

Standard

Criteria for Explosive Systems and Devices on Space and Launch Vehicles

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Standard

Criteria for Explosive Systems and Devices on Space and Launch Vehicles

Sponsored by

American Institute of Aeronautics and Astronautics

Approved

10 November 2005

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.

Library of Congress Cataloging-in-Publication Data

Criteria for explosive systems and devices used on launch and space vehicles / Sponsored by American Institute of Aeronautics and Astronautics.

p. cm.

"AIAA S-113-2005 Standard."

Includes bibliographical references.

ISBN 1-56347-772-6 (hardcopy) -- ISBN 1-56347-773-4 (electronic)

1. Explosives in astronautics--Standards.

TL784.P9.C75 2005

629.47'5--dc22

2005012387

Published by
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Reston, VA 20191

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Printed in the United States of America

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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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The above consensus body approved this document in October 2005.

The AIAA Standards Executive Council (Mr. Amr ElSawy, Chairman) accepted the document for publication in November 2005.

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Introduction

Explosive systems include components and assemblies that provide stimuli for initiation and propagation of explosive trains used to activate explosive devices. Explosive trains and devices are mechanical components or assemblies containing or operated by explosive materials. The latter 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.

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 exceptional 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.

AIA NASM 33540	<i>General Practices for Safety Wiring, Safety Cabling, Cotter Pinning</i>
AIAA-2005-4039	<i>Advanced Applications of Statistical Methods in Testing of Energetic Components and Systems</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-STD-810	<i>Environmental Engineering Considerations and Laboratory Tests</i>
MIL-STD-1168	<i>Ammunition Lot Numbering and Ammunition Data Card</i>

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

BKNO ₃	Boron Potassium Nitrate
BNCP	Tetra-amine bis(5-nitro-2H-tetrazolato-N ₂) cobalt(III) perchlorate
CAD	Cartridge Actuated Device

CP	Penta-amine(5-cyano-2H-tetrazolato-N2) cobalt(III) perchlorate
CSC	Conical Shaped Charge
DDT	Deflagration-to-Detonation Transition
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
F/CDC	Flexible/Confined Detonating Cord
F/LSC	Flexible/Linear Shaped Charge
GRMS	Root Mean Square Average Acceleration in Units of Gravity
HBW	Hot Bridgewire Device
HE	High Explosive
HMX	His Majesty's Explosive or High Melting Explosive, Cyclotetramethylene tetranitramine
HNS	Hexanitrostilbene
HVD/I	High Voltage Detonator/Initiator
LID	Laser Initiated Device
LPI	Lanyard Pull Initiator
LSC/A	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
PETN	Pentaerythritol Tetranitrate
RDX	Research and Development Explosive, Cyclonite, or Cyclotrimethylene Trinitramine

RF/I	Radio Frequency/Interference
S&A	Safe and Arm Device
SCB	Semiconductor Bridge
SDT	Shock-to-Detonation Transition
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

Batch

specific quantity of bulk explosive material prepared as a unit during manufacturing, chemical mixing or other processes and has been stored and handled as a unit

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 cartridges

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

NOTE Explosive signal propagation velocity is typically 6000 to 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

lowest temperature at which a detonation or deflagration of an explosive material occurs. Temperature exposure time/rate is application dependent

Crossover Booster

explosive connection or link between redundant explosive trains

Deflagration

very rapid combustion with a chemical reaction propagation velocity which is subsonic

Deflagration-to-Detonation Transition (DDT)

physical process in which the initial deflagration wave front in the material rapidly transitions into detonation

Detonation, High Order

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

Detonation, Low Order

see deflagration

Donor

charge that transmits an explosive signal into a receptor

Dud

explosive charge or component that fails to fire or function upon receipt of the prescribed initiating stimulus

Electro-Explosive Device (EED)

first and most sensitive 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 on the surface of solid objects

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)

EED in which the bridgewire explodes when functioned; this explosion is used to directly initiate secondary explosive materials

Exploding Foil Initiator (EFI)

detonator that produces a shock output from high voltage acceleration of a flyer plate that impacts the acceptor charge at supersonic speed

NOTE The EFI contains no primary explosive material.

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 including the first element, explosive transfer assembly, and 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 a hemisphere of very small curvature which is converted into a kinetic energy penetrator when detonated

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

High Voltage Detonator/Initiator

see Exploding Bridgewire Device

Hot Bridgewire Device

low voltage EED

Laser Initiated Device (LID)

first element containing explosives that is ignited by laser energy

Linear Shaped Charge

linear explosive charge in a metal sheath whose cross-section is formed into a chevron shape

NOTE The chevron shape results in a jet of flowing sheath material expelled perpendicular to the linear propagation of detonation waves.

Mild Detonating Fuse (MDF)

thin ductile metal tube containing high explosives

NASA Standard Initiator (NSI)

EED designed by the National Aeronautics and Space Administration

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 inorganic fuels and oxidizers that can explode

Receptor

see Acceptor

Refurbish

partially 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

Rotor Lead

explosive charge contained in a can or in pellet form used within a device to transfer a detonation from one point to another downstream of the first element

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 film semiconductor as the bridgewire element

Sensitivity

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

Shielded Mild Detonating Cord (SMDC)

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

Shock-to-Detonation Transition (SDT)

process occurring when a shock wave impacting a secondary explosive is not strong enough to initiate detonation directly but does cause a chemical decomposition that accelerates until it becomes a self-supporting detonation wave within the material

Squib

small first element device loaded with deflagrating material

Thermal Time Constant

characteristic time for heating up 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

NOTE Explosive signal propagation velocity is typically 1200 to 1500 m per second.

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

An explosive system comprises an initiation system, first element, transfer system and explosively actuated device. See Figure 1.

Explosive systems furnished under this specification, or under associated detail specifications, 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 test of Section 6.
- Components are from a lot which meets the requirements of this section and that has passed the acceptance tests specified in Section 6. If prior lot acceptance testing has not met the requirements herein, testing and/or analysis shall be conducted to verify the compliance.
- Components are from a lot that has verified service life for the scheduled operational use. Life extension testing is described in Section 6.

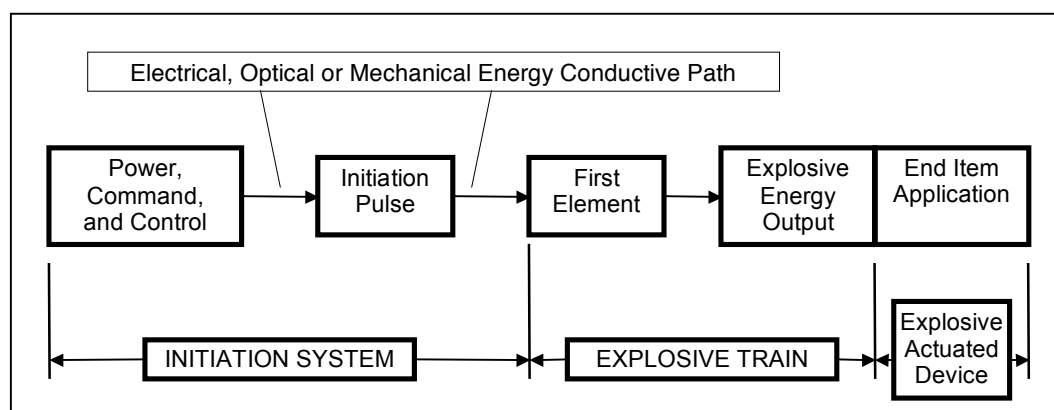


Fig. 1 — Explosive System Flow Diagram

5.1 General Requirements

Explosive systems and components shall meet the following general requirements.

5.1.1 Environmental Determination

Explosive systems and components shall be designed to survive and perform intended functions during and after exposure to dynamic, thermal, humidity, pressure, electromagnetic, safety, or other environments that are predicted to be encountered during transportation, storage, and handling in use of the end item application.

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 shall also ensure that all appropriate tests or analyses are performed.

5.1.2 Performance Requirements

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 Explosive System 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 explosive system should be designed to be two-fault tolerant. A catastrophic event is defined as loss of life, injury, or severe damage to equipment or facilities.

5.1.5 Design Life

Explosive systems and components shall be designed to have useful lives commensurate with the end item application. All explosive systems and components containing age-sensitive materials shall be identified, and an age surveillance program for them shall be established. Design life shall be reassessed periodically to ensure that performance has not degraded with time.

5.1.6 Sealing

Explosive devices shall be sealed with a maximum allowable leak rate equivalent to 5×10^{-6} (atm · cm³)/s of the gas medium used for the test. End item components or assemblies shall use environmental sealing techniques that prevent external elements or contaminants from interacting with explosive materials installed in them. 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

Explosive systems and components shall be designed to survive external applications of an ESD environment. 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.

Analyses shall confirm that there are no sneak circuits or unplanned capacitance discharges that could cause initiation. Verification of effectiveness of these features shall be based on inspection, test, and analysis.

First elements used in explosive systems that are potentially susceptible to premature initiation or degraded performance by an ESD energy field shall be tested to verify survivability.

5.1.7.3 EMC

The explosive system power, command, and control electrical circuitry shall be designed to limit generation of electromagnetic fields in sensitive components to a level at least 20 dB below the no-fire power rating of the first element. The explosive system shall also be capable of shielding these sensitive components to the same levels noted above when exposed to externally generated electromagnetic fields. Control circuits shall be designed to limit the power level at any inhibit to at least 6 dB below the minimum activation power.

5.1.7.4 Radio Frequency

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 exposures 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 or the explosive device 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, including explosives and adhesives, in contact with each other 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-Sensitive Material

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 Energetic Materials

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 components and systems containing them pass performance tests defined in this specification and conform with the safety regulations.

5.1.8.6.1 Primary Explosives

The use of primary explosives shall be minimized consistent with achievement of reliable performance.

5.1.8.6.2 Upper Temperature Limit

The decomposition, cook-off, 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, or orbit. Thermal shielding, if proven to be effective, may be adopted.

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

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

Cadmium and zinc platings shall not be used.

Plating with pure metals such as tin shall consider the detrimental effects of whisker growth.

5.1.8.7.2.2 Stress Corrosion

Materials 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.

High strength steel parts heat treated at or above 1241 MPa ultimate tensile strength 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 Nonmetallic Materials

Materials selected shall survive thermal and dynamic environments and demonstrate performance as described by tests in this specification. Use of materials with a high shock transmissivity shall be avoided in close proximity to explosively actuated devices.

5.1.8.9 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.

5.1.8.10 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 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 and contaminants, the component shall be mounted in such a manner as to protect optical sensors and thermal control surfaces.

5.1.11 Recovering from Environmental Exposure

The design documentation shall identify all explosive components that cannot be reworked to specification(s) after exposure to certain environmental conditions that could create permanent chemical or physical change.

For example:

- Explosive devices or components that fail gross leak check (using liquid as the test medium) shall not be reworked or repaired by resealing the leak joint by welding, application of additional sealant or any other method.
- Gross leaked TLX shall not be reworked as the test may cause powder redistribution inside the tube.

5.1.12 Mechanical Components

Requirements for mechanical components not referenced herein are presented in AIAA S-114-2005.

5.1.12.1 Threaded Parts

A minimum engagement of five full threads is required for threaded attachments or, 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.

5.1.12.2 Locking Devices

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

Preferred locking devices are safety wire, 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 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.

Use of thread-locking compound is acceptable and shall meet all compatibility requirements of this specification.

5.1.12.3 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.

5.1.13 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. A high output from the explosive device in staging application may deform the adjacent component of vehicle that may cause a failure.

5.1.14 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.

5.1.15 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 M Ω ;
- b) safe and arm housing to structure: Less than 10 M Ω ;
- c) non-electrical ordnance component to non-electrical component or to structure: Less than 1 Ω ;
- d) non-electrical, linear ordnance component end to end (LSC, FLSC, FCDC, etc): Less than 10 Ω .

5.1.16 Manufacturing and Quality

5.1.16.1 General

Explosive components and systems shall be manufactured in accordance with established processes and criteria that can be verifiable by established 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 and results documented. Traceability of critical materials, components, and processes shall be documented for each manufacturing lot.

5.1.16.2 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 and referenced specifications, procedures, drawings, and supporting documentation establishes 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 for evaluation. These changes, which shall be controlled by the supplier, provide the basis for flight accreditation of subsequent production lots.

5.1.16.3 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 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.

5.1.16.4 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.

5.1.16.5 Refurbishment

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

5.1.16.6 Identification and Marking

Explosive systems and components shall be permanently identified, to include as a minimum the part number, serial number, and manufacturer identifier.

5.1.16.6.1 Not-For-Flight Marking

Items not suitable for flight use, which could be substituted for flight or flight spare hardware, shall be red tagged or striped with a unique color paint, or both to prevent such substitution. The red tag shall be conspicuous and marked "NOT FOR FLIGHT."

5.1.16.6.2 Lot Number

Lot numbers shall be assigned to each production lot in accordance with MIL-STD-1168.

5.1.16.6.3 Serial Number

Components or assemblies requiring control shall be assigned a unique (non-repeating) serial number for each unit manufactured.

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.

5.1.17 Explosive Hazard Data

Explosive hazard data shall be maintained for each component, subassembly, and assembly, as appropriate. Data shall include chemical compositions and weights, net explosive weight, safety information, and may be contained in documents such as MSDS, Hazardous Component Safety Data Statements, or Competent Approval Authority letters. Data shall be updated as configuration changes are made and traceable to configuration.

5.1.17.1 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.

5.1.17.2 Material Safety Data Sheet

The supplier shall provide MSDS to address all hazards of the explosive component, subsystem, or system being delivered.

5.1.17.3 Ammunition Data Card

When specified, an Ammunition Data Card, or a copy, prepared by the supplier, shall accompany each shipment of explosive devices or assembly of devices.

Ammunition data cards shall meet the requirements of MIL-STD-1168.

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 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 worst 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.

Initiation system output parameters shall be maintained during margin testing.

5.2.2.1 Electro-Explosive Device

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 voltage level of the device.

5.2.2.2 High-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 2.0 times the sure-fire energy of the device.

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 device; maximum system output shall be less than maximum level at which the device is verified to perform acceptably. For primers and stab initiators, the statistical all-fire is defined as drop weight times the sum of mean firing height plus five standard deviations.

5.2.3 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.

5.2.4 Explosive Energy Transfer

5.2.4.1 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.

5.2.4.2 Detonation Transfer

5.2.4.2.1 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.

5.2.4.3 Transfer Through Bulkhead

All detonation transfer interfaces through solid material shall perform with margin when the solid material thickness is increased to 20% more than design maximum and with nominal donor and receptor charges. If the solid material is to remain unruptured 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.

5.2.5 Cartridge Actuated Device

All CADs shall perform within specified limits when actuated by a single cartridge having 80% or less of the minimum specified cartridge output.

All CADs shall perform within specified limits when actuated by dual cartridges having at least 120% of maximum specified cartridge output. The CAD shall not rupture under these conditions.

All CADs that are required to operate under a load, shall not rupture when functioned with two nominal cartridges in the no-load condition.

All CADs that are required to operate under a load, shall perform within specification limits with one nominal cartridge when the load is increased to 50% more than the maximum predicted operating load.

If there is any possibility that the CAD may function in a locked shut condition, the CAD shall not rupture when fired with two nominal cartridges and all internal moving components shall be restrained so no motion is possible.

5.2.6 Severing and Penetrating Device

Performance margins for devices used for severing or penetrating shall be determined by tests and analyses. Performance margins shall be demonstrated using nominal charges, positioned at maximum

standoff, directed at a substrate with a thickness 1.5 times the maximum thickness to be used in the end item application. Alternatively, the explosive charge may be reduced to 67% of nominal core load and the substrate maintained at nominal thickness. Substrate materials shall be identical to those to be used in the end item application. Test fixtures shall simulate the end item application, including all materials in contact with it, to the extent practical.

5.2.7 Fracturing Devices

Devices that rely on the fracturing of a load-carrying web, membrane, or annulus, such as those in frangible nuts and explosive bolts, shall meet the margin requirements of Section 5.2.4.1. However, when it is impractical to vary the explosive charge weight, a single nominal explosive charge shall be capable of fracturing a device with a cross sectional area at least 20% greater than the maximum design cross section.

5.2.8 Linear Thrusting Joints

Linear thrusting joints shall be capable of performing their end function when actuated by an explosive charge that is no greater than 80% of the minimum specified explosive charge weight, and when actuated by an explosive charge that is at least 120% of the maximum charge weight, with no increase in the initial free volume.

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 device.

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

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

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. Exceptions will be evaluated on a case-by-case basis.

Acceptable redundancy can be achieved by providing two ET inputs, one at each end of a linear device. Acceptable redundancy can also be achieved by using dual inputs to a single explosively actuated device.

Dual bridgewire EEDs are not considered to be redundant within themselves.

Redundant explosively actuated devices shall be used to perform a function. When vehicle design considerations necessitate the use of a single device to perform a function, dual inputs shall be used to initiate/actuate the device. Firing of either or both inputs shall provide operational success. Firing of the first input shall not compromise function of the redundant input.

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. To achieve this goal, higher reliability shall be apportioned to all components in the system.

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 k Ω .

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 k Ω 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 k Ω 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. The return path, on all circuits, shall be selected to minimize voltage buildup and transients on the firing circuit return with respect to the single point ground.

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, or shielded from the EED to eliminate RF energy into the shielded portion of the system. Isolators shall provide 20 dB attenuation (regardless of source and load impedance) at all frequencies of the expected electromagnetic environment. The adequacy of the RF protection provided by these isolators 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 mega-ohm.

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 20 dB below the no-fire current level in any firing circuit.

Control circuits shall be electrically isolated so that a stimulus in one circuit does not induce a stimulus greater than 20 dB below the no-fire current level in any firing circuit.

5.3.5.2.7 Physical Separation

Firing output circuits shall be physically separated 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 are 10 kΩ 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.

Monitoring currents shall be limited to 50 mA or one tenth of the no-fire current level of the EED, whichever is less.

Test equipment that applies current to the bridgewire shall be designed to limit the current to 10 mA.

Monitoring circuits shall be designed to preclude the possibility of a current greater than stated herein to flow during 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 backshell.

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 50 mA or one tenth of the no-fire current, whichever is less, 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 MΩ for low-voltage EEDs or 20 MΩ 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 1% of EED no-fire level or 10 mA, whichever is less.

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 above 500 VDC capacitive discharge source 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 output shall be less than maximum level at which the device is verified to perform acceptably. The capacitor used in the system shall have a capacitance at least as great as that used to determine device threshold level. System inductance and resistance shall be bracketed by those used during determination of device threshold level.

Power, command, and control circuits of the initiation system shall be failsafe and shall have a validated ability to prevent premature device initiation. 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 1% of device no-fire level.

High voltage ignition system designs shall provide voltage inputs to the EED that are at least 20% greater than EED all-fire ratings using capacitance values equal to or greater than those specified by the EED. These criteria should be verified by tests during development, acceptance and qualification of the ignition system design. The system should have validated an ability to provide the outputs specified when subjected to dynamic and thermal environments anticipated before or during use in the application. Electrical circuitry designs used for power, command and control should be fail-safe and have validated their ability to prevent premature EED activation. Validation that maximum energy inputs do not exceed EED design limits should also be done.

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

Devices in these systems shall not function or be degraded when subjected to a 500-VDC input from a 1.0 μ F capacitor, applied for 1 min minimum, across input electrical conductors of the EED.

Devices in these systems shall not function or be degraded 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. 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 energy applied to the LID shall be verified to be limited to no more than 1% of device no-fire level.

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 is preferred for the safety. A temperature off-set design shall be adopted in the laser firing package. 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 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, i.e., 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

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. See Figure 2.

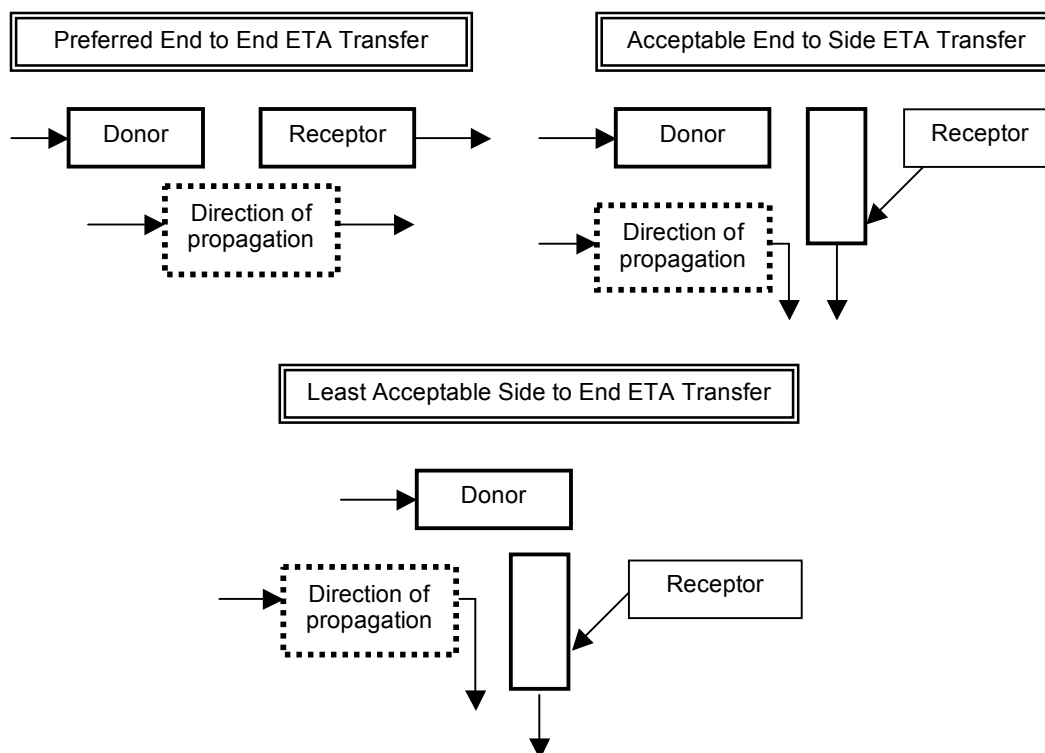


Fig. 2 – Acceptable Explosive Transfer Modes

5.3.8 System Installation Design

5.3.8.1 General

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

5.3.8.2 Accessibility

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

Ensure all circuits are 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 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 or 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.

Protective covers shall be designed to meet the requirements of 6.2.10.

5.4 Component Design Requirement

5.4.1 General

All explosive devices shall be designed so as not to require any scheduled maintenance or repair during their service life. The 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.

5.4.2.2 Bridgewire

For EED designs without discontinuities or gaps in their electrically conductive paths, the bridgewire 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.

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

5.4.2.3 Post-Fire Short Circuit Protection

As specified in Section 5.3.5.2.14, if the firing system is required to ensure an open EED firing circuit exists after EED firing, the EED must provide this post-fire minimum open circuit resistance.

5.4.2.4 Shorting Devices / RF Protection

The design shall include a provision for shorting all contacts to each other. Once the initiator is assembled, adequate protection from RF, ESD, and handling damage shall be provided.

5.4.2.5 Booster Charges

Booster charges can be configured to be an integral part of the first element or be a separable assembly.

Electrically conductive explosive charges within EEDs and adjacent to the bridgewire shall be electrically isolated from the EED case.

5.4.2.6 All-Fire

5.4.2.6.1 Statistical All-Fire

Tests and analysis should determine the current, power, or energy level at which a design will reliably function. This should yield an input energy level, known as the statistical all-fire rating, at which, as a minimum, 99.9% of the units from each design will function with a confidence level of 95%.

5.4.2.6.2 Sure-Fire

Each device shall have specified a firing level that will provide reliable function of the device over the range of applicable temperatures, for all lots, and before and after environments. It also must ensure that the maximum function time requirement is conformed.

5.4.2.7 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 MΩ minimum.

All EEDs in a low-voltage capacitive firing system shall fire when subjected to currents between sure-fire and 22 A.

The EED shall not fire when the bridgewire is subjected to the no-fire current. Unless otherwise specified, the minimum no-fire current shall be 1 A applied for at least 5 min. Firing probability when subjected to the no-fire current shall be less than 0.001 at 95% confidence level. Following exposure to this no-fire current, the EED shall be capable of performing within specified limits.

The EED shall not fire when the bridgewire is subjected to the no-fire power. Unless otherwise specified, the minimum no-fire power shall be a DC power of 1 W applied for at least 5 min. Firing probability when subjected to the no-fire power shall be less than 0.001 at 95% confidence level. Following exposure to this no-fire power, the EED shall be capable of performing within specified limits.

5.4.2.8 Semiconductor Bridge Device

SCBs shall meet the same requirements as low-voltage, capacitor-fired, EEDs. SCBs may be integrated into addressable, or intelligent, initiation systems. In this case, each individual SCB contains electronics that allow the device to be fired upon receipt of a properly encoded arming/firing signal, and reject improperly coded signals.

5.4.2.9 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 of the bridgewire shall be evaluated by first determining acceptable limits of resonant frequency measurements of the EED electrical circuit design and then performing measurements on each EED produced. Alternatively, the continuity may be measured by supplying a high voltage, limited duration current to break down the gap. The resistance can then be determined by measuring voltage and dividing that value by the current used.

For EED designs having interrupts or gaps in their electrically conductive paths, measurements of the amount of voltage required to arc across the gap shall be made as a means of the validating acceptability. The acceptable limits of this slow rise-rate breakdown voltage test are unique to each EED design and shall be determined during development.

5.4.2.10 Laser Initiated Device

LIDs shall have specific power density, spot size, pulse width, and wave length characteristics with 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 may use pyrotechnic or secondary explosive as the initiating explosive consistent with the LID end application. Modification of explosives is permissible (e.g., adding carbon) if required to ensure reliable initiation, however, their sensitivity characteristics shall be established in accordance with procuring authority approved government, commercial, or supplier procedures.

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

The all-fire and the 5-min no-fire power shall be determined. The minimum all-fire power level shall be at least 10 times the no-fire level. If the LFU has a built-in test, then the energy level shall not exceed 1/10,000 the no-fire energy measured at the LID.

5.4.2.11 Mechanical Device

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

5.4.2.11.1 General

Percussion initiators shall be designed such that the all-fire energy does not exceed 50% of the minimum supplied operating energy. The no-fire energy shall be no greater than 50% of the all-fire energy.

5.4.2.11.2 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.

5.4.2.11.3 Primer All-Fire

The all-fire 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 , is defined as the following:

$$AF = 2 \times W(\bar{h} + 5\sigma)$$

where

W = drop weight,

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

σ = standard deviation.

5.4.2.11.4 Firing Pin Energy Margin

Minimum firing pin energy when considering worst-case tolerances (e.g., minimum firing pin stroke, minimum spring strength and rate, or maximum friction during pin travel) shall be greater than the all-fire energy.

5.4.2.11.5 Firing Mechanism

Pre-cocked firing mechanisms shall not be used.

5.4.3 Safe and Arm Device

5.4.3.1 General

S&As shall be used in applications where unplanned initiation of the explosive system may cause injury, death, or severe damage to property.

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 device shall not be capable of being manually armed, but shall be capable of being manually disarmed.

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

5.4.3.2.2 Electrical Contacts

Electrical switching contacts shall be designed such that the specified vibration environment shall not cause an inadvertent make or break (chatter). Contacts that physically prevent closure (e.g. wiping type, disc-mounted) in the unarmed position are the preferred type of contact.

5.4.3.2.3 Safing

The S&A shall be safed by movement of a barrier between the EED and next explosive element to a position which inhibits detonation or initiation transfer, or misalign the EED and the next explosive element, and by disconnecting and shorting the firing electrical circuits as follows.

- a) In the safe position, both power and return firing lines shall be disconnected.