

Standard

Criteria for Explosive Systems and Devices on Space and Launch Vehicles

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Abstract

This standard establishes criteria for design, manufacture, and performance certification of explosive systems and explosive devices commonly used on launch, upper stage, and space vehicle systems. The requirements contained in this specification are intended to serve as a universal set of tools for use by explosive system manufacturers and users during all phases of development and certification. This information may also be used for guidance during preparation of acquisition contracts and program-specific documents, and may be used for explosive system applications unrelated to space vehicles.

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Foreword

The purpose of this standard, developed by the AIAA Ordnance Committee on Standards, is to clearly define technical requirements, practices and expectations associated with ordnance systems and components to be used on launch, upper stage, and space vehicles. It is to be applied by Space and Missile Center as part of the technical baseline for acquisition, contracting and program management. To the greatest extent possible, requirements from past and existing government and military specifications and standards have been incorporated herein. In addition, the requirements herein include those generated as a result of lessons learned from launch and space vehicle programs as well as from other military and aerospace programs.

This standard will be updated and revised as appropriate to incorporate technological advances and innovations as well as lessons learned.

This standard may be tailored by the contractor, in consultation with the procuring authority, or may be replaced by another document from the government, industry, technical society, international community, or contractor provided the new document is comparable in rigor and effectiveness. Tailoring must be relevant and hold members of the government/industrial partnership appropriately accountable to sound technical principles.

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Introduction

Explosive systems include initiation devices/mechanisms, explosive trains, and end effector ordnance devices that use explosive energy to do work. These systems consist of a series of explosive devices which are electrical or mechanical components or assemblies containing or operated by explosive materials. These are, by design, "one-shot" components that cannot be tested completely before use. Performance confidence of "one-shot" components can only be obtained by destructive tests of like samples from common production lots. This document describes criteria to certify safe and reliable performance of explosive systems and their "one-shot" components.

The criteria outlined in this standard are a composite of those verified by previous use in space and launch vehicle applications. Described are essential design characteristics, manufacturing controls, and methods for certifying performance, acceptance, qualification, and useful life.

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1 Scope

This standard establishes criteria for design, manufacture, and performance certification of explosive systems and explosive devices commonly used on launch, upper stage, and space vehicle systems. The requirements contained in this specification are intended to serve as a universal set of tools for use by explosive system manufacturers and users during all phases of development and certification to assure safe application and high quality products. This information may also be used for guidance during preparation of acquisition contracts and program-specific documents, and may be used for explosive system applications unrelated to space vehicles.

2 Tailoring

For a specific program or project, the requirements defined in this standard may be tailored to match the actual requirements of the particular program or project. Tailoring of requirements shall be undertaken in agreement with the procuring authority where applicable.

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

The criteria offered here are generic in nature; therefore, users are encouraged to consider tailoring these criteria to best fit individual applications. However, the tailored requirements shall achieve a level of verification equivalent to the baseline described herein. Rationale for each tailored requirement shall be established. If the requirements in this specification are not tailored by a contract, they stand as written.

3 Applicable Documents

The following applicable documents contain provisions that, through reference in this text, constitute provisions of this standard.

In the event of conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

AIAA-2005-4039	<i>Advanced Applications of Statistical Methods in Testing of Energetic Components and Systems</i>
AIAA-2007-5135	<i>Practical Problems and Solutions in Age Trend-Line Analyses for Energetic Components</i>
AIAA-2007-5138	<i>Correlation Between the Accelerated Aging Test (AAT) and Real World Storage Temperature</i>
AIAA S-114	<i>Moving Mechanical Assemblies for Space and Launch Vehicles</i>
CFR, Title 49	<i>Code of Federal Regulations, Transportation</i>
MIL-D-23615	<i>Design and Evaluation of Cartridge Actuated Devices</i>
MIL-STD-810	<i>Environmental Engineering Considerations and Laboratory Tests</i>
RCC 319-14	<i>Flight Termination Systems Commonality Standard</i>

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

CAD	Cartridge Actuated Device
CDC	Confined Detonating Cord

CSC	Conical Shaped Charge
EBW	Exploding Bridgewire Device
EED	Electro-Explosive Device
EFI	Exploding Foil Initiator
EFP	Explosively Formed Projectile
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
ET	Explosive Train
ETA	Explosive Transfer Assembly
FCDC	Flexible Confined Detonating Cord
FLSC	Flexible Linear Shaped Charge
GRMS	Root Mean Square Average Acceleration in Units of Gravity
HBW	Hot Bridgewire Device
HE	High Explosive
HNS	Hexanitrostilbene
HVD	High Voltage Detonator
HVI	High Voltage Initiator
LFU	Laser Firing Unit
LID	Laser Initiated Device
LPI	Lanyard Pull Initiator
LSCA	Linear Shaped Charge Assembly
MDF	Mild Detonating Fuse
MPE	Maximum Predicted Environment
MSDS	Material Safety Data Sheet
NDT	Non-Destructive Tests
NSI	NASA Standard Initiator
OTDR	Optical Time Domain Reflectometry
PAD	Propellant Actuated Device
RF/I	Radio Frequency/Interference
S&A	Safe and Arm Device
SCB	Semiconductor Bridge

SDS	Safety Data Sheet
SMDC	Shielded Mild Detonating Cord
TBI	Through Bulkhead Initiator
TLX™	Thin Layered Explosive, Shock Tube Assembly®, Nonel Tube®
VISAR	Velocity Interferometer System for Any Reflector
ZPP	Zirconium Potassium Perchlorate

4.2 Terms and Definitions

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

Acceptor

explosive element that receives an initiating impulse from a donor charge

Auto-ignition

spontaneous explosive reaction of energetic materials in an explosively loaded device due to exposure to environments or interfacing materials

Azide

a material capable of energetic output without the presence of an oxidizer

Booster Charge

explosive charge downstream of the first element of an explosive train that is used to cause initiation or detonation of a main explosive charge or to increase the energy output of the detonator or pyrotechnic input to the end item

Bridgewire

resistive element incorporated into the first element that converts electrical energy into heat or shock to cause initiation of an explosive charge

Cartridge

device that produces pressure which is used to actuate a mechanical device

Cartridge-Actuated Device (CAD)

mechanical device that is actuated by the output from a cartridge

Closed Bomb

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

Confined Detonating Cord (CDC)

linear explosive transfer assembly in which the explosive material is confined in a metallic sheath plus various layers of over-wrap materials intended to limit radial expulsion of detonation products, but sustain linear propagation of detonation waves typically between 6000 and 8000 meters per second

Conical Shaped Charge

explosive device with a concave metal liner which is converted into a jet of flowing material when detonated

Cook-Off Temperature

the maximum temperature within 25 degrees F to which an explosively loaded device can be exposed for a period of one hour without reaction. The determination of cook-off temperature is time and application dependent

Crossover Booster

explosive connection or link between redundant explosive trains

Deflagration

chemical decomposition propagating through the explosive at a subsonic velocity

Design Life

specified minimum life for a device to support end item application

Detonation

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

Donor

charge that transmits an explosive signal into a receptor

Electro-Explosive Device (EED)

that element of an explosive train which has a bridgewire and that transforms electrical energy into explosive output

Electrostatic Discharge

avalanche release of high voltage energy accumulated

Expanding Tube Separation System

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

Exploding Bridgewire Device (EBW)

high voltage device in which the bridgewire explodes when functioned

Exploding Foil Initiator (EFI)

high voltage device that generates a supersonic flyer plate when functioned

Explosion

exothermic chemical reaction resulting in a sudden conversion of potential energy into kinetic energy, heat, light, sound, and gas

Explosive

material which is capable of undergoing an explosion

Explosive Train (ET)

series of explosive components that transfer explosive signal from the first element to the final explosively actuated device

Explosive Transfer Assembly (ETA)

series of explosive components used to transfer the explosive signal from the first element to the explosively actuated device

Explosively Actuated Device

device that converts explosive energy into mechanical work

Explosively Formed Projectile (EFP)

variant on the conical shaped charge in which the concave metallic liner is formed into a slug when detonated

First Element

initial element of an explosive system that converts electrical, optical, or mechanical energy to explosive energy

Flexible Confined Detonating Cord (FCDC)

CDC whose over-wrap material allows for flexure of the cord for ease in handling and installation

Flexible Linear Shaped Charge (FLSC)

LSC with a ductile metal sheath which may be conformed to installation envelope

High Explosive

any chemical material in which the fuel and oxidizer are contained in the same molecule, the decomposition of which is a detonation

Hot Bridgewire Device

low voltage EED

Interrupter

similar to S&A's, except that they do not contain integral EEDs. Interrupters are used to isolate primary explosives from downstream secondary explosives (e.g., LPI from a destruct charge or laser light output to a LID).

Laser Initiated Device (LID)

first element containing explosives that is ignited by laser energy

Linear Shaped Charge

linear explosive device whose metal liner is converted into a jet of flowing material when detonated

Mild Detonating Fuse (MDF)

thin ductile metal tube containing high explosives

Maximum Predicted Environment (MPE)

maximum predicted environmental levels including all appropriate uncertainty margins and model maturity margins

NASA Standard Initiator (NSI)

1 amp/1 watt no-fire EED containing ZPP designed to meet the requirements of NASA's specification; initiator of choice for all NASA applications

No Damage

an energetic device still meets design and performance requirements after being exposed to a test or environment, e.g. ESD

Percussion

method of initiating an explosive reaction by intentional sudden pinching, crushing or otherwise compressing explosive materials, as between a blunt firing pin and an anvil

Primary Explosive

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

Procuring Authority

organization(s) imposing requirements of this document

Propellant

deflagrating explosive material whose output is essentially gaseous

Pyrotechnics

mixtures of fuels and oxidizers that can deflagrate

Receptor

see Acceptor

Refurbish

to replace components or elements in an explosive device or system to maintain reliability or extend service life

Repair

to perform work on a non-compliant device which renders it useable but not fully compliant with specification and/or drawing requirements

Rework

to perform work on a defective device which renders it useable and fully compliant with specification and/or drawing requirements

Lead

explosive charge contained in a can or in pellet form used within a device to transfer a detonation from one point to another

Safe and Arm Device (S&A)

mechanical or electromechanical device that provides a moveable barrier within the explosive train downstream of the first element

Secondary Explosive

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

Semiconductor Bridge Initiator (SCB)

EED that uses a semiconductor as the bridge element

Sensitivity

characteristic of an explosive that expresses its susceptibility to initiation by externally applied energy such as heat, mechanical shock, or other stimuli

Service Life

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

Shielded Mild Detonating Cord (SMDC)

CDC contained within a rigid metal sheath to contain detonation products and increase robustness for handling and dynamic environments

Sneak Circuit

an unexpected path or logic flow within a system which, under certain conditions, can initiate an undesired function or inhibit a desired function. The path may consist of hardware, software, operator actions, or combinations of these elements. Sneak circuits are not the result of hardware failure but are latent conditions, inadvertently designed into the system, coded into the software program, or triggered by human error

Squib

small EED typically without mounting threads and located inside another device, e.g. thermal battery

Statistical All-fire

current, power, or energy level determined by testing and statistical analysis at which a design will fire and meet specified reliability requirements

Sure-Fire

recommended firing parameters, e.g. current, rise rate, etc., that will function the device over the required temperature range for all lots before, during, and after exposure to all environments

Thermal Time Constant

characteristic time for heating up an element such as a bridgewire

Thin Layered Explosive (TLX™)

explosive transfer line in which the explosive powder is deposited on the interior walls of a hollow plastic tube.

Through-Bulkhead Initiator (TBI)

device that propagates a high-order detonation signal through an integral internal metal bulkhead leaving the bulkhead intact and initiating the downstream explosive materials

Trend Analysis Life Estimate

statistical method for shelf life estimation on the basis of analysis of key performance parameters of an explosive device as a function of age

Velocity Interferometer System for Any Reflector (VISAR)

optical interferometer that measures the velocity of a diffuse object by detecting the Doppler shift of reflected laser light

5 Design Requirements

Explosive systems, ref Figure 1, furnished under this standard shall be flight accredited. Items are considered to be flight accredited if they satisfy all of the following conditions.

- All components and systems meet the requirements of this section.
- All components and systems have passed the margin and qualification tests of Section 6.
- Components are from a lot that has passed qualification or acceptance tests specified in Section 6.
- Components are from a lot that is within the verified service life. Life extension testing is described in Section 6.

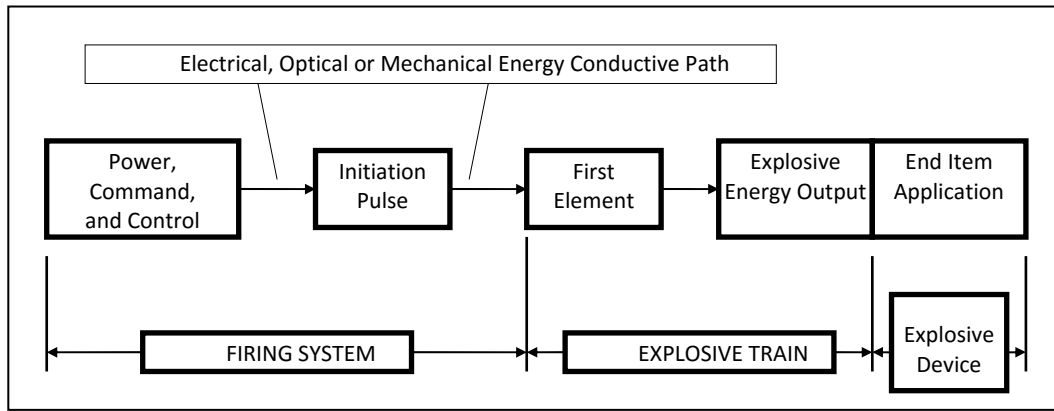


Figure 1 — Explosive System Flow Diagram

5.1 General Requirements

Explosive systems and components shall meet the following general requirements.

5.1.1 Environmental Survivability

Explosive systems and components shall be designed to survive and perform intended functions during and after exposure to dynamic, thermal, humidity, pressure, electromagnetic, or other environments that are predicted to be encountered during transportation, storage, handling, and flight.

The procuring activity of the explosive system or component shall determine the types of environments to be experienced throughout the service life in each application. These shall include predictions of magnitudes, durations, and margins of these environments as well as determinations if dynamic, thermal and/or humidity conditions may be combined into common tests. The user or procuring authority shall also ensure that all appropriate tests or analyses are performed.

5.1.2 Performance Requirements Updates

Predicted performance requirements shall be updated to reflect actual device performance as demonstrated in margin and qualification testing. This shall include maximum and minimum limits on key performance parameters.

5.1.3 Safety

Explosive systems and components shall be designed to minimize risk to personnel, equipment, and facilities. Handling and installation procedures shall be formally documented and clearly identify operations where warnings and cautions are necessary to deter accidents. Safety requirements and procedures shall conform to all appropriate regulations of the countries, states and localities in which items will be transported, stored, and used. It is the responsibility of both user and manufacturer of explosive systems and components to ascertain which regulations apply to their products. The ability of explosive systems and first elements to survive electrical energy fields without premature initiation or degraded performance shall be verified by tests, inspections, and/or analysis.

5.1.4 Fault Tolerance

Explosive systems shall be designed to be single-fault tolerant.

For those applications where premature initiation may result in a catastrophic event, the system shall not contain any single point or common mode failure that could result in inadvertent or premature firing prior to receipt of a valid initiation signal.

5.1.5 Design Life

Explosive systems and components shall be designed to have useful lives commensurate with the end item application.

5.1.6 Sealing

Explosive devices shall be hermetically sealed or contained in an assembly that is hermetically sealed with a maximum allowable leak rate equivalent to 5×10^{-6} cm³/sec Helium. Assemblies that are not hermetically sealed shall ensure the explosives within them are hermetically sealed. Assemblies that are hermetically sealed shall ensure energetic materials installed in them are protected from elements or contaminants in the assembly. Sealing shall be accomplished by fusion of metallic and/or non-metallic materials. Use of non-fused crimp-type joints shall not be used to effect the seal. Use of organic materials to enhance seal effectiveness is acceptable provided they are compatible with the explosive materials used.

Seal effectiveness shall be verifiable before and after exposure to thermal and dynamic environments described in destructive qualification and acceptance tests of this specification.

All interfaces in the explosive system shall provide adequate protection to preclude intrusion of water, salt, and other contaminants when exposed to worst case predicted environments. The designer should consider that a launch or space vehicle may remain on the launch pad through very extreme environments such as hurricanes and for a prolonged period up to one full year.

5.1.7 Electrical/Electromagnetic

5.1.7.1 General

Explosive systems shall be designed to operate without performance degradation or inadvertent firing when exposed to electrical energy environments such as electrostatic discharge, electromagnetic radiation, radio frequency interference, and lightning. An electromagnetic compatibility program may be required to meet system level requirements.

5.1.7.2 Electrostatic Discharge (ESD)

Explosive systems and components shall be designed to survive external applications of an ESD environment without inadvertent initiation or degradation in performance. Protective features shall be included to prevent premature initiation of first elements or deactivation of safety inhibits. All ESD-sensitive components shall be shielded or otherwise protected from the environment.

Explosive devices shall be evaluated for ESD sensitivity. Those that may be susceptible to premature initiation or performance degradation when exposed to ESD energy field shall be tested to verify survivability.

5.1.7.3 Electromagnetic Compatibility (EMC)

The shielding for firing circuits shall provide a minimum 20 dB safety margin between worst-case electrical noise and the electrical explosive device demonstrated no-fire rating. Shielding for other circuits shall provide a minimum 6 dB safety margin between worst-case electrical noise and the minimum activation power/no-damage rating.

5.1.7.4 Radio Frequency Interference (RFI)

All explosive systems and first element designs shall be capable of surviving exposures to externally applied RFI fields anticipated during transportation, storage, and use of the end item application.

5.1.7.5 Lightning

Explosive systems shall be designed to preclude premature activation due to electrical energy fields generated within the system by exposure to lightning strikes. Assessment of survivability may be accomplished by inspection and analysis of the explosive system and components design.

5.1.8 Materials

5.1.8.1 Selection of Parts, Materials, and Processes

The parts, materials, and processes shall be selected and controlled in accordance with the contractor established and documented procedures to satisfy the requirements specified herein. The selection and control procedures shall emphasize quality and reliability to meet the mission requirements and to minimize total life cycle costs for the applicable system. An additional objective in the selection of parts, materials, and processes shall be to maximize commonality and thereby minimize the variety of parts, related tools, and test equipment required in the fabrication, installation, and maintenance of the vehicle. The parts, materials, and processes shall be selected to meet the functional, performance, safety, reliability, contamination, and strength requirements of the end item during its design life, including all environmental degradation effects.

5.1.8.2 Fracture Toughness

Materials selection shall include assessment of susceptibility to cracking due to shock loads or shock loads combined with low temperatures.

5.1.8.3 Fungus Resistance

Inherently fungus-inert materials shall be used.

5.1.8.4 Material Compatibility

Dissimilar materials shall be evaluated for compatibility. In addition, materials exposed to the external environment shall not react when exposed to vehicle propellants, fluids, and gases.

5.1.8.5 Age-Sensitivity

Age-sensitive materials used in an explosive system or component shall be identified, assessed, and documented as to their support of design life of the system or component.

5.1.8.6 Energetics

Explosive materials used in explosive trains shall meet the performance and safety requirements of this specification and supporting documentation shall be readily available. Proprietary or other unique compositions that may result in superior performance, increased reliability, or improved safety may be used if the compositions are evaluated for safety (reference only documents MIL-STD-1751 which has been cancelled or AOP-7 which replaced 1751) and components and systems containing them pass performance and safety tests defined in this specification.

5.1.8.6.1

Primary Explosives

The use of primary explosives should be minimized and shall be evaluated and approved by the procuring authority.

5.1.8.6.2

Upper Temperature Limit

The decomposition, cook-off, auto-ignition, and melting temperatures of all explosives shall be at least 30°C higher than the maximum predicted environmental temperature to which the material will be exposed during storage, handling, installation, transportation, launch, flight, and orbit.

5.1.8.7 **Metals**

5.1.8.7.1

Dissimilar Metals

Dissimilar metals shall not be used in intimate contact with each other unless suitably protected against electrolytic corrosion.

5.1.8.7.2

Corrosion Resistance

Metals shall be corrosion resistant, or shall be suitably treated to resist corrosion when subjected to the specified environments including humid or corrosive environments during manufacture, installation, storage, handling and operation.

5.1.8.7.2.1 **Protective Coatings, Finishes, and Plating**

Material selections shall ensure that completed components are resistant to corrosion that interferes with mechanical, thermal, or electrical performance.

Cadmium and zinc platings are not recommended for use unless required by application or deployment environment.

Plating with pure metals such as tin shall evaluate for possibility of whisker growth and ensure no detrimental impacts to the design.

5.1.8.7.2.2 **Stress Corrosion**

Material selections shall ensure that completed components are resistant to stress corrosion cracking and brittle fracture failure modes, and preclude failures induced by hydrogen embrittlement.

5.1.8.7.3

Heat Treatment

All materials and associated heat treatments shall be approved by the procuring authority before use.

The selection of alloys and heat treatments shall be compatible with the stress and temperature environments.

Heat treatment of parts shall include appropriate test specimens from the same heat treat of material as the part. These test specimens shall accompany the parts through the entire fabrication cycle to ensure that the desired properties are obtained.

5.1.8.7.4

Galling

Threaded and moving interfacing metals and lubricants shall be selected to preclude galling during assembly or disassembly.

5.1.8.8 **Lubricants**

Lubricants shall not come in contact with explosive materials during manufacture, storage, and use.

Lubricants shall be selected with consideration given to corrosion, outgassing, temperature limits, operation in a vacuum, creep properties, effect of long-term storage, and compatibility with other lubricants and materials.

Precautions shall be implemented to ensure that lubricants do not migrate into explosive train transfer paths.

5.1.8.9 **Adhesives, Sealants, and Solvents**

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

5.1.9 Human Engineering

Explosive systems shall be ergonomically designed and developed to preclude human error, incorrect installation, and incorrect assembly.

System interfaces and/or installation shall be designed to preclude inadvertent interchange of the items or interconnections that could cause possible malfunction. Tabs, shoulders, different thread sizes, and different electrical connector clocking may be employed.

5.1.10 Contamination

5.1.10.1 Design

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

Performance and safety of explosive devices shall not be adversely affected by contamination from the environment.

5.1.10.2 Manufacturing, Handling and Storage

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

5.1.10.3 Combustion Products

There shall be no deleterious contamination resulting from the function of the explosive system. If a component design cannot ensure the containment of generated gas, contaminants, particles, or shrapnel, the component installation shall provide adequate protection for other systems of the vehicle, e.g. optical sensors and thermal control surfaces.

5.1.11 Mechanical Components

Requirements for mechanical components not referenced herein are presented in AIAA S-114.

5.1.11.1 Threaded Parts

For threaded interfaces that see operational loads, e.g. pressure cartridges and initiators, the minimum thread engagement shall be 3 full threads.

For through bolts, the threaded end shall protrude a minimum of two full threads beyond the end of the nut.

Screw sizes smaller than 3.6 mm (No. 8) in diameter shall be avoided where practicable.

Where there are areas that may be sensitive to debris generated during assembly of threaded parts, blind holes should be considered. Tolerances shall be controlled to prevent threaded parts from bottoming in blind holes.

5.1.11.2 Locking Devices

Positive locking devices shall be utilized on all threaded interfaces and fasteners.

Preferred locking devices are safety wire, weld washers, bent tab washers, cotter pins, self-locking threads, or threads with locking plastic inserts. Safety wiring, cables, and cotter pins shall comply with requirements of NASM33540 or an equivalent document.

Self-locking via interference fit threads shall not be used in applications where particulate contamination may cause damage or degradation to the equipment or vehicle.

When self-locking features are used, the screw length shall be sufficient to fully engage the locking feature at worst-case tolerances. If self-locking features are to be re-used, an allowable range of run-in torque and the maximum number of re-uses shall be specified.

5.1.11.3 Stops

Mechanical stops or shoulders and associated attachments shall be designed to a structural yield factor of safety on the basis of analysis of forces that occur upon full extension, actuation, or stopping of moving assemblies. A feature that dissipates energy and/or provides retention may be provided.

5.1.12 Explosive Material Output

Some explosive output properties are specified as minimum values. In some cases a more brisant material or a faster burn time may not be suitable in its intended application. In certain applications either the maximum and minimum values of the explosive performance parameters must be defined or the application shall accommodate all expected variations in explosive properties.

The performance of an explosive system must be coordinated with the user. For example, a high output from the explosive device in staging application may deform the adjacent component of vehicle that may cause a failure.

5.1.13 Mechanical Integrity

Components, when installed into their system interfaces, shall be designed to withstand at least 1.5 times maximum internal pressure resulting from functioning.

5.1.14 Electrical Bonding

Metallic components of the explosive system which are physically connected shall have measured direct current resistance values as follows:

- a. electrical firing circuit housing to structure: Less than 2.5 milliohm
- b. non-electrical ordnance component to non-electrical component or to structure: Less than 1 ohm
- c. non-electrical, linear ordnance component end to end (LSC, FLSC, FCDC, etc.): Less than 10 ohm

5.1.15 Manufacturing and Quality

5.1.15.1 General

Explosive components and systems shall be manufactured in accordance with established processes and criteria that can be verified by documented quality control methods. Development testing shall validate use of any innovative manufacturing technique before subjecting manufactured items to tests of this specification. Quality of all manufactured items shall be assessed for compliance with requirements and results documented. Traceability of critical materials, components, and processes shall be documented for each manufacturing lot.

5.1.15.2 Configuration Control

The manufacturing of explosive devices shall be accomplished in accordance with documented requirements, procedures, and process controls that ensure the reliability and quality required.

Manufacturing and process controls including flow charts, referenced specifications, procedures, drawings, and supporting documentation establish a supplier-controlled qualified baseline to ensure subsequent production items are equivalent in performance, quality, configuration, and reliability to initial production items used for qualification. This baseline shall be documented and controlled by the supplier.

Any change to this qualified baseline shall be documented by the supplier and shall be submitted to the procuring authority. These changes, which shall be controlled by the supplier, provide the basis for flight accreditation of subsequent production lots.

5.1.15.3 **Production Lot**

Explosive items shall be manufactured and tested in individual production lots during the various stages of manufacturing to assure that all items in a production lot are assembled to the approved configuration during the same time period using the same production materials, tools, methods, personnel, and controls.

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

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

5.1.15.4 **In-process Tests and Inspections**

The fabrication process shall provide for in-process tests and inspections. Documentation describing results of tests and inspections performed during manufacture of components containing or operated by explosive materials shall be made available to end item users before or on delivery of the items. These in-process test and inspection records shall be used as a means to measure validity of post-delivery tests and inspections of like parameters.

5.1.15.5 **Refurbishment**

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

5.1.15.6 **Identification and Marking**

Explosive systems and components shall be permanently identified, to include as a minimum the supplier identification/cage code, part number, lot number, and serial number. Additional identification will be specified by the procuring agency. Parts shall be serialized as early in the manufacturing process as possible.

5.1.15.6.1

Not-For-Flight Marking

Items not suitable for flight use, which could be substituted for flight or flight spare hardware, shall be permanently identified as NOT FOR FLIGHT, e.g. color coded with a unique color and/or addition of a distinguishing feature added such as a drilled hole.

5.1.15.6.2

Lot Number

Lot numbers shall be assigned to each production lot in accordance with Procuring Authority direction.

5.1.15.6.3

Serial Number

Components or assemblies requiring control shall be assigned a unique (non-repeating) serial number for each unit manufactured. New build lots shall not use previously assigned serial numbers unless approved by the Procuring Authority.

This serial number shall be assigned at an appropriate point in the manufacturing flow. This serial number shall be permanently marked on the item. If impractical, bag and tag is allowed.

5.1.16 Explosive Hazard Data

Explosive hazard data shall be maintained for each component, subassembly, and assembly, as appropriate. Each device shall have a Material Safety Data Sheet (MSDS) or Safety Data Sheet (SDS) that includes required information such as chemical compositions, weights, net explosive weight, and safety information. Data shall be updated as configuration changes are made and traceable to configuration.

5.1.16.1 Explosive Hazard Classification

The explosive component, subsystem, or system manufacturer is responsible for obtaining documentation that defines appropriate transportation and handling classification for each configuration produced for the countries, states, or localities through which it will be transported. The manufacturer shall include this documentation and any supporting information with the explosive component data package.

5.2 Margin Requirements

5.2.1 General

All interfaces in the explosive system shall include verified margin between donor component and acceptor component. Examples of this include voltage/current applied to EEDs, laser light energy applied to LIDs, EED output to booster charge, detonation transfer between devices and through TBI bulkheads, pressure cartridge output to CAD, and severing/penetrating device output to target.

Individual devices with internal interfaces must be designed and verified to have margin between donor material output and acceptor material input threshold.

5.2.2 Initiation System to First Elements

Tests and analyses shall be used to verify the amount of positive margin between initiation system worse case output parameters and ignition threshold limits of the first element. All-fire limits of first elements should be determined during tests and analysis described in Section 6. During these tests care shall be taken to ensure critical interface parameters between initiation system and first elements are maintained to be as close as possible to flight application, e.g. a flight-like fireset should be used whenever possible.

5.2.2.1 Low Voltage Initiator

The initiation system shall be designed such that the minimum stimulus applied to each device in the system is equal to or greater than 1.5 times the sure-fire current or 2 times the statistical all-fire current level of the device, whichever is greater.

5.2.2.2 High-Voltage Initiator

The EBW initiation system shall be designed to deliver a minimum of 150% of EBW all-fire voltage.

The EFI initiation system shall be designed to deliver a minimum of EFI all-fire voltage plus 100 volts.

5.2.2.3 Laser Initiators

The initiation system shall be designed such that the minimum stimulus applied to each initiator in the system is equal to or greater than 2.0 times the sure-fire power density or energy fluence level of the device.

5.2.2.4 Mechanical Initiators

For this type of system, the minimum system energy level when the firing pin strikes the first energetic element, e.g. primer or stab initiator, shall be at least two times the statistical all-fire level for the primer or stab charge.

5.2.2.5 **Booster Charges**

If booster charges are an integral part of the first element assembly, they shall be tested to first element requirements. Booster charge designs that are not integral with the first element shall be tested to the requirements for explosive energy transfer elements.

5.2.3 **Explosive Energy Transfer**

5.2.3.1 **General**

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

5.2.3.2 **Detonation Transfer**

5.2.3.2.1

Transfer Between Components

Energy transfer performance margins tests shall be conducted on all elements of an ET where transfer across a discontinuity, or gap, in the ET is required. This testing shall consider any material that is in the design detonation path. Axial and angular misalignment between donor and receptor shall also be considered.

Methods for verifying detonation transfer margin are presented in Section 6.

5.2.3.3 **Transfer Through Bulkhead**

All detonation transfer interfaces through solid material shall perform with margin when the solid material thickness is increased to 120% of the design maximum and with nominal donor and receptor charges. If the solid material is to remain un-ruptured during nominal performance, the interface shall perform without rupture when the solid material thickness is decreased to 80% of design minimum and with nominal donor and receptor charges.

These tests shall demonstrate structural integrity of the bulkhead during and after initiation of the receptor charge.

5.2.4 **Cartridge Actuated Device (CAD)**

a. Under-loaded cartridge

- o Dual and single cartridge CADs shall perform within specified limits when actuated by a single cartridge having 80% or less of the minimum specified weights of energetic output materials

b. Over-loaded cartridge

- o Dual cartridge CADs shall perform within specified limits when actuated by both cartridges having at least 120% of maximum specified weights of energetic output materials.
- o Single cartridge CADs shall perform within specified limits when actuated by the cartridge having at least 120% of maximum specified weights of energetic output materials.

c. No mechanical load

- o Dual cartridge CADs shall not rupture when functioned with two nominal cartridges in the no-load condition.

- o Single cartridge CADs shall not rupture when functioned with a nominal cartridge in the no-load condition.
- d. Maximum load
 - o CADs that are required to operate under a resistive or assistive mechanical load, shall perform within specification limits when with the load increased to 150% of the maximum predicted operating load. The dual cartridge CAD shall be fired with two nominal cartridges and the single cartridge CAD with one nominal cartridge.
- e. Locked-shut
 - o The CAD shall not rupture when fired with all internal moving components restrained so no motion is possible. The dual cartridge CAD shall be fired with two nominal cartridges and the single cartridge CAD with one nominal cartridge.

5.2.5 Pyrovalves

Actuation of pyrovalves with over-loaded and under-loaded cartridges/boosters as defined in 5.2.4 shall not result in blow-by of combustion products into the fluid system the valve is part of and the unit shall effectively seal or open the fluid system without contaminating or reacting the fluid.

5.2.6 Severing and Penetrating Device

Performance margins for devices such as linear/conical shaped charges, explosively formed projectiles, or detonating cords for severing or penetrating shall be determined by tests and analyses. Performance margins shall be demonstrated with the device positioned at flight design standoff, directed at a target representative of flight design but with thickness increased to 150% of the maximum design thickness, or with flight design standoff and a 67% explosive charge. Composite target design should carefully consider means to obtain the 150% thickness, e.g. add additional fiber layers or not.

5.2.7 Fracturing Devices

Devices including frangible joints that rely on the fracturing of a load-carrying web, membrane, or annulus, such as those in frangible nuts and explosive bolts, shall fracture a nominal web with explosive charge downloaded to 80% of design minimum, or shall fracture a 120% of the maximum design web with a single nominal explosive charge.

Programs shall consider performance of margin tests for each production lot to account for potential changes in material properties.

5.2.8 Cutters

Cutters shall be capable of severing a target having a cross sectional area at least 120% of the maximum operational target with a single nominally loaded pressure cartridge, or with a single pressure cartridge, loaded with 80% of the minimum designed explosive charge, fired against a nominal target.

Cutters shall not fragment when fired with no target or when fired with both pressure cartridge(s) loaded with 120% of the maximum designed explosive charges.

5.2.9 Linear Thrusting Joints

Linear thrusting joints shall be capable of meeting the specified structural and special separation energy when actuated with an explosive charge no greater than 80% of the minimum baseline explosive charge weight. Additionally the thrusting joint must maintain structural integrity when actuated with an explosive charge that is at least 120% of the maximum baseline charge weight.

5.3 System Design Requirements

5.3.1 General

Explosive systems are composed of an initiation system, first element and transfer system, and an explosively actuated end event.

System design shall also consider higher level system needs such as simultaneity, differential thrusts, shock levels, dynamic effects, and event sequencing.

5.3.2 Interfaces

Each interface of the explosive system shall be designed to meet the margin requirements of Section 5.2.

5.3.3 Redundancy

Crossover boosters shall not compromise redundancy requirements.

All explosive functions shall be designed so that a failure of any single explosive element to operate will not cause a failure of the function. If accepted by the procuring authority, acceptable redundancy may be achieved by providing two inputs, one at each end of a linear device or by using dual inputs to a single explosively actuated device. Firing of the first input shall not compromise function of the redundant input.

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

5.3.4 Reliability

The reliability design requirements shall ensure that the overall system reliability requirements are met under the most severe extremes of acceptance testing, storage, transportation, preflight testing, and operational environments. The overall design goal of explosive system reliability shall be a minimum of 0.995 at the 95% confidence level

5.3.5 Initiation System

5.3.5.1 General

Initiation systems utilize electrical, optical, or mechanical energy that is applied to the first element of the ET. These systems shall be controlled to ensure reliable initiation and to prevent inadvertent or premature initiation of the system. Requirements in this section apply when the system is subjected to all anticipated environments to include as a minimum dynamic, thermal, electromagnetic/RF, and humidity.

Initiation systems are powered, controlled, and commanded by inputs from the vehicle. The inputs are converted into electrical, optical, or mechanical energy stimuli that are applied to the first element. The limits of these stimuli shall be controlled and inhibited. Controls ensure reliable initiation, whereas inhibits prevent inadvertent or premature initiation.

The explosive system shall be designed to ensure that connecting and disconnecting the first element will not cause inadvertent initiation of the first element.

5.3.5.2 Electrical System

5.3.5.2.1

General

Ungrounded firing output circuits in safed condition shall be shorted together and connected to structure by static bleed resistors. If the resistor(s) remain connected to the initiation circuit in the armed mode, they shall have a minimum resistance of 10 kilohm

The design shall ensure adequate voltage/current is delivered to properly arm/safe the firing device.

5.3.5.2.2

Power Source

Separate and dedicated power distribution points shall be used for the electro-explosive system firing sources. A firing source can share the same power source with other loads, but all currents flowing from the firing source point shall be for firing circuits only.

If the host vehicle supplies power to the firing source circuit, one of the following options shall be used:

- a. The return side of the firing source circuit shall not be grounded on the payload side of the interface, and shall be isolated from payload structure by at least 10 kilohm measured at 1.5 times the bus voltage or greater, or equivalent isolation.
- b. Isolation transformers shall be used in the firing source circuit to provide at least 10 kilohm isolation between the payload return circuit and the host vehicle return circuit when measured at 1.5 times the bus voltage or greater.

5.3.5.2.3

Wiring

Electrical wiring within an explosive system and those to be used for explosive system testing shall be isolated using low inductance materials and be twisted shielded pairs of conductors, flex circuits, or coaxial cables.

The explosive system chassis or structure shall not be used as the return side of any circuit.

Firing circuits shall be selected to minimize voltage buildup and transients on the firing circuit.

Any grounding of the firing circuits shall be done at one point only. Ungrounded firing output circuits shall be connected to structure by static bleed resistors.

Wiring cable shielding shall be terminated on the circumference of the back-shell of each connector used.

The design shall preclude sneak circuits and unintentional electrical paths.

5.3.5.2.4

Shielding

The firing circuit, including the EED, shall be completely shielded to provide isolation from electromagnetic interference (EMI). Isolation shall provide a 20 dB minimum attenuation (regardless of source and load impedance) at all frequencies of the expected electromagnetic environment. The adequacy of the RF protection can also be demonstrated by test or analysis for each specific usage.

Cable shielding should be at minimum between 90% and 95% optical coverage. Double layer shielding is preferred. For all other elements of the shielding, there shall be no gaps or discontinuities, including the termination at the back faces of the connectors, or apertures in any container that houses elements of the firing circuit.

Shields shall not be used as intentional current carrying conductors but may be multiple-point grounded to structure.

5.3.5.2.5

Cables

Electrical cables may be fabricated such that several electro-explosive system circuits are contained in a common shielded cable bundle, provided that the isolation requirements are maintained.

There shall be no splices used to join elements of cables.

A connector shall be provided wherever mating or de-mating of a circuit is required.

All cable runs shall be routed to dissipate electrical charge build up.

5.3.5.2.6**Isolation**

To ensure that DC electrical circuits connected to the initiating device do not inadvertently cause a ground fault and to control leakage currents, the circuits shall be isolated from adjacent structures by at least one megohm.

Firing circuits that do not share a common fire command shall be electrically isolated from one another such that current on one firing circuit does not induce a current greater than 10 milliamps in any firing circuit.

Control circuits shall be electrically isolated so that a stimulus in one circuit does not induce a stimulus greater than 10 milliamps in any firing circuit.

5.3.5.2.7**Physical Separation**

Firing circuits shall be physically separated from other firing circuits and from all other types of circuits.

5.3.5.2.8**Electrostatic Protection**

EEDs shall be protected from electrostatic hazards by the placement of resistors from line-to-line and from line-to-ground (structure). The placement of line-to-structure static bleed resistors does not violate the single point ground requirements as long as the parallel combination of these resistors is 10 kilohms or more.

5.3.5.2.9**Monitor Circuits (Portable or Built-in)**

Application of operational voltage to the monitor circuit shall not compromise the safety of the firing circuit nor cause the electro-explosive system to be armed.

Low voltage EED bridgewire monitoring currents shall be limited to 10 milliamps through the EED, even in the event of a fault condition.

5.3.5.2.10**Payload Interface Controls**

Command and control interfaces with the host vehicle that are used for any arming or firing functions in the payload shall not be actuated or triggered by return currents flowing in the host vehicle or payload structure.

5.3.5.2.11**Connectors****5.3.5.2.11.1 Type**

All connectors used with the EEDs shall accomplish the following:

- a. be approved by the procuring authority;
- b. have a stainless steel shell or suitable electrically conductive finish;
- c. complete the shell-to-shell keyway engagement connection before the pins connect; and
- d. provide for 360 degree shield termination to the back-shell.

5.3.5.2.11.2 Pin Assignment

The circuit assignments and isolation of pins within any electro-explosive system circuit connector shall be such that any single short circuit occurring as a result of a bent pin or contamination will not result in more than 10 milliamps applied to any EED.

There shall be only one wire per pin, and in no case shall a connector pin be used as a terminal or tie-point for multiple connections.

Spare pins are prohibited in connectors that are part of firing output circuitry.

Connectors that source power to an EED shall be of the recessed-socket type and connectors containing circuits that lead to the EED should be of the scoop-proof pin type.

5.3.5.2.11.3 Locking

Connectors shall be selected so that they are not subject to de-mating when exposed to the maximum qualification environments.

5.3.5.2.11.4 Mismatching

Firing circuit connectors shall not be capable of being mismatched.

5.3.5.2.11.5 Separate Connectors

Where redundant circuits are required to meet fault tolerance requirements, separate output connectors shall be used.

5.3.5.2.12

Firing Switches and Relays

Electromechanical and solid state switches and relays shall be capable of delivering the maximum firing circuit current for a time interval at least 10 times the duration of the maximum firing pulse.

These switches and relays shall be capable of sustaining the post-fire short circuit current without exceeding any steady state or transient limits of the solid state or electromechanical device used.

The use of a solid-state device to provide isolation between the firing circuit and ground/structure requires specific approval from the procuring authority.

Relays that are series inhibits shall be mounted on axes to minimize the potential of vibration or shock activating more than one of the relays simultaneously.

5.3.5.2.13

Insulation Resistance

All current carrying components and conductors shall be electrically insulated from each other and system ground.

The insulation resistance between all insulated parts shall be greater than 2 megohms for low-voltage EEDs or 20 megohms for high-voltage EEDs.

5.3.5.2.14

Post-Fire Short Circuit Protection

Electro-explosive systems shall include positive protection from line-to-line and line-to-ground shorts that may develop within a fired EED. The system shall be designed to open firing switches after firing in a specified time, incorporated with current limiting serial resistor, or shall incorporate an EED with a specified minimum open circuit resistance after firing.

5.3.5.2.15

Safe and Arm Plug Device

Firing circuits that use arming plugs shall be designed to electrically interrupt the EED side of the firing circuit. They shall provide for the ESD protection of the EED with the arm plug removed. This protection may be achieved by installing a safe plug in the arm plug receptacle or by intrinsic design of the firing circuits. If a safe plug is not required, a suitable conductive cap shall cover the arm plug receptacle.

Arm and safe plugs or caps shall be designed to be positively identifiable by color, shape and name. The natural (unpainted) body color of the arm plug is required. The safe plug or cap should be green and shall have a red "REMOVE BEFORE FLIGHT" streamer attached. They shall be marked "ARM and "SAFE," respectively.

The design of the device and the firing circuit shall ensure easy access for plug installation and removal during assembly and checkout in all pre-launch and post-launch facilities.

Monitor and control circuits shall not be routed through safe plugs.

5.3.5.3 Low Energy Electrical System

Low energy electrical systems, which have a power source based on either battery, dedicated power bus, or a capacitor, shall be designed such that the amplitude and duration of the firing current or voltage meet the margin requirements of Section 5.2.

Maximum system output shall be less than maximum level at which the device is verified to perform acceptably. During system power on and power off checks, during all switching operations, during system exposure to range electromagnetic/RF energy, and considering bent pins in connectors, the maximum voltage/current applied to the EED shall be verified to be limited to no more than 10 milliamps.

Electrical circuit designs used for power, command, and control of the ignition system should be fail-safe and have validated an ability to prevent premature EED activation. The circuitry should preclude narrow band high-amplitude energy pulses near EED ignition thresholds during all switching operations. Measurements during switching operations should be made as part of system validation.

5.3.5.4 High Energy Electrical System

This type of initiation system uses a capacitive discharge source with voltage greater than 500 V to initiate EBW devices and EFI devices. For this type of system, minimum system capacitor energy shall meet the margin requirements of Section 5.2; maximum system capacitor energy shall be less than maximum level at which the device is verified to perform acceptably. Peak current and rise time associated with the laboratory firing setup shall be within 25% of those for the flight/operational system.

Power, command, and control circuits of the initiation system shall be failsafe and shall have a validated ability to prevent premature device initiation.

A safety device shall provide a positive interruption of the capacitor charging circuit and the trigger circuit. In addition, a redundant provision capable of gradually discharging the firing system capacitor circuit shall be provided.

Devices in these systems shall not function when subjected to a 500 V input from a 0.1 μ F -0% +20% capacitor, across input electrical conductors of the EED.

Devices in these systems shall not function when subjected to a 500 VDC applied across input electrical conductors for 5 minutes minimum.

Devices in these systems shall not function when subjected to 250 VAC applied across input electrical conductors for 5 minutes minimum.

5.3.5.5 Optical

This type of initiation system uses laser energy to initiate the LID. The minimum system energy level shall meet the requirements of Section 5.2; maximum system output shall be less than maximum level at which the device is verified to perform acceptably. The laser used in the system shall produce a pulse intensity and duration at least as great as that used to determine the device threshold level.

The optical interface with the fiber optic cable shall be designed to minimize the alignment loss and to protect against dust and moisture contamination.

Each lot of fiber shall be lot accepted to verify light transmission during and following exposure to environments. The fiber optic cable attaching to the LID shall be capable of surviving the same environmental exposures as the device itself.

Power, command, and control circuits of the initiation system shall be fail-safe and shall have a validated ability to prevent premature device initiation.

If a low energy end-to-end test is to be performed with the LID connected, the test shall use a different wavelength than that used by the firing laser and shall apply no more than 1% of the LID no-fire threshold when considering all single-failure modes of the system.

Electrical circuit designs used for power, command and control of optical ignition systems should be fail-safe and have validated their ability to prevent premature laser activation.

A system level built-in-test shall be utilized, in which a checkout laser pulse at a wavelength different from that of the firing laser pulse and the LID window design with wavelength transmission discrimination coating. The optical energy fluence in the fiber depends on the fiber core diameter and its numerical aperture, and therefore shall be selected for core diameter and numerical aperture to provide margin for initiating the explosive in the LID.

Testing of laser-initiated ordnance systems and components shall use flight-like firing systems and fiber optic cables including all intermediate cable connectors.

5.3.5.6 Addressable Initiator System

Addressable initiator systems allow coded signals to be multiplexed over a common line or conductor path to one or more initiators either simultaneously or sequentially. Use of addressable initiator systems shall ensure all safety, margin, reliability, and human engineering meet the intent of this standard for non-addressable initiation systems.

5.3.5.7 Mechanical

Mechanical initiation systems use kinetic energy to initiate explosive materials.

The system shall be fail-safe by providing a mechanical inhibit that will not be removed until the specified arming time. The inhibit will be designed to withstand all anticipated environments during handling, installation, and installed conditions. This type of system may require a mechanical interrupter in the explosive train.

5.3.6 Electro-Explosive System Protection

Electro-mechanical safe arm devices or electronic safe and arms, shall be used in applications where unplanned release of ET output energy, or its chain of events, may cause injury or death to people or severely damage property. These shall also be used in applications where first element designs are susceptible to initiation from external energy environments, e.g. EMI, RF, or ESD, if incident energy densities exceed accepted thresholds.

5.3.7 Transfer System

5.3.7.1 General

Explosive train systems transfer energy from the initiation system to the explosively actuated device. These systems shall be designed to ensure reliable initiation of the downstream element, and to reliably preclude initiation of the downstream element when an inhibit is required as part of the system.

5.3.7.2 Explosive Transfer Modes

As shown in Figure 2, end-to-end detonation transfer mode is preferred, but end-to-side and side-to-end modes may be used, in that order of preference. The side-to-side detonation transfer mode shall not be utilized.

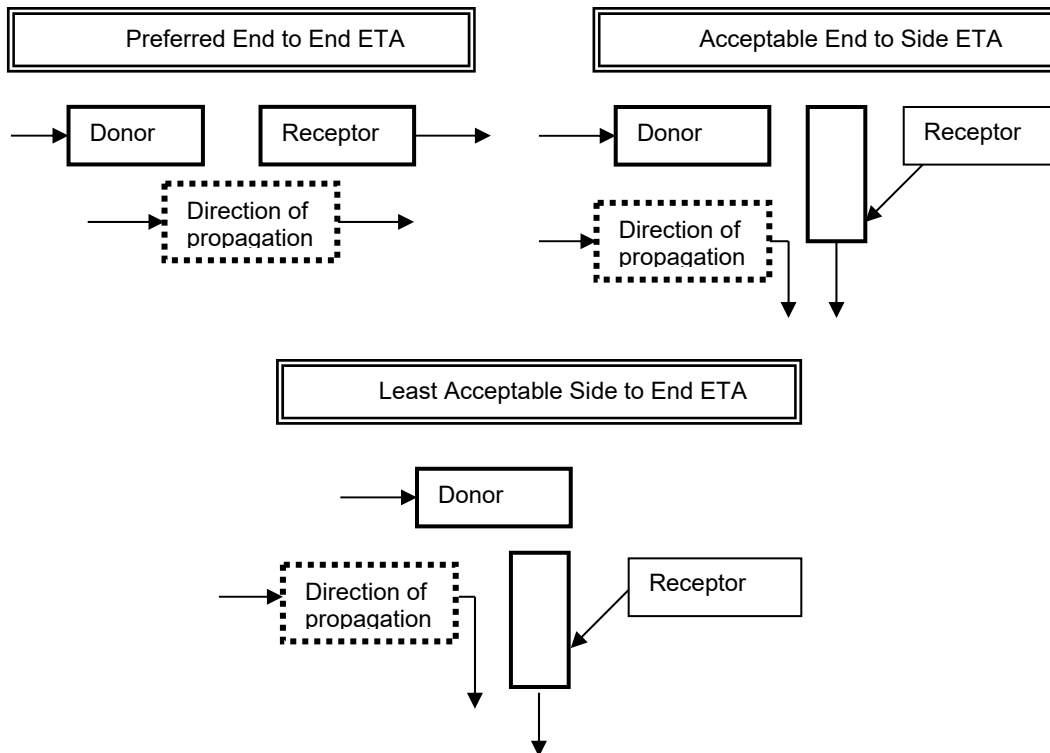


Figure 2 – Acceptable Explosive Transfer Modes

5.3.8 System Installation Design

5.3.8.1 General

Installation design must ensure that explosive components or systems do not need to be removed and replaced during normal vehicle maintenance.

5.3.8.2 Accessibility

System installation design shall provide for human access for installation of components into the vehicle and spacecraft.

All circuits shall be capable of being physically disconnected between the first element and its power supply as close to the first element as possible throughout all phases of ground operation.

First elements and associated circuitry shall be accessible to facilitate electrical checkout and final electrical connection as late as possible in the processing schedule.

Visual indicators shall be always visible through an access in an assembled spacecraft and vehicle configuration.

Safing pins shall be capable of installation into and removal from a completely assembled spacecraft or vehicle.

Explosive systems protected by an electro-mechanical S&A shall be capable of being manually safed during any phase of ground operations.

If the system is to undergo an arming verification test during any phase of ground operations, there shall be a capability to access and disconnect the explosive train from the S&A.

5.3.8.3 Flexible Transfer Line Installation

5.3.8.3.1

Free Length/Slack

Maximum length between tie points and allowable slack/routing shall be established to prevent damage in dynamic environments. Design shall ensure the installation remains within established limits.

5.3.8.3.2

Shrinkage

The design length of flexible cords shall allow for shrinkage after firing to prevent loss of confinement, damage to other components, and disconnection of end fittings.

5.3.9 Fragmentation and Fratricide

With the exception of destruct systems, there shall be no deleterious fragmentation resulting from the operation of any device in the explosive train. Fratricide in which the operation of one system disrupts function of another system, or in which the operation of one leg of a redundant system disrupts function of the other leg shall not be allowed.

For unconfined detonating cords, installation must ensure that the functioning of one cord does not damage any adjacent cords.

5.4 Component Design Requirements

5.4.1 General

All explosive devices shall be designed so as not to require any scheduled maintenance or repair during their service life. Designs shall accommodate easy installation, testing, or replacement at the user facility.

5.4.2 First Element Devices

5.4.2.1 General

First elements include low-voltage EEDs, EBWs, EFIs, LIDs, and mechanical initiators.

The output of electrical first elements of the ET shall be configured to be compatible with the next element of the ET. Performance shall also not be degraded by exposure to dynamic and thermal environments anticipated before or during use in the end item application.

5.4.2.1.1

Statistical All-Fire

Threshold tests and statistical analysis shall determine the current, power, or energy level at which a design will fire with a 99.9% reliability with a one-sided confidence level of 95%.

5.4.2.1.2

Sure-Fire

Each device shall have specified a sure-fire level that will provide reliable function of the device to meet all performance requirements over the range of applicable temperatures, for all lots, and before, during, and after environments. The surefire level shall be above the Statistical All-Fire level.

5.4.2.1.3

Bridge

For EED designs without discontinuities or gaps in their electrically conductive paths, the bridge shall be capable of withstanding repeated measurements of its resistance value throughout its service life without degrading functional performance or safety.

Carbon bridgewires are prohibited.

Electrically Conductive mix explosives shall not be used to replace the bridgewire.

5.4.2.1.4**RF Protection**

All low voltage EEDs and S&A Devices shall have shielding (Faraday) caps attached during storage, handling, transportation, and installation. The shielding cap shall have a solid metal outer shell which makes contact with the EED case in the same manner as the mating connector. Spring clips (shorting springs) or foil shall not be used to short EED pins.

5.4.2.2 Low-Voltage Electro-Explosive Device

All electrically conductive paths of the EED shall be isolated from the EED outer case. The insulation resistance between these conductors and the EED case shall be greater than 2 megohm minimum.

The EED shall not fire when the bridgewire is subjected to 1 amp or 1 Watt, whichever is greater, for 5 minutes. Following this test, the EED shall be capable of performing within specified limits.

5.4.2.3 Semiconductor Bridge Device

SCB devices shall meet the same requirements as low-voltage, capacitor-fired, EEDs.

5.4.2.4 High-Voltage Electro-Explosive Device

These include EBW and EFI EED designs that require more than 500 VDC for initiation. They use high-energy electrical systems for initiation.

Spark gaps, if used, shall be independently hermetically sealed.

For EED designs with gaps, the condition/continuity of the bridgewire may be determined by performance of a resonant frequency test, i.e. grid dip, or by breaking down the gap by a high voltage, short duration pulse coupled with a low current pulse applied while the gap is conducting. Acceptable limits for this test shall be established during the non-recurring phase of a program and then applied to subsequent flight lots.

For EED designs with gaps, acceptable limits for gap breakdown voltage shall be established during the non-recurring phase of a program and then applied to subsequent flight lots.

5.4.2.5 Laser Initiated Device

LIDs shall be fully characterized and shown to be compatible with firing system specific power density, spot size, pulse duration, and wave length characteristics applied at the LID light-to-energetic material interface. This characterization shall include a specified tolerance level for each characteristic.

LIDs contain an optical interface to allow passage of the laser energy from the firing system to the first fire explosive element. When containment of explosive combustion products is a requirement, the window shall withstand an internal pressure equal to four times its maximum internal peak operating pressure.

LID design shall maintain contact of the initiating explosive with the optical interface.

LID design shall verify that installation torque does not degrade reliability.

LIDs shall have an environmentally sealed protective cap installed on its input end at all times to maintain cleanliness of the optical interface.

The statistical all-fire and no-fire power levels shall be determined.

For LFUs with a built-in test including continuity to the LID, the test shall use a maximum of 1% of the LID no-fire level.

5.4.2.6 Mechanical Device

Mechanical devices utilize springs that convert potential energy to kinetic energy to initiate a primer.

5.4.2.6.1**Safing Mechanism**

Each device of this type shall have an integral safing mechanism connected to a removable safing pin and a "REMOVE BEFORE FLIGHT" streamer. With the safing mechanism installed, the device shall be incapable of firing.

5.4.2.6.2**Primer All-Fire**

The all-fire energy level of the primer shall be determined by statistical drop tests. Given a drop weight of W and statistical results of mean drop height and sigma, all fire level, AF , has been traditionally defined as the following

$$AF = W(\bar{h} + 5\sigma)$$

where

W = drop weight,

$\bar{h}$ = mean drop height,

σ = standard deviation.

The customer may alternatively specify the all-fire according to the definition in Appendix A2.

5.4.2.6.3**Firing Pin Energy Margin**

Minimum firing pin energy when considering worst-case tolerances (e.g., minimum firing pin stroke, minimum spring strength and rate, maximum friction during pin travel) shall be a minimum of two times (2X) the primer all-fire energy.

5.4.2.6.4**Firing Mechanism**

Pre-cocked firing mechanisms shall not be used.

5.4.3 Electromechanical and Mechanical Safe and Arm Devices**5.4.3.1 General**

For low voltage systems, electromechanical or mechanical S&A's shall be used in applications where unplanned initiation of the explosive system may cause injury, death, or severe damage to property.

5.4.3.1.1**Safe Position**

The S&A shall be safed by movement of a barrier between the EED and next explosive element or by misalignment of the EED and the next explosive element either of which will prevent propagation of the explosive path, and by disconnecting and shorting the firing electrical circuits. The safe condition is defined as

- a. The power and return firing lines shall be disconnected from the EED.
- b. The EED bridgewire shall be shorted and grounded through a resistor with a value between 10 and 100 kilohms.
- c. The explosive path shall be interrupted by the mechanical barrier between EED and downstream ET elements, that inhibits explosive energy transfer, or by misaligning the EED from remainder of explosive path.
- d. This disarming operation shall be accomplished without passing through the "armed" position.

5.4.3.1.2**Arm Position**

The arm position is defined as

- a. The short of the EED bridgewire shall be removed and power and return firing lines shall be connected to the bridgewire.
- b. The interrupter of the explosive path shall be removed to allow explosive energy transfer

5.4.3.1.3**Switch Chatter**

Chatter on ordnance firing circuits shall not result in any dropouts of more than 0.1 ms in duration. This limit is based on the typical EED firing time (bridgewire burnout time) of 1 ms.

5.4.3.1.4**Fratricide**

For S&A's with redundant EEDs, firing of one EED shall not result in firing of the other EED or damage to the other EED precluding it meeting performance requirements when fired.

5.4.3.1.5**Barrier Design**

The ET shall be termed "safe" when the S&A barrier is positioned between these elements so that explosive energy transfer cannot occur. Likewise, it shall be termed "armed" when the barrier is positioned to allow explosive energy transfer.

The electromechanical S&A design shall allow it to be driven to the "arm" position electrically but shall not allow it to be manually driven to the "arm" position.

The mechanical S&A design shall allow it to be driven to the arm and to the safe position mechanically.

The S&A barrier design shall provide a mechanical means to allow it to remain in "armed" or "safe" positions during all environmental conditions predicted for the application.

5.4.3.1.6**Barrier Performance**

The S&A barrier shall reliably inhibit explosive energy transfer between ET first and downstream elements. The demonstrations shall evaluate limits of all possible barrier misalignments relative to "safe" and "armed" positions to establish performance margin limits for both inhibit reliability and energy transfer reliability.

5.4.3.1.7**Status Indicators**

The S&A design shall provide remote and visible means to indicate the status of the device, i.e. armed or safe.

Visual indicators shall be located within the S&A and visible from the exterior. The visual indicator shall be readily discernible at least 15 degrees from a line-of-sight normal of the center of the indicator. It shall also be readable at a distance of 1.5 m away from the S&A. The visual indicators shall be highlighted using different colors, e.g. red background with a black "A" for "armed" and green background with a white "S" for "safe." The "safe" status indicator can be visible when the S&A barrier is within safe operation performance margin limits as determined by test or analysis. The "armed" indicator shall be visible when the S&A barrier position is within the region determined by tests and analysis to allow explosive energy transfer to the ET. The S&A user shall assume responsibility to ensure that indicators are visible when the S&A is installed in the application.

Remote indicators shall also ensure that "safe" and "armed" status is within the performance margin limits determined by tests and analysis, and use the same criteria established for positioning of visual indicators. The electrical continuity of one status circuit shall completely break before electrical continuity for the other status circuit is made.

The visual and remote “safed” indication shall not appear until the S&A has progressed more than 50% beyond the .999 at 95% no-fire transition position.

5.4.3.1.8

Safing Pin

The S&A shall include a fail-safe mechanical device that inhibits remote arming of the S&A during hardware processing. The safing pin shall be manually removed from the S&A to allow arming.

Removal of the safing pin shall not cause the S&A barrier to transition to the “armed” position. The S&A design shall prevent safing pin removal when electrical circuits are commanded to position the S&A barrier to “armed”.

When installed, the safing pin shall prevent the S&A barrier from being positioned to “armed,” as established by tests and analysis. A feature such as a highly visible “REMOVE BEFORE FLIGHT” streamer shall be attached to the safing pin to identify it as an item that needs to be removed before final use in the application.

It is the responsibility of the S&A user to ensure ready access in the application for safing pin removal and installation.

When the S&A is in the “safe” mode, the safing pin shall be retained within it by design features that can survive environmental conditions predicted by the application. These design features shall apply resistance during safing pin removal and installation but not more than 45 N of tension or 1.1 N-m of torque. The design shall also prevent removal of the safing pin if the S&A is energized. This design shall provide resistance of at least 450 N of tension or 11 N-m of torque without failure.

Mechanical retention of the safing pin shall be possible only when the S&A is in the safe position.

5.4.3.1.9

Stall

The S&A design shall be capable of meeting all performance requirements after application of maximum arming voltage applied for 5 minutes with safing pin installed. The S&A design shall also prevent premature initiation of any explosive component within the S&A if maximum operation voltages are applied to control circuits for 1 hour with the safing pin installed.

5.4.3.1.10

Switching Networks

Switching network designs using mechanical contacts for make-or-break circuits shall be validated by testing that they will not inadvertently open or close during dynamic environments predicted during use in the application. During transition from S&A barrier safe to armed positions, each switching network contact shall completely disconnect before connecting to the next circuit.

5.4.3.1.11

Power Circuit Safety

When the S&A barrier is in the safe position, the switching network shall ensure power paths to all ET first elements are disconnected; this is to be established by test and analysis. Also, in the safe position as established, the paths to ET first elements shall be shorted through appropriate resistance to ground. If this ground path remains connected when the S&A barrier is in the “armed” position, the ground path resistance value shall be at least 10 kilohm.

5.4.3.1.12

Simulator Resistors

An S&A may use a simulator resistor across each of the firing lines in the safe position to permit checkout of the firing circuit without energizing the electrical initiators. The resistor shall be capable of withstanding the application of twice the worst case current level and duration of the checkout equipment without initiation of any explosive component within the S&A or degradation of S&A subsequent performance. Programs should consider using the operational firing current and duration that will be applied by the vehicle avionics as that to be used for checkout of the firing circuits.

5.4.3.1.13**Rotor Leads**

All lots of rotor leads shall be acceptance tested as a separate component. Rotor leads shall be qualified as an installed component in the S&A.

5.4.3.2 Electrically Actuated

This type of device shall incorporate a means of remote electrical arming and disarming from any barrier position.

Remote and manual disarming shall be accomplished without passing through the arm position.

The operation of safing the unit shall be accomplished without passing through the "armed" position.

The device shall remain mechanically secured in the selected position under all operational environments without the application of any electrical signal.

There shall be no current flow exceeding 2 milliamps in the disarm or safe command circuit during the arming cycle nor in the arm command circuit during disarm or safing.

The S&A shall 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. The S&A barrier shall be capable of being manually positioned to "safe" during any phase of this cyclic life. This requirement shall be demonstrated during qualification tests. Post-test disassembly and inspection shall be used to confirm design adequacy.

5.4.3.2.1**Electrical Arming and Safing Time**

The time required to arm or safe the S&A, electrically actuated arm-disarm device, or other approved safing and controlling device shall not exceed 1 second after application of the actuation current.

5.4.3.3 Mechanically Actuated

This type of device shall incorporate the same features as electrically actuated devices except that arming and safing is performed mechanically. Normally these devices are armed by a lift-off lanyard or by stage separation. Electrically actuated devices shall be used unless justification for mechanical actuation is provided and approved by the procuring authority.

This device shall be designed to withstand repeated cycling from the armed to safe position for at least 300 cycles without malfunction, failure, or deterioration in performance.

5.4.4 Electronic Safe Arms (ESA)

Electronic Safe Arms are capacitive discharge firing units used in conjunction with EBWs or EFIs. The firing unit shall have a remote means of charging and discharging of the unit's firing capacitor.

5.4.4.1 Command Processing

The command and firing circuitry shall not trigger inadvertently when subjected to the guaranteed no-fire trigger performance levels. The trigger threshold shall be at least 10 times the worst case noise or leakage voltage.

The command and firing circuits shall trigger at 75% amplitude and 50% of the pulse duration of the lowest firing signal that could be delivered in flight.

The command and firing circuits shall trigger at 125% amplitude and 150% of the pulse duration of the highest firing signal that could be delivered in flight.

5.4.4.2 High Voltage Output

All high voltages shall be generated internally within the firing unit.

The firing (high voltage) capacitor circuit shall have a dual-bleed system with either system capable of independently discharging the capacitor charge.

At lowest system battery voltage and worst-case system tolerances, the firing unit shall deliver an output to the EBW or EFI that has margin above the all-fire level.

The EBW firing unit shall incorporate a high voltage capacitor adequate to store and deliver the required all-fire voltage plus a 50% margin.

The EFI firing unit shall incorporate a high voltage capacitor adequate to store and deliver the required all fire voltage plus an agreed-to margin not less than 100 volts.

Any high energy trigger circuit used to initiate the firing unit's main firing capacitor shall deliver an output signal of no less than a 50% voltage margin above the nominal voltage threshold level.

The high voltage system shall not arc at any atmospheric pressure up to the highest altitude for the system application.

Isolation resistance between each firing circuit and between firing circuit and any other circuit shall be a minimum of 40 megohms at 500 VDC.

The firing unit shall be hermetically sealed to the equivalent of 10^{-6} cm³/second of helium at one atmosphere differential pressure.

5.4.4.3 Output Monitors

Monitor circuits shall, as a minimum, provide status of the high voltage firing capacitor, trigger capacitor if used, inhibits, safe/arm status if different from high voltage capacitor status, and fire command status.

The monitor circuit for the firing capacitor shall provide an output voltage that is proportional to the voltage on the capacitor within an accuracy of +5%.

The firing unit shall be considered armed when the monitoring circuit indicates a firing capacitor voltage of at least 95% of nominal operating voltage but not less than the minimum allowable outputs to the EBW or EFI defined above.

The firing unit shall be considered safe when the firing capacitor voltage is one-fifth of the EBW/EFI no-fire voltage or 200 VDC, whichever is less.

5.4.4.4 Inhibit/Safing Circuitry

The firing unit shall provide a master arm/safe command for a positive, remotely controlled means of interrupting power to the firing circuit that is independent of other inhibits.

The firing unit shall provide for inhibits that remove continuity to the high voltage firing circuit power.

The firing capacitor shall have a bleed resistor between the high and return side of the firing capacitor.

Any logic device, e.g. FPGA, used in the implementation of safety features shall be permanently programmed for its final flight configuration, not load any data, not be reconfigured at power-up, and not use microprocessor based controls.

At least two of the safety features will be implemented with dissimilar logic devices.

Safety timing features, implemented within logic, shall not be susceptible to common cause failures resulting in premature arming.

The firing unit shall power-up in the safe condition.

5.4.4.5 Built-In Test (BIT)

If BIT is part of the design, it shall detect any condition that could prevent the firing pulse from being delivered to the EBW/EFI. If BIT includes delivery of energy to the EBW/EFI, that energy shall not degrade performance of the EBW/EFI or result in initiation as a result of firing unit piece-part failures.

The level used for BIT shall ensure a minimum margin of 100 between EBW/EFI no-fire level and the maximum BIT output. No failure or combination of failures in BIT circuitry shall result in a violation of this requirement.

BIT power and control circuitry shall be routed through a dedicated connector.

5.4.5 Laser Diode Firing Unit (LFU)

Laser firing units are used in conjunction with LIDs.

5.4.5.1 Command Processing

The command and firing circuitry shall not trigger inadvertently when subjected to the guaranteed no-fire trigger performance levels. The maximum guaranteed no-fire trigger threshold shall be at least 20dB above the worst case noise or current leakage environment.

The command and firing circuits shall trigger at 75% amplitude and 50% of the pulse duration of the lowest firing signal that could be delivered in flight.

The command and firing circuits shall trigger at 125% amplitude and 150% of the pulse duration of the highest firing signal that could be delivered in flight.

5.4.5.2 Firing Output

At lowest system battery voltage and worst-case system tolerances, the firing unit shall deliver a signal to the LID that is 50% greater than the LID all-fire level.

The firing unit shall be hermetically sealed to the equivalent of 10^{-6} cm³/second of helium at one atmosphere differential pressure.

The laser diode output spectrum shall be repeatable and reflect the output characteristics that were present during qualification.

Pulse duration delivered to the LID shall be a minimum of twice the duration used to determine the LID all-fire level.

5.4.5.3 Output Monitors

Monitor circuits shall, as a minimum, provide the following

- a. Status of all inhibits
- b. Continuous spurious energy monitor and/or detection circuit on the input firing line capable of indicating a minimum of one-tenth of the minimum input firing voltage
- c. Indication of commanded firing output
- d. Status of the master arm/safe circuit
- e. Status or result of BIT

5.4.5.4 Inhibit/Safing Circuitry

The firing unit shall provide a master arm/safe command for a positive, remotely controlled means of interrupting power to the firing circuit that is independent of other inhibits. A fire command shall not be processed while the unit is safed.

The firing unit shall provide for inhibits that remove continuity to the laser high and return firing circuit power. Each of these inhibits shall be initiated by a separate driver circuit though they may be activated by the same command input.

Any logic devices, e.g. FPGA, used in the implementation of safety features shall be permanently programmed for its final flight configuration, not load any data, not be reconfigured at power-up, and not use microprocessor based controls

At least two of the safety features will be implemented with dissimilar logic devices

Safety timing features, implemented within logic, shall not be susceptible to common cause failures resulting in premature arming.

The firing unit shall power-up in the safe condition

5.4.6 Linear Explosive Transmission

All energetic components, including the first and/or the S&A, must reliably transmit a detonation or deflagration to the subsequent components with all products being fully contained within their respective housings.

Linear explosive transfer devices, e.g. confined detonating cords, shall have fittings at each end to allow connection of them in the ET. The end fittings containing explosive charges shall accept inputs from the first element or S&A and continue to propagate the signal to the next device in the ET.

5.4.6.1 Interfaces

For applications where fragmentation of the fittings and failure to retain the fitting is not acceptable, tests and analysis shall show that the structural integrity during and after the explosive transfer event is maintained. Swelling of inert fittings should be taken in consideration in their design to avoid dumping the load to the mounting fasteners.

Interfaces shall be designed to correctly position and align the ETA end fittings to ensure reliable explosive energy transfer to the next element in the ET. Gap and alignment tolerances shall be minimized using geometrical dimensioning and tolerancing principles. Evaluation of these tolerances for reliable transfer shall include off-axis alignment of the ETA end cup.

5.4.6.2 Interrupters

All applicable S&A requirements above shall be satisfied.

5.4.7 Time Delays

In specific applications where sequencing of ballistic events is required, time delay components provide this timing. Accepting an input signal, providing the correct delay, and generating the required output signal is the primary function for these components. There are two general types of time delay components, pyrotechnic and electronic.

5.4.7.1 Pyrotechnic Delays

For pyrotechnic time delay components, a linear column of pyrotechnic or other energetic material having a defined burn rate is used. The time delay component shall accept a system input (e.g., detonation, ballistic, or mechanical signal) that initiates the deflagration of the time delay column and, after the defined delay, generates an output signal (e.g., detonation, deflagration, etc.) to another

explosive device in the system. Performance verification of time delays use the same methods used for energy transfer elements qualification and destructive acceptance, except that tests shall be performed with samples at predicted operating temperatures of the end item application in lieu of default temperatures to ensure that the time delay duration is within required limits in the thermal environment in which it will be used.

5.4.7.2 Electronic Delays

For electronic time delay components, an internal independent power supply shall accept a system input (e.g., detonation, ballistic, or mechanical signal), function a delay circuit, and provide sufficient energy to reliably initiate the energetic material required to generate the required output signal (e.g., detonation, deflagration, etc.) to another explosive device in the system. Performance verification of time delays use the same methods used for energy transfer elements qualification and destructive acceptance, except that tests shall be performed with samples at predicted operating temperatures of the end item application in lieu of default temperatures to ensure that the time delay duration is within required limits in the thermal environment in which it will be used.

5.4.8 Explosively Actuated Device

5.4.8.1 General

Explosively actuated devices are the final element of an explosive system.

Performance margin verification methods for explosively actuated devices are discussed in Section 5.2. Tests deemed necessary for performance verification of unique or novel configurations shall be included in the series of demonstrations. Examples of explosively actuated devices commonly used in space vehicle systems include CADs; TBIs; severance devices including LSCs; penetrating devices including EFPs, CSCs and LSCs; and fragmenting/fracturing devices.

5.4.8.2 Cartridge Actuated Device

CADs shall be designed to contain all explosive gas products upon actuation.

CADs are explosively actuated devices that usually contain internally moving parts and which perform a mechanical function. CADs are usually actuated by the pressure output from one or more separable pressure cartridges; however, CADs may contain an integral explosive charge. Pressure actuated separation nuts, separation bolts, pin-pullers, cutters, pyrovalves, and thrusters are examples of CADs.

All operational environments, mechanical loads, and the CADs associated interface and application shall be evaluated during design and verification of the CAD. Test set-ups, at both the component and system level, shall simulate the flight configuration to maximum extent practical. CADs shall be subjected to the margin test requirements of this specification where appropriate.

CAD performance shall not degrade due to potential pressure cartridge ejecta (e.g., closure disc, insulator materials, and unburned propellant) that might restrict gas flow through internal passageways.

Internal pressures shall be measured during development, margin testing, qualification, and lot testing. This information can then be used to establish performance limits for associated pressure cartridges. This is especially important if the pressure cartridges are manufactured and accepted separately from the CAD, or if the CAD and pressure cartridge are manufactured by separate organizations. Post-test radiographic inspection, disassembly, and dissection shall be used to assist evaluation of device performance.

5.4.8.2.1

Separation Nuts

Pressure actuated separation nuts are defined as those that use pressure from one or more explosive cartridges to actuate an internal mechanism to release a pre-segmented and assembled nut which in turn releases the bolt or stud. Systems utilizing separation nuts shall include the following provisions:

- a. 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 preloading.
- b. A means to accurately determine bolt preload shall be incorporated into the system design and assembly procedures.
- c. Separation nut applications shall preclude application of moments to the separation nut.
- d. Separation nut design shall consider minimum and maximum bolts insertion lengths.

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

5.4.8.2.2 Pin Pullers

Pin pullers are explosively actuated devices with a pin that retracts on actuation of one or more explosive cartridges.

The retractable pin shall have a mechanism that prevents rebound of the pin after its initial stroke.

Pin pullers shall be designed to accommodate loads in double shear. However, the pin puller also must accommodate any bending that might occur during pin retraction.

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

5.4.8.2.3 Thrusters

Thrusters are explosively actuated devices with a piston that extends on actuation of one or more explosive cartridges.

Thrusters shall be designed to accommodate compressive loads as well as loads in double shear.

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

5.4.8.2.4 Mortars

Mortars are cartridge or gas generator driven devices that typically consist of a separable cartridge, a cylindrical housing, a sabot, and a mass to be ejected at a predetermined velocity. Upon initiation, hot gas is introduced into a volume behind the sabot, and both the mass and the sabot are ejected.

Mortars shall be capable of deploying a defined mass (maximum design limit) at a velocity that allows basic function of the deployed mass, e.g. bag strip or line-stretch. This functional event shall be accomplished with a gas cartridge loaded to 80% of the minimum designed explosive charge, fired against a nominal target.

Mortars shall not induce a detrimental load into the platform on which the Mortar is mounted, when the mortar is fired with pressure cartridge(s) loaded with 120% of the maximum designed explosive charge(s).

5.4.8.2.5 Cutters

Cutters are explosively actuated devices that contain a blade and anvil. On initiation of one, or both explosive cartridges, the blade is driven towards the anvil severing any item in its path (e.g., electrical wires, braided textiles, steel cables, rods, tubing, or bolts). Systems utilizing cutters shall include the following provisions:

The target material to be severed shall be defined in all specifications, test procedures, and installation procedures. Target drawings shall also specify that no changes be made that effect cutter performance.

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

The cutting of electrical cables may cause prolonged contact between conductors and this characteristic must be conveyed to appropriate system designers and users.

Cutters with removable anvils shall have removable explosive cartridges.

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

5.4.8.2.6

Pyrovalves

Pyrovalves are used for fluid flow control. On actuation, the explosive train drives the piston to either shear the flow barrier to open the media flow path or push the flow barrier into the media flow path to close it.

If the fluid flow direction is critical then mating tube fittings shall be differently configured.

The pyrovalve piston shall remain in its actuated position when subjected to a back pressure of at least twice the peak fluid operating pressure.

Pyrovalves shall be designed to isolate explosive gas products from any reactive fluid flow path or any flow path with contamination concerns.

5.4.8.3 Separation Bolts

Separation bolts are devices that fracture at a specified position along their length to permit release and separation of two bodies. Systems utilizing separation bolts shall include the following provisions:

The bolt, and its application, shall consider worst case loading, dimensional tolerances and environments in its design.

If bolt capture devices are used, they must be designed and tested to ensure that bolt halves do not degrade any adjacent structure, system or component.

A means to accurately determine bolt preload shall be incorporated into the system design and assembly procedures.

Separation bolt design shall consider flight containment structure to ensure adequate bolt separation.

5.4.8.4 Shaped Charge

Charge holders, or locating devices as appropriate, shall be used for all shaped charge functions to ensure proper charge orientation and standoff. Charge holders and other attachment fittings to position shaped charges shall be designed to survive the same environmental exposures as the devices themselves.

Linear Shaped Charge Assemblies shall be designed to accommodate any dimensional change in structural interfaces due to thermal expansion/contraction or expansion due to flight conditions.

5.5 Operations and Maintenance

5.5.1 Age Surveillance of Explosive Components

5.5.1.1 General

Although the specific component design may have satisfied all material compatibility tests and analysis, subtle lot-to-lot manufacturing and processing variations may have adverse effects on a particular production lot of the design. Potential adverse effects can only be determined by inspections of samples from each production lot. These inspections are destructive; therefore, they cannot be performed on items to be used in the end item application. The solution is to perform a periodic age

surveillance test of samples from each production lot. Surveillance tests can then be used as tools to detect potential anomalous conditions before other items from the lot are used in the end item application.

5.5.1.2 Age Surveillance

Age surveillance tests are performed to extend the service life of the component lot by one year.

Testing should be performed in a timely manner to support end use but allow schedule recovery should an anomaly occur.

The tests can be repeated at time intervals determined to best fit end item application needs.

There is no limit to the number of tests performed on any specific production lot of components.

5.5.1.3 Accelerated Age Surveillance

Accelerated age surveillance tests are performed to extend the service life of the component by more than one year. The accelerated aging factor is a ratio of reaction rate at test temperature compared that at the highest storage temperature. One method of conducting an accelerated aging test program is presented below. These extensions can be three years or more depending on the specific application.

This test exposes the components to 71°C for 30 days and 40 to 60 percent relative humidity. Longer test durations may be used to provide life extension beyond three years. Shorter test durations may be used to provide life extension less than or beyond three years if the maximum storage temperature is verified to be low; ref AIAA-2007-5138.

The tests can be repeated at time intervals determined to best fit end item application needs.

There is no limit to the number of tests performed on any specific production lot of components

If the component to be tested is in any way damaged by exposure to 71°C, lower temperatures may be used according to the Arrhenius equation:

$$k = A \times \exp\left(\frac{-E_a}{R \times T}\right)$$

where

k = the reaction rate coefficient,

A = Arrhenius rate constant,

E_a = the activation energy,

R = the universal gas constant ($8.314 \times 10^{-3} \text{ KJ mol}^{-1} \text{ K}^{-1}$), and

T = the temperature (in degrees Kelvin).

k, A, E_a need to be determined from chemical reaction data specific to the material being tested.

The following simplified equation may be used for engineering purposes to determine the extension of service life as a function of test time and temperature:

$$H_L = H_T \times 3^{\frac{(T_1 - T_2)}{11.1}}$$

where

H_L = service life (in hours),