
# Space engineering

## Explosive systems and devices

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This Standard is one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. ECSS is a cooperative effort of the European Space Agency, national space agencies and European industry associations for the purpose of developing and maintaining common standards. Requirements in this Standard are defined in terms of what shall be accomplished, rather than in terms of how to organize and perform the necessary work. This allows existing organizational structures and methods to be applied where they are effective, and for the structures and methods to evolve as necessary without rewriting the standards.

This Standard has been prepared by the ECSS-E-33-11A Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.



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# Change log

This is the first issue of ECSS-E-33-11A.

ECSS-E-33-11A cancels and replaces ECSS-E-30 Part 6A.

The main changes between ECSS-E-33-11A and ECSS-E-30 Part 6A are:

- the use of the more accurate term "explosive" rather than "pyrotechnics" in relation to the subject components and systems;
- the emphasis on reliability coupled with confidence level for performance properties;
- the inclusion of detailed requirements for the different types of explosive device;
- and the emphasis on the requirement for properties of components to be agreed with the end user before commitment to purchase.

# Table of contents

**Figures**

## Tables

# Introduction

As any 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 the testing of identical items. Test results and theoretical justification are essential for demonstration of 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 the explosive system be tested and characterized extensively. The variability in components requires that manufacturers prove to customers that delivered items are identical to those qualified.

The 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 where ever used are to be treated similarly, the same requirements, regulations, practices and standards need to be applied which will help to avoid human error.

In case 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 and be incorporated into the reliability and confidence analysis.

# 1
# Scope

This Standard defines the requirements for the use of explosives on all spacecraft and other space products including launch vehicles. It addresses the aspects of design, analysis, verification, manufacturing, operations and safety.

# 2
# Normative references

The following dated normative documents are called by the requirements of this ECSS Standard and therefore constitute requirements to it. Subsequent amendments to, or revisions of any of these publications do not apply.

NOTE However, parties to agreements based on this ECSS Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated be-low.

| | |
|---|---|
| ECSS-P-001B | ECSS - Glossary of terms |
| ECSS–E-10C [1] | Space engineering - System engineering general requirements |
| ECSS-E-10 Part 6A rev.1 | Space engineering - System engineering - Part 6: Functional and technical specification |
| ECSS-E-10-02A | Space engineering - Verification |
| ECSS-E-10-03A | Space engineering - Testing |
| ECSS-E-10-24A [1] | Space engineering - Interface control |
| ECSS-E-20A | Space engineering - Electrical and electronic |
| ECSS-E-20-07A [1] | Space engineering - Electromagnetic compatibility |
| ECSS-E-32-10A [1] | Space engineering - Structural factors of safety for spaceflight hardware |
| ECSS-E-30 Part 3A | Space engineering - Materials - Part 3: Mechanisms |
| ECSS-M-00B | Space project management – Policy and principles |
| ECSS-M-00-03B | Space project management – Risk management |
| ECSS-M-40B | Space project management – Configuration management |
| ECSS-Q-20B | Space product assurance - Quality assurance |
| ECSS-Q-30B | Space product assurance - Dependability |
| ECSS-Q-30-02A | Space product assurance - FMECA |
| ECSS-Q-40B | Space product assurance - Safety |
| ECSS-Q-70B | Space product assurance - Material, mechanical parts and processes |
| ECSS-Q-70-01A | Space product assurance - Cleanliness and contamination control |
| ISO 16269-6:2005 | Statistical interpretation of data - Part 6: Determination of a statistical tolerance interval. First edition 2005-04-01 |
| ST/SG/AC.10/1 Rev. 14 (UNECE publication) | Recommendation on the Transport of Dangerous Goods |

[1] To be published.

# 3
# Terms, definitions and abbreviated terms

## 3.1 Terms defined in other standards

For the purpose of this Standard, the terms and definitions from ECSS-P-001B apply, in particular for the following terms:

**life time**

## 3.2 Terms specific to the present standard

### 3.2.1 all fire

stimulus with a probability of functioning equal to or better than 0,999 at 95 % confidence level

### 3.2.2 armed

condition that allows the probability of a wanted event to be above an agreed limit

### 3.2.3 cartridge

explosive device designed to produce pressure for performing a mechanical function

NOTE A cartridge is called an initiator if it is the first or only explosive element in an explosive train.

### 3.2.4 catastrophic failure

failure resulting in loss of life or life-threatening or permanently disabling injury or occupational illness or loss of an element of an interfacing manned flight system or loss of mission or loss of launch site facilities or long term detrimental environmental effects

### 3.2.5 charge

explosive loaded in a cartridge, detonator, or separate container for use in an explosive device

### 3.2.6 component

smallest functional item in an explosive subsystem

### 3.2.7 deflagration

reaction of combustion through a substance at subsonic velocity in the reacting substance

### 3.2.8 detonation

chemical decomposition propagating through the explosive at a supersonic velocity such that a shock wave is generated

### 3.2.9 detonator

initiator for high explosives

### 3.2.10 electro explosive device

explosive cartridge that is electrically actuated

### 3.2.11 end-user

person who or organization that actually uses a product

NOTE The end-user need not be the owner or buyer

### 3.2.12 explosive actuator

mechanism that converts the products of explosion into useful mechanical work

### 3.2.13 explosive train

series of explosive components including the initiator, explosive transfer assembly and explosive actuator

### 3.2.14 explosive component

any discrete item containing an explosive substance

### 3.2.15 explosive function

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

### 3.2.16 explosive system

collection of all the explosive trains on the spacecraft or launcher 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

### 3.2.17 extreme envelope

positive margin over the conditions of the qualification envelope

NOTE The device or system design is based on the conditions that define the extreme envelope.

### 3.2.18 end of life

point in time when no characteristic has any further significant effect

### 3.2.19 fail operational

the mission is possible after a failure

### 3.2.20 gas generators

explosive devices that produce a volume of gas or exothermic output or both

NOTE E.g. pyrotechnic igniters for solid propulsion applications, gas generator for inflatable structures.

### 3.2.21 initiator

first explosive element in an explosive train that, upon receipt of the proper mechanical, optical or electrical impulse, produces a deflagrating or detonating action

NOTE 1 The deflagrating or detonating action is transmitted to the following elements in the train.

NOTE 2 Initiators can be electrically actuated (EEDs), optically actuated, or mechanically actuated.

### 3.2.22 limit testing

testing to establish the limit of a performance characteristic of a component

### 3.2.23 lot

group of components produced in homogeneous groups and under uniform conditions

NOTE A batch is the same as a lot.

### 3.2.24 lot acceptance

demonstration by measurement or test that a lot of items meets requirements

### 3.2.25 no fire

stimulus with a probability of functioning equal to or less than 0,001 at 95 % confidence level

### 3.2.26 operational envelope

set of conditions in which the device or system shall meet its requirements

### 3.2.27 packaged charge

explosive material in a closed container

### 3.2.28 qualification envelope

positive margin over the conditions of the operational envelope

### 3.2.29 safe

condition that renders the probability of an unwanted event below an agreed limit

### 3.2.30 secondary characteristic

any characteristic other than the function

### 3.2.31 sequential firing

application of the firing pulses to initiators separated in time

### 3.2.32 success

simultaneous achievement by all characteristics of required performance

### 3.2.33 sympathetic firing

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

### 3.2.34 transfer line

linear explosive assembly for propagation of deflagration or detonation

### 3.2.35 through-bulkhead initiator (TBI)

initiator for transfer of detonating input to detonating or deflagrating output

## 3.3 Abbreviated terms

The following abbreviations are defined and used within this standard:

| Abbreviation | Meaning |
|---|---|
| **DC** | direct current |
| **DMPL** | declared materials and processes list |
| **DSC** | differential scanning calorimetry |
| **DTA** | differential thermal analysis |
| **DRD** | document requirements definition |
| **EED** | electro explosive device |
| **EMC** | electromagnetic compatibility |
| **EMI** | electro magnetic interference |
| **ESD** | electro static discharge |
| **FOSU** | ultimate design factor of safety |
| **FOSY** | yield design factor of safety |
| **GSE** | Ground support equipment |
| **TGA** | thermo gravimetry analysis |
| **MEOP** | maximum expected operating pressure |
| **NA** | not applicable |
| **NC** | normally closed |
| **NO** | normally open |
| **RF** | radio frequency |
| **SRS** | shock response spectrum |
| **TBI** | through-bulkhead initiator |
| **TBPM** | to be provided by manufacturer |
| **TBPU** | to be provided by user |
| **VTS** | vacuum thermal stability |

## 3.4 Symbols

| | |
|---|---|
| **g** | standard surface gravity (9,80665 $m/s^2$) |
| **h** | drop height (m) |
| **M** | mass of drop weight (kg) |
| **σ** | standard deviation |
| **A** | Ampere |
| **V** | Volt |

# 4
# Requirements

## 4.1 General

### 4.1.1 Overview

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

Explosive systems and devices use energetic materials (explosives, propellants, powder) initiated by mechanical, electrical, thermal, or optical stimuli, for unique (single shot) functions e.g. solid booster initiation, structure cutting, stage distancing, pressurized venting, stage neutralisation, valve opening or closing, release of solar arrays, antennas, booms, covers and instruments.

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 actuator.

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 is needed in their development, qualification, procurement and use. Explosive components are not governed by the institutional component control organisations.

### 4.1.2 Application

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

### 4.1.3 Properties

a. The two states of the properties of the explosive system before firing and after firing shall be identified and listed.

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 of clause a. shall remain stable over time before firing and after firing when subject to external loads or environmental conditions, within the qualification values.

## 4.2 Design

### 4.2.1 General

a. In case of redundancy, no component shall adversely affect its substitute.

b. The system lay-out 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 shall be listed in the User's Manual of the explosive system and devices.

### 4.2.2 Reliability and confidence

a. The explosive system shall achieve the specified properties within defined levels of reliability and confidence agreed with the customer.

NOTE 1 All components are contributors.

NOTE 2 This standard specifies the properties of particular concern.

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

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

d. The performance characteristics of components at any level of assembly shall be specified at the specified level of reliability and confidence (see 4.2.2b) in accordance with ISO 16269-6:2005.

e. The safety characteristics of items at any level of assembly shall be specified at the specified level of reliability and confidence (see 4.2.2c).

f. It shall be agreed with the customer which performance characteristics shall be declared as mean values with associated standard deviation (see 4.2.2g).

g. Manufacturer shall provide justification of the validity of the statistical methods for customer approval.

### 4.2.3 Performance

a. Except as specified in 4.2.3b, all performance shall be quantified by measurement versus time of initial, transitional, and final values of the specified properties.

NOTE Specified properties are listed in clause 4.11 and 4.12.

b. The time interval specified in a shall be measured between either:

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

— the initiation event and 90 % of the measured performance value.

c. For performance that cannot be quantified based on measurements, an acceptance procedure shall be agreed with the customer.

d. The basis of the time shall be specified and justified.

### 4.2.4 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 customer and 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 customer and supplier.

NOTE This applies to safety and failure.

### 4.2.5 Dimensioning

#### 4.2.5.1. 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 end-user.

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

#### 4.2.5.2. Integrity

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

b. 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 a factor FOSU.

c. The factor FOSU shall be according to Table 3 or Table 4 in ECSS-E-32-10A depending on the material used.

d. Deformation of any component shall not

1. reduce its specified performance,
2. affect any part of the spacecraft system,
3. cause leakage.

e. The factor FOSY shall be according to Table 3 or Table 4 in ECSS-E-32-10A depending on the material used.

#### 4.2.5.3. Explosive charge sizing

a. For phases A and B of the component, the methodology for dimensioning explosive devices shall be justified.

b. A “margin policy” factor $K_{MP}$ shall be:

1. defined,
2. justified,
3. applied.

NOTE 1 This factor, used to give confidence to the design, covers (not exhaustive list):

- The lack of knowledge on the failure modes and associated criteria.
- The lack of knowledge on the effect of interaction of loadings.
- The non-tested zones.

NOTE 2 Justification can be performed based on relevant historical practice, analytical or experimental means.

c. $K_{MP}$ can have different values according to the explosive behaviour.

d. When modelling is performed , a "model factor" $K_M$ shall be:

1. defined,
2. justified,
3. applied during simulations and analysis.

NOTE 1 A model factor $K_M$ is applied in cases where uncertainty exists in the model in terms of predicted response and loads. It encompasses the lack of confidence in the information provided by the model, (e.g. ageing, temperature or batch influences, non accuracy of the mathematical model), non correlated behaviour.

NOTE 2 While going through the design refinement loops, $K_M$ can be progressively reduced down to 1,0 after the demonstration of satisfactory correlation between model and test measurements

e. A specific "project factor" $K_P$ shall be:

1. defined according to programme maturity and the uncertainty in the programme level requirement,
2. justified,
3. applied.

NOTE 1 $K_P$ is generally defined by the project and can be reduced during the development.

NOTE 2 $K_P$ can also cover a growth potential for some further development.

f. An "Explosive factor" $K_E$ shall be applied for uncertainties on the behaviour of explosive materials in the mission profile.

NOTE 1 E.g. ageing and temperature influence, batch influence, material compatibility.

NOTE 2 Typical values are given in Table 4-1:

**Table 4-1 Values for explosive factor**

| Explosive materials | $K_E$ |
|---|---|
| Pyrotechnic compositions | ≥1,1 |
| Propellants (e.g. NC; NC/NG, composite) | ≥1,2 |
| HE (pure) | ≥1,1 |
| HE ( composite) | ≥1,2 |

NOTE 3 Ageing programme and manufacturing qualification process (e.g.: batch influence, wear of manufacturing tool) can be used to reduce the $K_E$ factor.

NOTE 4 Dimensioning are done at the worst temperature of the qualification envelope.

g. For Phases C and D of the component, the reliability demonstration shall be used to justify design margins including the influence of ageing, temperature and explosive batch.

NOTE 1 See Figure 4-1.

NOTE 2 R is the estimated reliability, $R^+$ and $R^-$ are the limits according to the confidence level required.

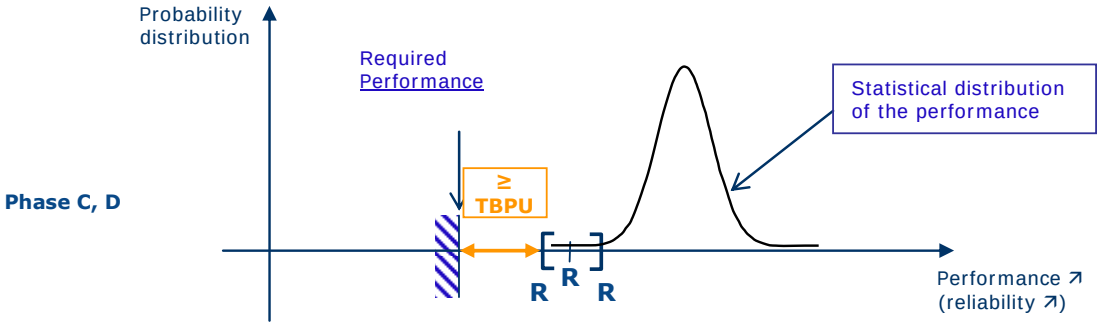


**Figure 4-1 Margin and reliability relationship**

#### 4.2.5.4. Motorization

ECSS-E-30 Part 3A Clause 4.7.4.3 shall apply to explosively actuated devices.

## 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 the functions being activated shall be specified.

NOTE E.g. ground storage, transport, launcher ignition, staging and safety functions, payload 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 timing of each function of the explosive system shall be specified.

b. The explosive system shall react only to a specified stimulus and be insensitive to all others.

NOTE Specified stimulus: e.g. nature, range of values.

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 reaching the initiator at any other time.

e. Unwanted function or malfunction shall be prevented.

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

NOTE This applies to secondary characteristics as well as for 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.

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 end-user.

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

## 4.5.2 Prevention of unintentional function

### 4.5.2.1. General

a. The firing pulse shall be prevented from reaching any explosive initiator at any time except the correct instant by means of switchable barriers.

NOTE 1 E.g. firing pulse: detonating shock, electrical pulse, light pulse.

NOTE 2 E.g. switchable barriers: electrical, mechanical, plugs, pins.

b. Provision shall be made to prevent firing in response to radio frequency, lightning, magnetic field and electrostatic discharge.

NOTE See ECSS-E-20-07A clauses 4.2.3 and 5.3.4.

c. If the explosive system contains two or more barriers then at least two of these barriers shall:

1. be independent,
2. not be subject to common cause failure,
3. each provide complete disconnection of the firing circuit.

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

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

f. 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 may 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. It 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. The functionality shall be provided to restore its initial (disarm) 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 several 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 the specified sequence of conditions without malfunctioning or degrading 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 conform to the specified reliability and confidence.

d. The end-user 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 end-user to avoid disturbance or damage to other sensitive elements on the space vehicle.

NOTE 1 Examples of disturbance: shock, electrical short circuits, and magnetic fields.

NOTE 2 For tests see 4.14.

## 4.7 Interface requirements

### 4.7.1 General

The nature of the interfaces are:

- geometry, including the analysis of the dimensions for all phases of life.

  NOTE E.g. assembly, transport, and flight.
- mechanical, including induced loads, static and dynamic;
- fluids, including venting;
- thermal loads;
- electrical, including ensuring electrical continuity and EMC;
- materials, including ensuring compatibility.

### 4.7.2 Functional

a. Each interface shall
   1. ensure no assembly errors can be made,
   2. prevent damage during assembly or dismantling.

b. Whilst separated, protection shall be provided to each interface.

   NOTE 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 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 at each interface with margins over the input requirements of the next element or the explosive system output requirements.

   NOTE E.g. electrical, mechanical, thermal, optical outputs.

### 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. In case 4.7.4a. is not met, it shall either:
   — be agreed with the end-user to change the on-board system requirements, or
   — be agreed with the end-user to provide protection against the environmental conditions or to reduce the external loads on the explosive system.

## 4.8 Mechanical, electrical, and thermal requirements

### 4.8.1 Mechanical

#### 4.8.1.1. Inertial properties

The supplier shall provide, before and after firing, the customer with the following information of the component:

a. the mass,

b. the centre of mass,

c. the inertial properties, and

d. the numerical model upon request of the end-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. The capability shall be provided 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

a. It shall be ensured that components intended for different applications cannot be confused.

b. Inert components, dummies and test models used for test purposes shall be visibly different from live items with the colour code in Annex A.

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,
3. to all elements for inspection.

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

### 4.8.2 Electrical

#### 4.8.2.1. General

a. The explosive system firing sources shall have their own power distribution points.

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 initiator input requirements.

d. It shall be demonstrated by test that 4.8.2.1c is met.

e. If the firing source circuit takes power from the host vehicle either:

— The return side shall not be grounded on the payload side of the interface, and be isolated from payload structure by at least 10 kΩ measured at least 1,5 times the bus voltage, or

— Isolation converters shall be used to provide at least 10 kΩ isolation between payload return circuit and host vehicle return circuit when measured at least 1,5 times the bus voltage.

#### 4.8.2.2. Circuit independence

a. EEDs shall not be connected in series or in parallel with each other.

b. A separate command shall activate each component for launch vehicles.

c. In case 4.8.2.2a is not met, the alternative circuit shall be justified and agreed with the customer and suppliers.

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

NOTE See subclauses 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 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 noted above when exposed to externally generated electromagnetic fields.

c. Control circuits shall limit the power level at any barrier to at least 20 dB below the minimum activation power.

#### 4.8.2.5. Electrostatic discharge

a. Explosive systems and components shall
   1. survive,
   2. not be degraded by specified electrostatic discharges,
   3. be tested to verify survivability.

b. Protective features shall be provided to
   1. prevent initiation,
   2. prevent change of state of 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. shall not violate single-point grounding requirements.

f. All ESD-sensitive components shall be 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 incorporated in the provision of the required firing pulse.

#### 4.8.2.7. Electrical Bonding

a. The resistance to electrical ground shall not exceed the specified value.

   NOTE See ECSS-E-20-07A clause 4.2.11.2.

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

c. The shielding of the firing circuits shall be bonded at least at both ends.

#### 4.8.2.8. Isolation

a. Every electrical firing circuit and monitoring circuit shall be electrically independent.

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

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

NOTE This is to prevent continued drain on the power system after firing when e.g. short circuit to ground can occur.

d. Provisions for redundancy shall not prevent fulfilment of the requirement 4.8.2.8a.

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

1. be independent of the firing circuits,
2. use separate non-interchangeable connectors.

#### 4.8.2.9. Insulation resistance

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

#### 4.8.2.10. Dielectric strength

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 RF energy

a. When exposed to RF conditions, the induced power shall not exceed a level which is:

1. 20 dB below the no-fire power,
2. 20 dB below the RF sensitivity threshold.

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

b. When exposed to RF conditions, 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 components.

c. The explosive system shall not generate magnetic fields exceeding the electromagnetic interference safety margins defined in ECSS-E-20A subclause 6.1.3.1b.

#### 4.8.2.13. Lightning

a. Explosive systems shall preclude activation due to electrical potential differences generated within the explosive system by exposure to lightning.

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

NOTE For description of lightning see ECSS-E-20-07A.

### 4.8.3 Thermal

#### 4.8.3.1. Sensitivity

a. Explosive systems and components shall

1. survive to defined thermal loads in terms of intensity, duration and cycling,
2. not be degraded by defined thermal loads in terms of intensity, duration and cycling,
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,
   3. be tested to verify effectiveness.

c. Build-up of heat shall be prevented.

d. All thermally-sensitive components shall be shielded or otherwise protected from the environment.

e. Explosive systems and components shall not ignite at temperatures at least 30 °C higher than the maximum expected environmental temperature.

NOTE This is to ensure no auto-ignition or cook-off.

#### 4.8.3.2. Heat generation

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

### 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;
   2. the indication of at least the status of the pre-arm and select barriers during the mission.

b. The functionality shall be provided to verify the status of the barriers protecting the initiator before inserting the arming plug.

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 $10^{-2}$ × the "no-fire" current on the bridge wire.

e. Any checking-out of the status of optical initiators shall limit check-out energy to:$10^{-4}$ × the "no-fire" power density at the fire wavelength on the optical interface if the fire wavelength is used.

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

g. Any checking-out of the insulation resistance of the explosive system shall limit the voltage to 50 VDC.

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.

NOTE E.g. thermal control requirements or material temperature limits.

#### 4.8.4.2. initiator status

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

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

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

NOTE Range safety sometimes prohibits use of these features.

## 4.9 Materials

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

NOTE 1 Outgassing can occur during e.g. polymerization, degradation of polymers.

NOTE 2 Selection of materials and processes are done in accordance with ECSS-E-32-08A, ECSS-Q-70B, and ECSS-Q-70-71A.

NOTE 3 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.

b. Continued exposure to the expected environmental conditions shall not cause degradation or increased sensitivity in excess of agreed limits.

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

d. No cracking shall be allowed due to shock loads.

NOTE Materials can become brittle at low temperatures.

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

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

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

h. Explosives that can react in response to normal environmental stimuli shall only be used in agreement with the end-user.

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

j. Degradation of the explosives shall not exceed agreed limits.

k. Degradation of explosive characteristics shall be determined by test.

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

## 4.10 Non-explosive components and equipment

### 4.10.1 Connectors

a. There shall be only one connection per pin.

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

c. Mis-mating of connectors shall be impossible.

NOTE E.g. by geometry, lay-out, 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. Source circuits shall be terminated by female contacts.

f. Spare or un-terminated contacts shall not exist.

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 shall be used.

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

### 4.10.2 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.

b. All connections between conductors shall be made by soldering, crimping or connectors.

NOTE For soldering see ECSS-Q-70-08A, for crimping ECSS-Q-70-26A, for connectors see 4.10.1.

### 4.10.3 Shielding

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

b. 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 elements shielding, there should be shielding at 100 % optical coverage.

NOTE For example, no gaps or discontinuities, full shielding at the back faces of the connectors, no apertures in any container housing elements of the firing circuit.

f. Shields shall not be used for current carrying.

NOTE Shields can be multiple-point grounded to the structure.

### 4.10.4 Faraday cap

a. Faraday caps shall be used.

b. The Faraday cap shall prevent EEDs to be initiated by electromagnetic fields.

### 4.10.5 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.

### 4.10.6 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 timing for each of the functions.

b. The firing pulse requirements in Table 4-3 row 5 and Table 4-5 row 1 shall apply for EEDs and laser initiators respectively.

c. The power provided at the power distribution points shall be such that the requirements of 4.8.2.6 allowing for losses are met.

### 4.10.7 Safe and arm connector

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,
   3. testing of any explosive system.

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

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

d. The safe and arm connector shall be visibly identifiable.

e. The safe and arm connector shall be qualified for the number of specified connection cycles.

   NOTE E.g. to cover integration, test and use.

f. The receptacle shall meet the requirements of subclause 4.10.1.

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

g. A connector-saver shall be used.

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

### 4.10.8 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,
   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, with n defined by the end-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, test and use,
   4. scoop proof,
   5. lockable,

      NOTE E.g. sub-D connector, bayonet or triple-start thread type.

   6. visibly identified,
   7. carrying a “Remove before Flight” banner.

### 4.10.9 Arming plug

The arming plug shall:

a. provide electrical continuity between the supply and firing circuits with electrical properties in any line agreed with the customer,

   NOTE Electrical properties include resistance, isolation, bonding, and faraday protection.

b. be compatible with the safe and arm connector,

c. be scoop-proof,

d. be lockable,

NOTE E.g. sub-D connector, bayonet or triple-start thread type.

e. be visibly identified.

## 4.10.10 Test plug

The test plug shall:

a. provide electrical access to the firing circuits with electrical properties in any line agreed with the end-user.

NOTE Electrical properties include resistance, isolation, bonding, and faraday protection.

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,

g. be lockable.

NOTE E.g. sub-D connector, bayonet or triple-start thread type.

## 4.10.11 Safe and arm device

### 4.10.11.1. 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 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 remaining in any state between ‘safe’ and ‘arm’,
10. arm within a time interval agreed with the end-user,
11. not require a force or torque to safe, exceeding a value agreed with the customer.
12. if actuated remotely, safe within a time interval agreed with the end-user.

c. It shall not be possible to arm the safe and arm device in case 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 (“Armed” condition) when commanded.

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.

### 4.10.11.2. Electrically Actuated

The electrically actuated safe and arm device shall

a. not have current flow exceeding 2 mA in the disarm or safe command circuit during the arming cycle nor in the arm command circuit during disarm or safing;

b. have a demonstrated cyclic life of 1000 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.

### 4.10.11.3. Mechanically Actuated

The mechanically actuated safe and arm device shall have a demonstrated cyclic life of 300 safe-to-arm-to-safe transitions without failure or degraded performance.

### 4.10.11.4. Safing

a. Safing shall prevent detonation or initiation transfer by
   1. the placement of a barrier between the initiator and next explosive element, or
   2. misalignment of the initiator and the next explosive element.

b. Safing shall disconnect power and return firing lines.

c. Safing shall short the EEDs.

d. Safing should ground the shorted EEDs through a resistance agreed with the end-user.

e. Safing shall have resistor(s) with a resistance exceeding 10 kΩ if these resistor(s) remain connected to the firing circuit in the arm position.

NOTE Clause 4.1.3.4.1.3a applies.

### 4.10.11.5. 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. Arming shall
   1. connect firing power lines and return lines to EEDs,
   2. remove the short from the EEDs,
   3. disconnect the EEDs from the ground.

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

NOTE Clause 4.1.3.4.1.3a applies.

### 4.10.11.6. Status indicators

a. The device shall:
   1. provide remote status indications,
   2. provide local status indications,
   3. indicate “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.

#### 4.10.11.7. Initiator-Simulator resistors

Application of operational voltages for at least 20 seconds shall not degrade the Safe and Arm performance or cause initiation of explosives.

### 4.10.12 Initiator harness connector

The initiator harness connector shall:

a. conform to the interface requirements of the integral connector of the initiator;

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

### 4.10.13 Initiator test substitute

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

## 4.11 Explosive components

### 4.11.1 General

#### 4.11.1.1. Applicability

This subclause 4.11 applies to explosive components, which 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 end-user 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 4.5.

#### 4.11.1.2. Identification

a. ECSS-Q-20B clause 5.4.2 shall apply.

b. For launchers colour coding shall be used on components to indicate behaviour.

c. Each component containing explosives shall be visibly and permanently marked with:

   1. a unique identification,

   2. coding to indicate behaviour.

d. Identification should include Manufacturer, Part number, Lot number, Serial number, Manufacturing date.

e. Colour coding should be according to Annex A.

#### 4.11.1.3. Contamination

a. Contamination shall be prevented.

NOTE 1 The contamination to be analyzed are:

- from environment to the components;
- from components to the environment;

- related to the innocuousness of component during and after functioning.

NOTE 2 E.g. by the use of approved materials according to ECSS-Q-70-71A and by design to contain products of the operation of explosive components.

b. In case subclause 4.11.1.3.a 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.

#### 4.11.1.4. After functioning

After functioning, no explosive component shall cause

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

b. contamination beyond limits agreed with the end-user.

### 4.11.2 Initiators, cartridges, detonators, and packaged charges

#### 4.11.2.1. General

a. The properties of initiators given in Table 4-2 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-2 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-2 Common requirements for initiator, cartridge, detonator, and packaged charge properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | AC leakage current | mA | TBPM | TBPM | | |
| 2 | Bonding resistance | mΩ | 10 | NA | To next level assembly | |
| 3 | Thermal response | V/t | TBPM | TBPM | | |
| 4 | Leak rate | scc He/s | $10^{-6}$ | NA | @ Δp= 0,1 MPa before and after firing | |
| 5 | Structural integrity | MPa | | TBPM | | According to ECCS-E-32-10A applies on MEOP |
| 6 | Temperatures: | | | | | |
| (a) | Auto-ignition | °C | NA | TBPM | | |
| (b) | Non-operating | °C | TBPM | TBPM | | |
| (c) | Operating | °C | TBPM | TBPM | Duration TBPM | |
| (d) | Storage | °C | TBPM | TBPM | Duration TBPM | |
| (e) | Transport | °C | TBPM | TBPM | Duration TBPM | |
| 7 | Generated: | | | | | |
| (a) | Pressure | MPa | TBPM | TBPM | TBPM | Only the known and relevant output parameter shall be provided |
| (b) | Heat | J | TBPM | TBPM | TBPM | Only the known and relevant output parameter shall be provided |
| (c) | Light | lm | TBPM | TBPM | TBPM | Only the known and relevant output parameter shall be provided |
| (d) | Shock pressure | GPa | TBPM | TBPM | TBPM | Only the known and relevant output parameter shall be provided |
| 8 | Probability of ignition of a reference charge | | | 99,8 % | 95 % confidence | |
| 9 | Nr of mating./ de-mating cycles | | TBPM | TBPU | With / without change of seals | |
| 10 | Life time | Year | TBPM | NA | For transport, storage and operation | |

#### 4.11.2.2. 1W / 1A No-Fire initiators

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

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

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

d. The properties of the 1W / 1A No-Fire initiator given in Table 4-3 shall be quantified and conform to the figures where shown.

e. Under the conditions in column E of Table 4-3 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-3 Requirements for low voltage initiator properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | DC insulation resistance | M Ω | NA | 2 | @ ≥250 V, ≥60 s | |
| 2 | Breakdown voltage | kV | 11 | NA | | |
| 3 | ESD survival | kV | NA | 25 | @ 500 pF and 5000 ohms for pin to pin test<br>@ 500 pF and 0 ohm for pin to case test | |
| 4 | Dielectric strength | μA | 500 | NA | @ 200 V (AC) ≥60 s | |
| 5 | All fire current | 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 | NA | for 'all fire' current or power | |
| 8 | 'No fire' current | A | NA | 1 | ≤0,1 % of the units function with a confidence level of 95 % @ 5 minutes, at specified conditions. | |
| 9 | 'No fire' power | W | NA | 1 | ≤0,1 % of the units function with a confidence level of 95 % @ 5 minutes, at specified conditions. | |
| 10 | Bridge wire resistance | Ω | TBPM | TBPM | @10 mA, ≤60 s Number of applications TBPM | |

#### 4.11.2.3. High voltage initiators

a. The properties of the high voltage initiator given in Table 4-4 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-4 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-4 Requirements for high voltage initiator properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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 minutes, test temperature TBPM | |
| 3 | Operating voltage | V | | > 500 | | |

#### 4.11.2.4. Laser initiators

a. The properties of the laser initiator given in Table 4-5 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-5 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-5 Requirements for laser initiator properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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 minutes, at specified conditions. ( wavelength TBPM) | Factor of safety for spurious lights (TBPU) |
| 3 | Pulse width | ms | NA | TBPM | | |
| 4 | Wave length | nm | TBPM | TBPM | | Depending on optical source: solid laser, laser diode |

#### 4.11.2.5. Mechanical initiators

a. The properties of the mechanical initiator given in Table 4-6 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-6 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-6 Requirements for mechanical initiator properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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 | NA | TBPM | | |

#### 4.11.2.6. Packaged charges

a. The properties of the packaged charge shall conform to the requirements of Table 4-7, with the exception of the structural integrity requirements, and Table 4-6, and be quantified.

b. Under the conditions in column E of Table 4-7 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-7 Requirements for packaged charge properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Structural integrity | | NA | NA | handling and transport loads | |
| 2 | Detonation? Yes / No | | TBPM | NA | Intended operational mode | |
| 3 | Deflagration? Yes / No | | TBPM | NA | Intended operational mode | |

### 4.11.3 Integral initiator connectors

#### 4.11.3.1. 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.

#### 4.11.3.2. 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-demating cycles without degradation.

d. The connection shall be able to undergo specified shocks without degradation.

#### 4.11.3.3. Laser initiator connector

a. The initiator shall incorporate an interface to match the interfaces on the fibre optic connector and the adapter which is 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.

### 4.11.4 Transfer devices

#### 4.11.4.1. General

a. The properties of transfer devices shall conform to the general requirements of Table 4-8 and be quantified.

b. Under the conditions in column E of Table 4-8 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-8 General requirements for transfer device properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Critical diameter | mm | NA | TBPM | | information about explosive to be provided |
| 2 | Temperatures: | | | | | |
| (a) | Auto-ignition | °C | NA | TBPM | | |
| (b) | Non-operating | °C | TBPM | TBPM | | |
| (c) | Operating | °C | TBPM | TBPM | Duration TBPM | |
| (d) | Storage | °C | TBPM | TBPM | Duration TBPM | |
| (e) | Transport | °C | TBPM | TBPM | Duration TBPM | |
| 3 | Probability of Ignition of a reference charge | | | 99,8 % | 95 % confidence | |
| 4 | Nr of mating/de-mating cycles | -- | TPBM | TBPU | With/without change of seals | |
| 5 | Life time | Year | NA | TBPU | For transport, storage and operation | |

#### 4.11.4.2. Transfer line assembly

a. The properties of transfer line assembly given in Table 4-9 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-9 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-9 Requirements for transfer line assembly properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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 | NA | From end to end | |
| 6 | Leak rate (together with interfaces) | scc He/s | $10^{-6}$ | NA | @ Δp= 0,1 MPa before firing | |
| 7 | Leak tightness (together with interfaces) | scc He/s | $10^{-3}$ | NA | @ Δp= 0,1 MPa after firing (ends implemented in the specified interface) + No debris | |
| 8 | Organic contamination of surfaces | mg/m² | 2 | NA | See ECSS Q-70-01A. | |
| 9 | Radius of curvature | m | NA | TBPM | Bending | |
| 10 | Nr. Of times one can bend | -- | TBPM | TBPU | Bending | |
| 11 | Twist angle | rad/m | TBPM | NA | | |
| 12 | Tension | daN | TBPM | NA | | |
| 13 | Overall mass | g/m | TBPM | NA | Linear mass of flexible part (g/m) + ends (g) | |
| 14 | Explosive mass | g/m | TBPM | NA | Linear mass of flexible part (g/m) + ends (g) | |

#### 4.11.4.3. Through-bulkhead transfer devices

a. The properties of through-bulkhead transfer devices given in Table 4-10 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-10 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-10 Requirements for through-bulkhead transfer device properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Output | | | | | |
| (a) | Pressure | MPa | TBPM | TBPM | In TBPM cm3 at 20°C | |
| (b) | Energy | J | TBPM | TBPM | TBPM | |
| (c) | Leak rate | scc He/s | 10-6 | NA | @ Δp= 0,1 MPa before firing | |
| 2 | Barrier tightness leak rate | scc He/s | 10-5 | NA | @ Δp= 0,1 MPa before firing | |
| 3 | Barrier tightness leak rate | scc He/s | 10-3 | NA | @ Δp= 0,1 MPa after firing | |
| 4 | Structural integrity | MPa | TBPM | TBPM | | (barrier resistance after firing). |

#### 4.11.4.4. Shaped charges

a. The properties of shaped charges given in Table 4-11 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-11 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-11 Requirements for shaped charge properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Cutting capabilities | | | | | |
| (a) | Structure thickness | mm | TBPM | NA | associated with material properties | |
| (b) | Structure loads | MPa | TBPM | TBPM | | |
| (c) | Cutting delay | ms | TBPM | TBPM | | |
| 2 | Debris/contamination/induced | | | | | |
| 3 | Temperatures: | | | | | |
| (a) | Auto ignition | °C | | | | |
| (b) | Survival Non operating | °C | TBPM | TBPM | | |
| (c) | Operational operating | °C | TBPM | TBPM | | |
| (d) | Storage | °C | TBPM | TBPM | | |
| (e) | Transport | °C | TBPM | TBPM | | |
| 4 | Life time | Year | TBPM | NA | during transport, storage and mission | |

### 4.11.4.5. Expanding tube devices

a. The properties of expanding tube devices given in Table 4-12 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 the above.

b. Under the conditions in column E of Table 4-12 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-12 Requirements for expanding tube device properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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) | Cut Structure loads during cutting | kN | TBPU | TBPU | Associated with material properties (e.g. : ductility, elongation, strain rate, plasticity) | |
| (c) | 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 | NA | Number and size of windows for the expanding tube assembly | |
| 5 | Cutting conditions: | | | | | |
| (a) | Response time | ms | TBPM | TBPM | Between first input and completion of cutting | |
| (b) | Generated Shock | “g”/ms | TBPM | NA | Time history and TBPU sampling rate. Test configuration TBPU | |
| 5 | Device leak rate | scc He/s | $10^{-6}$ | NA | @ Δp= 0,1 MPa before firing | |
| 6 | Device leak rate | scc He/s | $10^{-3}$ | NA | @ Δp= 0,1 MPa after firing | |
| 7 | Particle generation | | TBPU | NA | Test method TBPU | |
| 8 | Temperatures : | | | | | |
| (a) | Auto ignition | °C | NA | TBPM | | |
| (b) | Non operating | °C | TBPM | TBPM | | |
| (c) | Operational | °C | TBPM | TBPM | | |
| (d) | Storage | °C | TBPM | TBPM | | |
| (e) | Transport | °C | TBPM | TBPM | | |
| 9 | Life time | Year | TBPM | NA | | |

#### 4.11.4.6. Distribution Boxes

a. The properties of distribution boxes given in Table 4-13 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-13 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-13 Requirements for distribution box properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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 | NA | Time history and TBPU sampling rate. Test configuration TBPU | |
| (b) | Device leak rate | scc He/s | $10^{-6}$ | NA | @ Δp= 0,1 MPa before firing | |
| (c) | Device leak rate | scc He/s | $10^{-3}$ | NA | @ Δp= 0,1 MPa after firing | |
| 5 | Temperatures : | | | | | |
| (a) | Auto ignition | °C | TBPM | TBPM | | |
| (b) | Non operating | °C | TBPM | TBPM | | |
| (c) | Operating | °C | TBPM | TBPM | | |
| (d) | Storage | °C | TBPM | TBPM | | |
| (e) | Transport | °C | TBPM | TBPM | | |
| 6 | Life time | Year | TBPM | NA | During transport, storage and mission | |

### 4.11.4.7. Explosive delays

a. The properties of explosive delays given in Table 4-14 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-14 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-14 Requirements for explosive delay properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Delay type | | TBPM | TBPM | | With or without gas generation |
| 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 | NA | @ Δp= 0,1 MPa after firing | |
| 8 | Temperatures : | | | | | |
| (a) | Auto ignition | °C | TBPM | TBPM | | |
| (b) | Non operating | °C | TBPM | TBPM | | |
| (c) | Operating | °C | TBPM | TBPM | | |
| (d) | Storage | °C | TBPM | TBPM | | |
| (e) | Transport | °C | TBPM | TBPM | | |
| 9 | Life time | Year | TBPM | NA | During transport, storage and mission | |

### 4.11.5 Safe and arm devices containing explosive

a. Clause 4.10.11 shall apply.

b. Only secondary explosive with less or equal sensitivity to Hexogen shall be used.

### 4.11.6 Gas generators

a. The properties of gas generators given in Table 4-15 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-15 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-15 Common requirements for gas generator**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Bonding resistance | mΩ | 10 | NA | To next level assembly | |
| 2 | Leak rate | scc He/s | $10^{-6}$ | NA | @ Δp= 0,1 MPa before and after firing at initiator interface | |
| 3 | Structural integrity | MPa | | TBPM | According to ECCS E 32-10 A applies on MEOP | |
| 4 | Temperatures: | | | | | |
| (a) | Auto-ignition | °C | NA | TBPM | | |
| (b) | Non-operating | °C | TBPM | TBPM | | |
| (c) | Operating | °C | TBPM | TBPM | Duration TBPM | |
| (d) | Storage | °C | TBPM | TBPM | Duration TBPM | |
| (e) | Transport | °C | TBPM | TBPM | Duration TBPM | |
| 5 | Generated: | | | | | |
| (a) | Pressure | MPa | TBPM | TBPM | | Only the known and relevant output parameter shall be provided |
| (b) | Heat | J | TBPM | TBPM | | Only the known and relevant output parameter shall be provided |
| (c) | Nr of mating./ de-mating cycles | | TBPM | TBPU | With / without change of seals | |
| (d) | Generated Shock | “g”/ms | TBPM | NA | Time history and TBPU sampling rate. Test configuration TBPU | |
| 6 | Life time | Year | TBPM | NA | For transport, storage and operation | |

## 4.12 Explosively actuated devices

### 4.12.1 General

a. For any explosively actuated device which incorporates initiation and explosive charges the requirements of Clause 4.11 shall apply.

b. No released part shall cause damage.

c. The requirements of Table 4-16 shall apply.

d. Under the conditions in column E of Table 4-16 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-16 General requirements for explosively actuated device properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Leak rate | scc He/s | TBPU | NA | At Δp= 0,1 MPa before firing | |
| 2 | Leak rate for spacecraft | Pa/l | 2,5.10-2 | | at $10^{-2}$ Pa during firing | |
| 3 | Leak rate | scc He/s | TBPU | NA | At Δp= 0,1 MPa after firing | |
| 4 | Temperatures: | | | | | |
| (a) | Non operating | °C | TBPM | TBPM | | |
| (b) | Operating | °C | TBPM | TBPM | duration TBPM | |
| (c) | Storage | °C | TBPM | TBPM | duration TBPM | |
| (d) | Transport | °C | TBPM | TBPM | duration TBPM | |
| 5 | Functional delay | ms | TBPM | TBPM | | |
| 6 | Nr of assemblies / disassemblies | -- | TBPM<br>TBPM | TBPU<br>TBPU | to the maximum load of the device attachments | |
| 7 | Generated Shock | "g"/ms | TBPM | NA | Time history and TBPU sampling rate. Test configuration TBPU | |
| 8 | Life time | Year | TBPM | NA | during, transport, storage and mission | |

### 4.12.2 Separation nuts and separation bolts

a. The properties of the separation nut and bolt given in Table 4-17 shall be quantified and conform to the figures where shown.

b. Re-settable separation nuts shall include a means of verifying that the nut is properly reset before and after its mating bolt or stud installation and torquing.

c. The pre-load shall be specified.

d. The pre-load shall exceed the maximum expected amplitude of the dynamic tension in the bolt and effects of thermal variations.

e. Under the conditions in column E of Table 4-17 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-17 Requirements for separation nut and separation bolt properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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 | | |

### 4.12.3 Pullers

a. The properties of the puller given in Table 4-18 shall be quantified and conform to the figures where shown.

b. The puller shall be capable to withdraw the pin under maximum shear and bending loads.

c. The retractable pin shall not rebound.

d. Under the conditions in column E of Table 4-18 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-18 Requirements for puller properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Pin Preloads: | | | NA | | |
| (a) | Axial | N | TBPM | NA | | |
| (b) | Shear | N | TBPM | NA | | |
| (c) | Bending moment | Nm | TBPM | NA | | |
| 2 | Traction force | N | TBPM | TBPM | Minimum at end of stroke | |
| 3 | Pulling stroke | mm | TBPM | TBPM | | |

### 4.12.4 Pusher

a. The properties of the pusher given in Table 4-19 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 and shear and bending moment.

c. Under the conditions in column E of Table 4-19 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-19 Requirements for pusher properties**

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

### 4.12.5 Cutters

a. The properties of the cutter given in Table 4-20 shall be quantified and conform to the figures where shown.

b. Under the conditions in column E of Table 4-20 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-20 Requirements for cutter properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 1 | Cutting capabilities | | | | At worst case temperatures | |
| (a) | dimensions | mm | TBPM | NA | associated with material properties | |
| (b) | ultimate strength | MPa | TBPM | TBPM | | |
| (c) | tension load | kN | NA | TBPM | | |
| 2 | Mass of generated particles | mg | TBPM | NA | | 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 |

### 4.12.6 Valves

a. The properties of the valve given in Table 4-21 shall be quantified and conform to the figures where shown.

b. After firing the valve piston shall remain in its actuated position.

c. The type of valve NO or NC shall be marked on the device.

d. The flow direction shall be marked on the device.

e. Under the conditions in column E of Table 4-21 the property in column A in the units in column B shall be between the values in column C (maximum) and column D (minimum).

**Table 4-21 Requirements for valve properties**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Property** | **Unit** | **Maximum value** | **Minimum value** | **Condition** | **Notes** |
| 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) | Valve passage diameter | mm | TBPM | | in fluid circuit, nominal | |
| (d) | Fluid circuit leak rate | scc He/s | 10-6 | TBPM | At $\Delta p$= 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 | NA | in fluid circuit | |
| 3 | Dimensions of generated particles | mm | TBPM | TBPM | in fluid circuit | |

## 4.13 Items external to the flight equipment

### 4.13.1 GSE

a. ECSS-E-10-02A, subclause 6.3 shall apply.

b. Ground support equipment shall provide support and protection within specified limits including ESD and EMI.

c. Test equipment shall be energy limited in accordance with 4.8.4.

NOTE E.g. electrical; optical.

d. The status indication of the explosive system shall be provided.

e. Changes in the status indications shall be provided.

f. Status and status changes shall be recorded.

### 4.13.2 Test equipment

a. ECSS-E-10-02A subclause 6.3 6 shall apply.

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

### 4.13.3 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 induces a catastrophic risk.

NOTE The space vehicle comprises e.g. the launcher, satellite, spacecraft.

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 shall be notified to the authorities.

NOTE Example of external environment: e.g. EMI.

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

# 4.14 Verification

## 4.14.1 General

Following exposure to the conditions specified in Clause 4.14.3 below explosive devices and systems shall meet the performance requirements specified in the appropriate Subclauses of Clauses 4.10, 4.11 and 4.12 when measured according to the requirements of Clause 4.14.3.

## 4.14.2 Inspection

a. ECSS-Q-20B, subclause 8.9 shall apply.

b. Non-destructive inspection shall be used to demonstrate specified assembly and condition of every explosive component.

NOTE E.g. X-Ray or N-Ray.

c. Resolution shall be better than the dimension of the smallest feature to be checked.

NOTE To be able to detect 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.

## 4.14.3 Tests

### 4.14.3.1. Test specification

a. Test specification shall be performed, according to ECSS-E-10-03A clause 4.11.2.

b. The test conditions for explosive components and systems shall be derived from the operational conditions and constraints.

NOTE E.g. ground, flight, in orbit.

c. Qualification and lot acceptance tests shall be according to clause 4.14.4 below.

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.

### 4.14.3.2. Test operations

Test operation shall be performed, according to ECSS-E-10-03A clause 4.11.3.

### 4.14.3.3. Test results

Test results shall be performed, according to ECSS-E-10-03A clause 4.11.4.

#### 4.14.3.4. Essential confirmation

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

#### 4.14.3.5. Routing tests

a. It shall be demonstrated that the correct stimulus arrives at the correct initiator and no other.

b. Records shall be kept of the routing test.

#### 4.14.3.6. End-to-end tests

a. Functional tests shall be performed, according to ECSS-E-10-03A clause 8.2.3.

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.

#### 4.14.3.7. Safety tests

Safety tests shall be performed on unpacked articles according to Table 4-22.

**Table 4-22 Safety tests**

| Reference tests | TEST Method | Recommended sequence | |
|---|---|---|---|
| | | L | S |
| Slow cook-off | UNO "Manual of tests and criteria" test 7 (h) | R | NA |
| External Fire | UNO "Manual of tests and criteria" test 7 (g) | R | NA |
| Handling Drop test (e.g. 2 m height) | TBPU | R | O |
| 12m Drop test | UNO "Manual of tests and criteria" test 4(b) | R | NA |
| Mechanical Shock | TBPU | O | NA |
| Lightning | ECSS E-20-07A clause 4.2.3.2 | O | NA |
| L : launcher<br>S : Spacecraft<br>R : Required<br>O : Optional<br>NA : Not Applicable | | | |

#### 4.14.3.8. Lifetime demonstration

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

b. If accelerated aging is used, it shall be justified.

#### 4.14.3.9. Reliability tests

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

b. The methods given in Table 4-23 shall be used for the component listed in the same row.

**Table 4-23 Reliability methods**

| Component | Method |
|---|---|
| Initiator | Bruceton or Neyer |
| Cutter / Release nut /Valve/Pusher/Puller | Severe method |
| TBI | Severe method |
| Shaped charge | Probit or severe method |
| Expanding tube | Probit or severe method |
| Transmission lines | Bruceton or Neyer or Severe method |

## 4.14.4 Qualification and lot acceptance

### 4.14.4.1. General

a. Qualification and acceptance of explosive components and systems shall be in accordance with ECSS-Q-20B.

b. For qualification, each device shall meet the requirements specified in the appropriate table of subclauses 4.11 and 4.12 after exposure to the complete sequence of conditions specified in Table 4-24.

c. For lot acceptance, each device shall meet the requirements specified in the appropriate table of subclauses 4.11 and 4.12 after exposure to the selected conditions specified in Table 4-25.

d. For lifetime, each device shall meet the requirements specified in the appropriate table of Clause subclauses 4.11 and 4.12 after exposure to the complete sequence of conditions specified in Table 4-24.

e. Dynamic leak measurement shall be made under vacuum.

### 4.14.4.2. Qualification tests

Qualification tests shall be performed in accordance with Table 4-24.

NOTE Typical values are given in Annex B.

**Table 4-24 Qualification tests**

| Qualification test | E-10-03A reference | E-10-03A sequence | Spacecraft component | Launcher component |
|---|---|---|---|---|
| no-fire stimulus | none | additional | R | R |
| physical properties (measurement) | 5.1.4 | 1 | R | R |
| secondary characteristics measurement | none | additional | R | R |
| functional and performance (measurement) | 5.1.5 | See note 1 | NA | NA |
| no-damage drop | none | additional | O | R |
| Salt fog | none | additional | NA | R |
| rain | none | additional | NA | R |
| humidity | 5.1.6 | 3 | O | R |
| leakage test | 5.1.7 | 4,6,11,14 | O | O |
| generated shock | none | none | O | O |
| pressure | 5.1.8 | 5 | NA | NA |
| acceleration | 5.1.9 | 7 | O | R |
| sinusoidal vibration | 5.1.10 | 8 | R | R |
| random vibration | 5.1.11 | 9 | R | R |
| acoustic | 5.1.12 | 9 | NA | R |
| shock | 5.1.13 | 10 | R | R |
| corona and arcing | 5.1.14 | 12 | NA | NA |
| thermal vacuum | 5.1.15 | 13 | O | O |
| thermal cycling | 5.1.16 | 13 | R | R |
| emc/esd (for initiator only) | 5.1.17 | 15 | R | R |
| life | 5.1.18 | 16 | O | |
| microgravity | 5.1.19 | 17 | NA | NA |
| audible noise | 5.1.20 | 18 | NA | NA |
| radiation | none | additional | O | NA |
| functional and performance (measurement) | 5.1.5 | See note 2 | R | R |
| destructive physical analysis | none | additional | R | R |
| R : Required O : Optional NA : Not Applicable | | | | |
| Note 1: Only possible at the end of the qualification sequence.<br>Note 2 : See 4.14.4.1 e. | | | | |

### 4.14.4.3. Acceptance tests

a. Lot acceptance tests shall be performed.

b. Acceptance tests shall be in accordance with Table 4-25.

c. Lot acceptance tests results shall confirm that the hardware conforms to the qualified product.

**Table 4-25 Acceptance tests**

| Acceptance test | E-10-03A reference | E-10-03A sequence | Spacecraft component | Launcher component |
|---|---|---|---|---|
| physical properties | 6.1.3 | 1 | R | R |
| Secondary characteristics | none | additional | R | R |
| functional and performance | 6.1.4 | See Note 1 | NA | NA |
| leak | 6.1.5 | 3,5,8,11 | R | R |
| pressure | 6.1.6 | 4 | NA | NA |
| random vibration | 6.1.7 | 6 | O | O |
| acoustic | 6.1.8 | 6 | NA | NA |
| generated shock | 6.1.9 | 7 | NA | NA |
| thermal vacuum | 6.1.10 | 9 | O | NA |
| thermal cycling | 6.1.11 | 9 | O | NA |
| burn-in | 6.1.12 | 10 | NA | NA |
| microgravity | 6.1.13 | 12 | NA | NA |
| audible noise | 6.1.14 | 13 | NA | NA |
| functional and performance | 6.1.4 | See Note 2 | O | O |
| destructive physical analysis | none | additional | O | O |
| R : Required O : Optional NA : Not Applicable | | | | |
| Note 1 : Only possible at the end of the acceptance sequence.<br>Note 2 : See 4.14.4.1 e. | | | | |

# 4.15 Transport, facilities, handling and storage

## 4.15.1 General

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

## 4.15.2 Transport

a. Devices containing explosives shall be transported in accordance with ST/SG/AC.10/1 Rev.14.

b. The transport classification should be 1.4 S.

c. The containers shall protect the component from the mission.

d. Definition of containers shall be in accordance with UNO regulations (ST/SG/AC.10/1 Rev. 14 - Manual of Tests and criteria).

NOTE 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 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) in kilograms
4. Contract number
5. Supplier name and address
6. EXPLOSIVE label with Hazard and compatibility classifications
7. Following label : “Open only in clean-room area by qualified operators” if necessary

h. Container shall indicate the orientation to be kept maintained.

### 4.15.3 Facilities

a. No explosive component shall be stored with other types of equipment.

b. The nature of and precautions required for all explosive components and systems shall be communicated to facility providers and authorities.

c. ECSS-Q-20B subclause 5.8.2 b shall be applied for the storage of explosive devices.

d. All explosive devices shall be stored in temperature and humidity controlled secure storage areas except when required for controlled spacecraft activities.

e. 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 E.g. environmental conditions such as thermal, humidity.

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

### 4.15.4 Handling

a. All handling shall be done by certified personnel according to ECSS-Q-20B Clause 4.5.

NOTE Handling includes testing, measuring, installing.

b. All handling shall be done according to specified procedures.

c. Personnel and equipment shall be grounded to a common ground.

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

e. 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 upon the break-in activities.

f. Restoration of the original accepted condition shall be required.

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

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

## 4.16 In-service

### 4.16.1 Information feedback

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

b. Results of the checks specified in 4.16.2.a. shall be recorded.

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

d. RF links, wiring, connectors and pin functions shall be specified to check 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.

### 4.16.2 Launch site procedures

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

b. The activities specified in 4.16.2.a. shall include contingency actions.

c. Rehearsals shall be performed.

### 4.16.3 Monitoring

Confirmation of operation shall be made available immediately.

## 4.17 Product assurance

### 4.17.1 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.

### 4.17.2 Dependability

a. The explosive system shall conform to all dependability requirements ECSS-Q-30B Clauses 6, 7, 8 and 9.

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

### 4.17.3 Safety

a. The properties of the subsystem and all activities shall meet the safety requirements defined in ECSS Q-40B.

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 operator and parts are grounded to a common ground.

## 4.18 Deliverables

The documentation listed in Table 4-26 shall be delivered.

NOTE Additional specific documents can be established at customer request.

**Table 4-26 Documentation to be delivered**

| | | RFP | KO | DKP | MRR & TRR | DRB | AN | Reference Standard |
|---|---|---|---|---|---|---|---|---|
| **DRD FOR MANAGEMENT** | Management and development Plan | X | X | | | | | ECSS-M-00B Annex B |
| | Risk assessment report<br>Risk management plan | | | | | | X | ECSS-M-00-03B Annex D<br>ECSS-M-00-03B Annex C |
| | 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 | | | | ECSS-E-10-02A Annex C |
| | Declared Materials list<br>Declared Mechanical part list<br>Declared Processes list | | | Xd | X | | | ECSS-Q-70B Annex B<br>ECSS-Q-70B Annex C<br>ECSS-Q-70B Annex D |
| | Qualification Status list | | | | X | | | |
| | FMECA | | | X | X | | | ECSS-Q-30-02A |
| | Request for deviation | | | | | | X | ECSS-M-40B Annex J |
| | Request for waiver | | | | | | | ECSS-M-40B Annex K |
| **DRD FOR ENGINEERING & VERIFICATION** | Functional and Technical specifications | X | X | X | X | X | | ECSS-E-10 Part 6A rev.1 |
| | Mechanical, Thermal, Electrical ICD's | | | X | X | X | | ECSS-E-10-24A |
| | Design Justification File | X | X | X | X | X | | ECSS-E-10C Annex K |
| | Verification matrix | X | X | X | X | X | | ECSS-E-10-02A Annex C |
| | Verification Control Document (Design, Reliability, qualification plan ) | X | X | X | X | X | | ECSS-E-10-02A Annex E |
| | Verification report (Design, Reliability, Qualification justification reports ) | | | X | X | X | | ECSS-E-10-02A Annex L |
| | User Manual | | | X | X | X | | ECSS-E-10C Annex P |

**Table 4-26 Documentation to be delivered *(continued)***

| | | RFP | KO | DKP | MRR & TRR | DRB | AN | Reference Standard |
|---|---|---|---|---|---|---|---|---|
| MANUFACTURING & TEST DOCUMENTS | Test procedure | | | Xd | X | | | ECSS-E-10-02B Annex G |
| | Production tree | Xd | | X | X | | | ECSS-M-40B Annex B |
| | Acceptance test plan | | | Xd | X | | | ECSS-E-10-02A Annex D |
| | Configuration Item data list | | | | X | X | | ECSS-M-40B Annex D |
| | As-built configuration list | | | | X | X | | ECSS-M-40B Annex E |
| | Test reports | | | | | X | | ECSS-E-10-02A Annex H |
| | Logbook | | | | | X | | ECSS-Q-20B Annex B |
| | End Item Data Package (EIDP) | | | | | X | | ECSS-Q-20B Annex C |
| | Certificate of conformity | | | | | X | | ECSS-Q-20B Annex D |

- RFP: to be included in the Request For Proposal documentation
- KO: to be included in the Kick Off Meeting documentation
- DKP: to be included in the Design Key Point 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)
- AN: As Necessary or as required
- Xd: draft document.

# Annex A (normative)
# Explosive component colour code

Called by requirements 4.8.1.4.b and 4.11.1.2.e.

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

# Annex B (informative)
# Component qualification test levels

Table B- 1 provides test levels that can be used for the qualification of components.

**Table B- 1 Component qualification test levels**

| Environment | Ariane 5 ESC<br>(see A5-SG-1-X-40 (Section Number)) | Satellite |
|---|---|---|
| Cold | -80°C / 10 hours (5.2)* | -120°C / 48 hours |
| Dry heat | +110°C / 5 hours (5.3)* | +120°C / 48 hours |
| Damp heat | 2 x 24h 20°C to 35°C _100 % RH (5.4)* | NA |
| Thermal cycles in damp air | 40 x (21°C (1h) to 33°C (1h)) 100 % RH | NA |
| Thermal Vacuum | 0,1 MPa to $10^{-6}$ MPa in 30 s at -80°C | NA |
| Rain | Equipment sprinkled 50mm/h, 30'/face | NA |
| Salt Fog | 24h with salt fog + 24h without (5.9)* | NA |
| Sine Vibrations | 4 min/axis (6.2)*<br>Per axis<br>5 Hz – 16 Hz: 10 mm peak to peak<br>16 Hz – 30 Hz: 10 g peak (1/3 oct/min)<br>30 Hz – 70 Hz: 22,5 g peak<br>70 Hz - 200 Hz: 50g peak (2 oct/min)<br>200 Hz - 2000 Hz: 22,5g peak<br>Test temperature: -80°C / +110°C | 3 axis - 1 sweep<br>Per axis<br>5 Hz - 25Hz: ±11 mm<br>25 Hz - 100Hz: 25 g peak (2 oct/min)<br>Test temperature: ambient |
| Random Vibrations | 4 min/axis (6.9)*<br>20 Hz: 0,0913 g2/Hz<br>20 Hz -150Hz: +6 dB/oct<br>150 Hz: 4 $g^2$/Hz<br>350 Hz: 4 $g^2$/Hz<br>350 Hz - 700 Hz: tbd dB/oct<br>700 Hz: 3 $g^2$/Hz<br>700 Hz - 2000 Hz: -10,7 dB/oct<br>2000 Hz: 0,1 $g^2$/Hz<br>Test temperature: -80°C / +110°C | 6 min/axis - 3 axes<br>20 Hz - 50 Hz: +3 dB/oct<br>50 Hz - 600 Hz : 2 $g^2$/Hz<br>600 Hz - 2000 Hz: -3 dB/oct<br>Test temperature: ambient |
| Medium shocks | ½ sinus 50g, 11ms<br>Test temperature: ambient (6.5)* | ½ sinus 50g, 11ms<br>Test temperature: ambient |
| Pyroshocks | SRS _ Z1 level : Appendix<br>Test temperature: ambient (6.6)* | SRS _ Z4 level :<br>Test temperature: ambient |
| Radiations | NA | 30 krad<br>Test temperature: ambient |
| Firing Tests conditions | -80 °C and +110 °C | -120 °C and +120 °C |
| * Note that the information within the brackets refers to the section number within A5-SG-1-X-40. | | |

Table B- 2 provides the pyroshock that can be used for launchers and satellites.

**Table B- 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 |
| Tolerances for the amplitudes are: + 40 % and – 50 % | | |

# Bibliography


| | |
|---|---|
| ECSS-E-32-08A [2] | Space engineering - Materials |
| ECSS-Q-70-08A | Space product assurance — The manual soldering of high-reliability electrical connections |
| ECSS-Q-70-26A | Space product assurance — Crimping of high-reliability electrical connections |
| ECSS-Q-70-71B | Space product assurance — Data for selection of space materials and processes |


[2] To be published.

# ECSS Change Request / Document Improvement Proposal

A Change Request / Document Improvement Proposal for an ECSS Standard may be submitted to the ECSS Secretariat at any time after the standard's publication using the form presented below.

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## ECSS Change Request / Document Improvement Proposal

| 1. Originator's name:<br>Organization:<br>e-mail: | | | | 2. ECSS Document number:<br>3. Date: | |
|---|---|---|---|---|---|
| **4. Number.** | **5. Location of deficiency**<br>clause (e.g. 3.1) | page (e.g. 14) | **6. Changes** | **7. Justification** | **8. Disposition** |
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7. **Justification -** Describe the purpose, reasons and benefits of the proposed change
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