Each timeline contains a detailed description (i.e. down to the level of each single operational action) of the complete sequence of operations to be carried out, including a description of the rationale behind the chosen sequence of events, a definition of any constraints (e.g. absolute timing, relative timing) and the interrelationships between operations in the sequence.
	<4.9.3>	**Product modes**
		a) The PUM describes all nominal and contingency modes, including
		1. their purpose (i.e. circumstances under which they are used),
		2. the related procedures,
		3. operational constraints,
		4. resource utilization,
		5. the definition of the associated modes, and
		6. monitoring requirements.
		b) The PUM describes the allowable mode transitions and the operations procedure corresponding to each such transition.
		c) Appropriate cross-reference are made to product constituent modes and procedures.
	<4.9.4>	**Product failure analysis**
		a) The PUM provides the results of the product failure modes, effects and criticality analysis (FMECA) and the resulting list of single-point failures.
		b) Potential product failures are identified by means of a fault-tree analysis (FTA).
	<4.10>	**Maintenance**
		The PUM describes the conditions, procedures and logistics for the maintenance of the product, be it integrated or stand-alone.
	<4.11>	**Disposal**
		a) The PUM describes the conditions and procedures for the disposal of the product, be it integrated or stand-alone.
		b) The procedures include passivation, as relevant.
		c) The PUM identify the risks during and after disposal.
	<5>	**Products constituents description**
	<5.1>	**General**
		The information specified in <5.2> to <5.9> is provided for each product constituent.

	<5.2>	**Product constituent design summary**
		The PUM describes the product constituent, including
		a) the overall functions of the product constituent and the definition of its operational modes during the different mission phases,
		b) a description of any product constituent management functions, fault management concept and redundancy provisions,
		c) a summary description of the component units/equipment and software, including the functions which each supports,
		d) product constituent functional block diagrams and a diagram showing the source of telemetry outputs and the sink of telecommand inputs, e) interfaces, and
		f) budgets.
	<5.3>	**Product constituent design definition**
		The following is provided for each product constituent:
		a) a detailed design description, including block diagrams, functional diagrams, logic and circuit diagrams;
		b) physical characteristics, including location and connections to the support structure, axes definition and alignment where relevant, dimensions and mass properties;
		c) the principle of operation and operational constraints of the product constituent;
		d) if a product constituent is composed of many complex elements, it may be necessary to provide a lower level of breakdown.
	<5.4>	**Software**
		a) The PUM includes
		1. a description of the software design,
		2. the product constituent software,
		3. the application process service software, and
		4. a memory map.
		b) The PUM describes the organization of the software and its physical mapping onto hardware.
		c) The PUM describes the details of each software component, i.e. scheduler, interrupt handler, input/output system, telecommand packet handling system, telemetry packet handling system, including, for each component, its functions, component routines, input/output interfaces, timing and performance characteristics, flowcharts and details of any operational constraints.
		d) For the application process service software, the PUM
		1. describes the services implemented “Telemetry and telecommand packet utilization”, as tailored for the mission;
		2. summarizes all telemetry and telecommand structures (e.g. packets) including the conditions under which they are generated, the generation frequency, content and interpretation.
		e) For each memory block, a map is provided showing RAM and ROM address areas, areas allocated for program code, buffer space and working parameters (e.g. content of protected memory).
	<5.5>	**Product component performance**
		The PUM describes all relevant product constituent performance characteristics, define the expected performance degradation as a function of time during the mission, and identify the resulting impact in terms of modifications to operational requirements or constraints.

	<5.6>	**Product component telemetry and telecommand lists**
		a) For each product constituent, the following lists are provided:
		1. a list of the housekeeping telemetry parameters;
		2. a list of the telecommands.
		b) Each housekeeping telemetry has a functional description with validity conditions, telecommand relationship, and all technical information necessary for using it.
		c) Each telecommand has a functional description with utilization conditions (e.g. pre-transmission validity, criticality level), command parameters (syntax and semantics) and execution verification in telemetry.
	<5.7>	**Product component failure analysis**
		The PUM describes the following:
		a) the identification of potential product constituent failures by means of a systematic failure analysis (including a subsystem FMECA and FTA);
		b) the identification of the methods by which the higher levels can identify a failure condition from analysis of the telemetry data and isolate the source of the failure.
	<5.8>	**Product components operations**
		a) The PUM describes the following:
		1. product constituent modes;
		2. nominal operational procedures;
		3. contingency procedures.
		b) Product constituent modes are defined for all distinct nominal and back-up modes of the subsystem, including
		1. purpose (i.e. conditions under which each is used),
		2. operational constraints,
		3. resource utilization,
		4. the definition of the associated modes for each product constituent and its software functions,
		5. higher-level monitoring requirements, and
		6. identification of the allowable mode transitions and any product constituent operational constraints.
		c) Nominal operational procedures are defined for each nominal mode transition identified under <5.8 b) 6>.
		d) For each procedure described in <5.8 c)>, the following is provided:
		1. an introduction describing the purpose of the procedure and the phase(s) or conditions, when applicable;
		2. the body of the procedure, structured according to operational steps, including:
		i. pre-conditions for the start of the step defining, where applicable:
		— product or product constituent level pre-requisites (e.g. configuration and resource requirements, such as power, fuel);
		— external interfacing products pre-requisites.
		ii. telecommands to be sent;
		iii. telemetry data to be monitored to verify correct execution of the step;
		iv. interrelationships between steps (e.g. conditional branching within the procedure, timing requirements or constraints, hold and check points);
		v. conditions for completion of the step.

		e) Contingency procedures are defined for each failure case identified in the product constituent failure analysis (FMECA/FTA).
		NOTE This can utilize a nominal operational procedure already identified in <5.8 c)>.
		f) For contingency procedures, the same details are provided as for nominal operational procedures in <5.8 d)>.
		g) Where the recovery method for a failure or group of failures is mode-, mission-, or phase- dependent, separate procedures are described for each mode/mission phase.
	<5.9>	**Product component data definition**
		a) For each operational mode of the product constituent, sensor output data, conditions under which they are generated, their contents and data rate are described.
		b) Required on-board processing performed on sensor data and algorithms used for this are described.

E.2.2 Special remarks

Where the objective is to allow for the accommodation of equipment designed *a posteriori* with regard to an existing platform or vehicle, the following documents should be included in the UM:

a) the accommodation handbook describing the location, mounting, all interfaces and clearances of equipment in a platform or vehicle;

b) the installation plan describing the approach, methods, procedures, resources and organization to install, commission and check the operation of the equipment in its fixed operational environment.

Annex F
(informative)

Safety data sheet

COMPANY's LOGO	MATERIAL SAFETY DATA SHEET Written in accordance with the regulation (EC) n° 1907/2006 and n° 1272/2008 modified		
	Reference (As used on Label and List):	Index :	Revision date: Visa of preparer:

1 – PRODUCT IDENTIFICATION AND MANUFACTURER

Field of use:	Civilian ☐	Defence ☐	Civilian and Defence ☐
NATO stock number (NSN):			
Configuration annex Code (CAG) :			
Type:	Complete round ☐	Initiated complete round ☐	Other ☐
Supplier site:			
Address(Number, Street, City, State, Zip Code, Country):			
Contact numbers for information (phone, fax, Email):			
Emergency Telephone number:			

2 – HAZARDS IDENTIFICATION

➢ FOR A NOMINAL PYROTECHNIC USE

Effects	Overpressure – Shock wave		Projection		Heat flow	
	Yes ☐	No ☐	Yes ☐	No ☐	Yes ☐	No ☐
Other effects						

➢ FROM NON PYROTECHNIC MATERIALS of THE DEVICE (in case of bare active matter without pyrotechnic function)

Human health hazards :	
Environmental Hazards :	

3 – PRODUCT CHARACTERISTICS

Object presentation: Ingredient identification: Hazardous ingredients and associated mass:	Rep	Components/ingredients identification		
	1 2 ...			
	Mass of pyrotechnic matter (kg):		Total per object:	
			TNT Equivalent:	
	Total mass mass of the object (kg):			
Detailed description of a nominal functioning with a normal use:				
Main effect:				

4 – FIRST AIDS AND MEASURES

(Protect yourself, call the emergency services and ensure the victim is safe.
In case of thermal injury, rinse for a long time the burnt part with water.
In case of faintness, seek immediate medical attention.)

COMPANY's LOGO	MATERIAL SAFETY DATA SHEET Written in accordance with the regulation (EC) n° 1907/2006 and n° 1272/2008 modified		
	Reference (As used on Label and List):	Index :	Revision date: Visa of preparer:

5 – FIRE FIGHTING MEASURES

Feared effects in case of fire:	
General measures:	(Set up a safety perimeter There must be no human intervention to fight fire against pyrotechnic objects. When possible, measures to stop fire spread must be taken. Once fire is extinguished, access to the site is possible only after making sure the whole area has cooled down.)
Suitable extinguishing means:	(do not try to extinguish a pyrotechnic fire)
Forbidden extinguishing means:	
Special protective equipment:	
Other provisions:	

6 – ACCIDENTAL DISPERSION MEASURES

(Steps to be taken in case material is released or spilled :
Any pyrotechnical matter, accidentally scattered, shall be immediately recovered by an authorized staff to be carried away and destroyed if necessary (see disposal consideration in section N°13)
Avoid impacts, friction, indeed anything that could create a spark or an electrostatic discharge
Keep away from non-compatible products. (keep away from fire, avoid naked flame, remove from heat immediately)

Particular measures:	

7 – HANDLING AND STORAGE

Handling precautions:	(Handle with care avoiding any drop, impact, friction and exposure to heat, naked flame, electromagnetic radiation (including mobile phones), electrostatic discharges … Operations not provided for by technical instructions or carried-out by a non-qualified person are forbidden. Do not smoke)
Storage conditions:	(Store in an authorized location with compatible material, and with recommended environmental conditions)
Storage compatibility:	(follow the rules provided by the local regulations)
Other particular measures:	

8 – EXPOSURE CONTROLS /PERSONAL PROTECTION

Whilst handling:	
Personal protective equipment:	(suitable clothing and equipment recommended : gloves, safety glasses, acoustic protection … and that will minimize electrostatic discharge)
For a nominal use:	
Nature of decomposition products:	
Nature of substances making up the object and intentionally released without chemical transformatiion:	
Personal protective equipment:	(suitable clothing and equipment recommended : gloves, safety glasses, acoustic protection … and that will minimize electrostatic discharge)

9 – PHYSICAL / CHEMICAL CHARACTERISTICS

Auto-Ignition temperature:	(………… °C for the object or the most dangerous substance …………... following operative process ……………………)
Other:	

COMPANY's LOGO	MATERIAL SAFETY DATA SHEET Written in accordance with the regulation (EC) n° 1907/2006 and n° 1272/2008 modified		
	Reference (As used on Label and List):	Index :	Revision date: Visa of preparer:

10 – STABILITY AND REACTIVITY DATA

Chemical stability:	(Stable in storage conditions as recommended in section 7 Precise condition to avoid instability.)
Incompatibility (materials to avoid):	
Hazardous decomposition or byproducts	
Shock and impact sensitivity:	
Electrostatic discharge sensitivity:	
Vibrations sensitivity:	
Electromagnetic radiation sensitivity:	(Not applicable / data not available)

Observations:	Configuration	Color code if existing (GAM – DRAM regulation ...)	R	T	U	V	W	Y	Z
	All configurations								
	Storage – transport								
	Implementation								
	At firing station								
Others:									

11 – TOXICOLOGICAL DATA

12 – ECOLOGICAL AND ENVIRONMENTAL INFORMATION

Do not throw in natural environment

13 – DISPOSAL CONSIDERATIONS

Do not place in refuse bins, sewage systems or on rubbish tips.
Treatment and destruction processes shall be specific and subject to a particular safety analysis and survey depending on the state of the object and treatment of waste after destruction.
Any material pollution by pyrotechnic matter coming from the object shall be considered as pyrotechnic waste.
For further information, please contact the designated company.

14 – CLASSIFICATION FOR TRANSPORTATION

UN Number: Official transport designation:
Classification code: Transport label:
Reference/ date of transport classification certificate:
Transportation means: Road ☐ Rail ☐ River ☐ Air ☐ Sea ☐

Packaging approved for transport according to UN regulations:

	Description	Dimensions (m)	Number of packages	Amount of objects per package	Mass per package (kg)	
Exterior					Gross (objects + package)	
Intermediairy						
Interior					Total active matter	

Authorized packaging reference:

Ex: un 1A2 / Y / 55 / S / Année de fabrication
F – Entreprise XXX
TÜV 12345

Additional information:

COMPANY's LOGO	MATERIAL SAFETY DATA SHEET Written in accordance with the regulation (EC) n° 1907/2006 and n° 1272/2008 modified		
	Reference (As used on Label and List):	Index :	Revision date: Visa of preparer:

15 – REGULATORY INFORMATION

(Main applicable regulations are:
- Decree from local regulation (US, EC, Jp, CN, …) (from manufacturer to end user)
- Regulations for transport of dangerous goods
- Labor code
- Defence Code
- …)

16 – OTHER INFORMATION

Other information:

Warning:

This document was prepared based on our knowledge of the related object on the specified date. As a result, the mentioned data cannot be considered as exhaustive.
Please remember that explosive matter and objects are generally sensitive to all type of stress (mechanical, thermal, electrical…).
Therefore, the user must take precautions whilst handling them based on the information given in this document. In compliance with the regulations in force, the handling of explosive matter or objects must be performed by qualified staff with specialized knowledge.
Any change brought to the object or its packaging may lead to a change in its original characteristics and/or in its classification detailed in paragraph 14. Consequently, it is necessary to draw user' attention to potential risks when the object is used for purposes other than those it was designated or intended for.
This document shall be also written in the user language and spaceport language, to avoid any misunderstandings.
The user is in charge of :
-Formulating safety measures regarding all handling of the object, considering the data presented in this document,
-Communicating to all users and operators the safety information and the warnings regarding the aforementioned risks, in all the documents pertaining to the use of the object.
This warning does not exempt the recipient from making sure that any other regulatory obligations apply to him or, particularly those that may govern his own activity regarding the ownership and handling of the object for which he is solely responsible.
Technical services of the XXXXX company are available for the user to provide assistance in the matter within the limits of their knowledge.

Bibliography

[1] AIAA S-113A, *Criteria for Explosive Systems and Devices on Space and Launch Vehicle*

[2] ECSS-E-ST-33-11C, *Explosive subsystems and devices*

[3] MIL-STD 1576, *Electro-explosive Subsystem Safety Requirements and Test Methods for Space Systems, USAF*, 1992

[4] ST/SG/AC.10/1, *UN Recommendations on the transport of dangerous goods (Model Regulations)*

[5] UNO Manual of Tests and Criteria. United Nations, Fifth Edition, 2010

ICS 49.140
Price based on 77 pages