DOCUMENT 319-10
(PUBLIC RELEASE)

RANGE SAFETY GROUP

FLIGHT TERMINATION SYSTEMS COMMONALITY STANDARD (PUBLIC RELEASE)

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REAGAN TEST SITE
YUMA PROVING GROUND
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ELECTRONIC PROVING GROUND
HIGH ENERGY LASER SYSTEMS TEST FACILITY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

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FLIGHT TERMINATION SYSTEMS COMMONALITY STANDARD

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Prepared by

RANGE SAFETY GROUP

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PREFACE

This document is a publicly releasable version of Range Commanders Council (RCC) Document 319-07, "Flight Termination Systems Commonality Standard." Selected technical details concerning frequencies and tones contained in the RCC 319-07 document are not contained in this document and, therefore, this document is available to the public.

Note that the RCC 319-07 document has not changed and is available only on the RCC private web portal.

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ACRONYMS AND INITIALISMS

ADS	Automatic Destruct System
AFD	Arm and Fire Device
AFTO	Air Force Technical Order
AFTS	Autonomous Flight Termination System (FTS)
AFTU	Autonomous Flight Termination Unit
AGC	Automatic Gain Control
AM	Amplitude Modulation
ANSI	American National Standards Institute
BIT	Built In Test
CAD	Cartridge Activated Device
CDR	Critical Design Review
CFR	Code of Federal Regulations
COTS	Commercial off The Shelf
CSCI	Computer Software Configuration Item
CV	Constant Voltage
CW	Continuous Wave
DoD	Department of Defense
DODD	DoD Directive
DOE	Department of Energy
DOP	Dilution of Precision
DOT	Department of Transportation
DSCC	Defense Supply Center, Columbus
EAFD	Electronic AFD
EBW	Exploding Bridgewire
EED	Electro-Explosive Device
EFI	Exploding Foil Initiator
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOCV	End of Charge Voltage
ESAD	Electronic Safe and Arm Device (SAD)
ETS	Explosive Transfer System
FAA	Federal Aviation Administration
FM	Frequency Modulation
FMECA	Failure Modes, Effects, and Criticality Analysis
FPGA	Field Programmable Gate Array
FSS	Flight Safety System
FTR	Flight Termination Receiver
FTS	Flight Termination System
FTSR	FTS Report
GIDEP	Government/Industry Data Exchange Program
GPS	Global Positioning System, (Navigation Satellite Timing and Ranging (NAVSTAR))
GSE	Ground Support Equipment
HWCI	Hardware Configuration Item
IAW	In Accordance With

IEEE	Institute of Electrical and Electronics Engineers
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IRIG	Inter-Range Instrumentation Group
ISDS	Inadvertent Separation Destruct System
IV&V	Independent Validation and Verification
JANS	Joint Army Navy Space
JANTX	Joint Army Navy Technical Exchange
LASER	Light Amplification by Stimulated Emission of Radiation
LFU	Laser Firing Unit
LID	Laser Initiated Detonator
LRSO	Lead Range Safety Office
LVI	Low Voltage Initiator
MIL-STD	Military Standard
MEOP	Maximum Expected Operating Pressure
MPE	Maximum Predicted Environment
MRTFB	Major Range and Test Facility Base
NASA	National Aeronautics and Space Administration
NAVSTAR	Navigation Satellite Timing and Ranging
NAVSEAINST	Naval Sea Systems Command Instruction
NFPA	National Fire Protection Association
NPR	NASA Procedural Requirements
OCV	Open Circuit Voltage
OSHA	Occupational Safety and Health Administration
PAD	Percussion Activated Device
PDR	Preliminary Design Review
PIND	Particle Impact Noise Detection
QA	Quality Assurance
QML	Qualified Manufacturers List
QPL	Qualified Products List
RCC	Range Commanders Council
RF	Radio Frequency
RFP	Request For Proposal
RSC	Range Safety Console
RSG	Range Safety Group
RSO	Range Safety Office, Range Safety Officer
S&A	Safe and Arm
SAD	Safe and Arm Device
SNR	Signal to Noise Ratio
SRR	System Requirements Review
SS	Statistical Sample
SSTO	Signal Strength Telemetry Output
STD	Standard
TIM	Technical Interchange Meeting
TM	Telemetry
UN	United Nations
VSWR	Voltage Standing Wave Ratio

CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 The Flight Termination System (FTS) Standard. In an effort to establish a set of common design and testing requirements for programs launching from multiple ranges, several key organizations have worked together and set forth this standard to assist the Range Users in the development of flight termination systems (FTSs). These organizations include the major Department of Defense (DoD) test ranges, Department of Energy (DOE), Federal Aviation Administration (FAA), and National Aeronautics and Space Administration (NASA) launch and test facilities.

1.1.2 Terms and Use of This Document. For purposes of this document, the following applies:

a. A flight termination system (FTS) terminates the flight of a vehicle.
b. A flight safety system (FSS) is a range safety tool used to reduce the overall risk of a mission to an acceptable level. An FSS consists of an FTS, a method to track the vehicle, and a method to receive status data from the vehicle. The FSS may also contain a method to input commands into the vehicle's flight control system, and place the vehicle into a recovery mode.
c. Diagrams of typical FSSs with FTSs are shown in Figure 1.1-1.
d. This standard only applies if the Range Safety Office (also referred to herein as "Range Safety") determines that an FTS is required.
e. Each chapter of this standard addresses different phases of launch system policy, development, design, testing, analysis, and documentation. All chapters in this document shall be satisfied before FTS approval can be granted.

1.1.3 Mandatory Systems Testing. Individuals who use the ranges (referred to herein as "Users" or "Range Users") are cautioned to make provision for the mandatory system testing and monitoring functions as specified herein. Users are strongly urged to coordinate with the Range Safety personnel as early as is practical to ensure proper recognition and interpretation of these requirements.

1.1.4 Flight Safety System (FSS) Requirements. The FSS requirements established in this document do not negate, supersede, or include other range requirements such as ground safety.

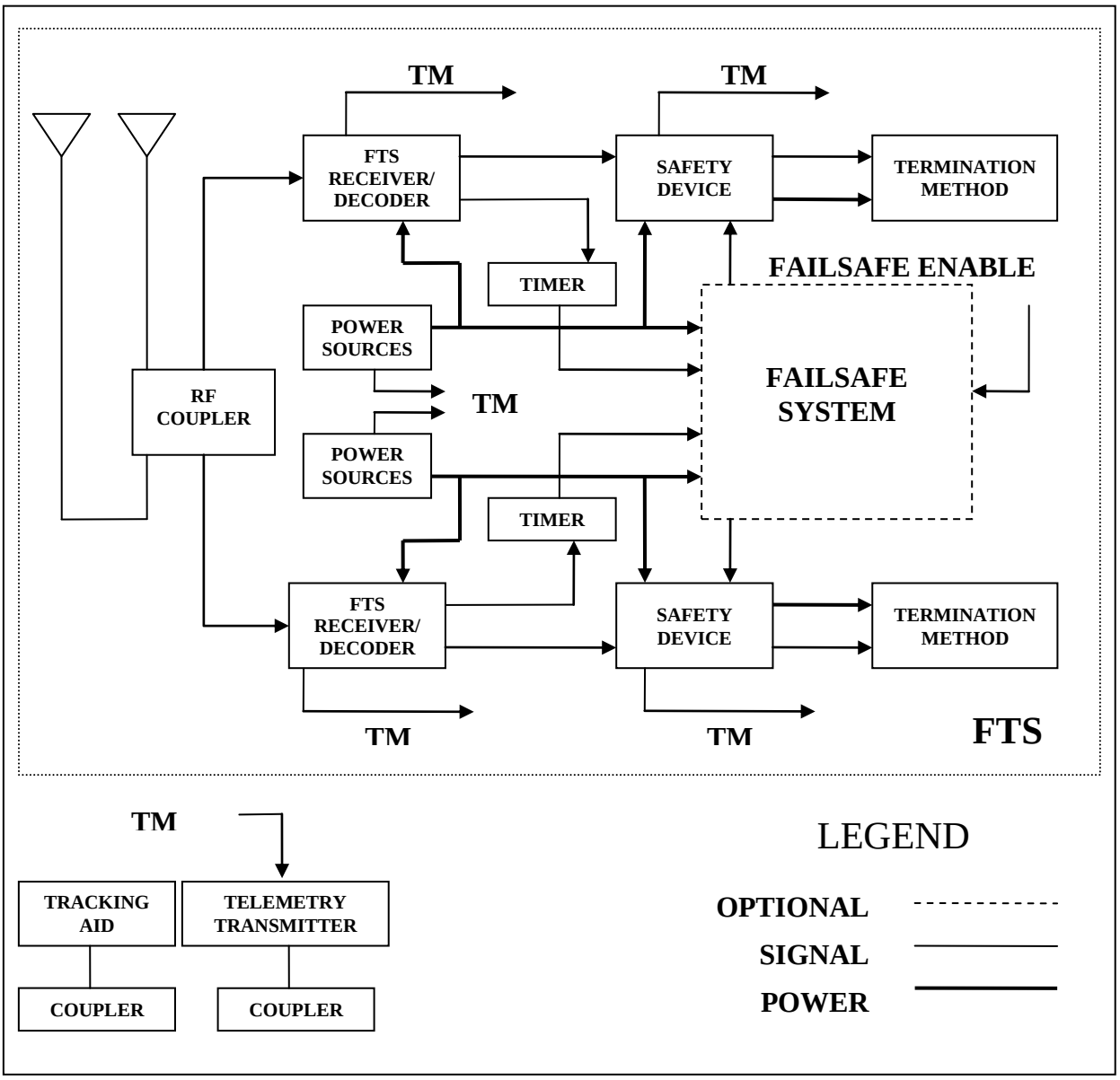


Figure 1.1-1. Typical flight safety system with flight termination system (FTS).

1.1.5 Organization of This Document.

a. Open Text. The open text contains the mandatory performance-based requirements. The only tailoring expected for these requirements would be the deletion of non-applicable requirement or a waiver.

b. Text Boxes. Text box paragraphs demonstrate the detailed solution that meets the required parent performance requirement. These text box paragraphs contain lessons learned from previous applications of the performance requirement, where a certain design may have been found successful, or have been tried and failed to meet the requirement. These detailed solutions may be tailored or replaced with other solutions that meet the parent performance requirement as long as Range Safety agrees that the performance requirement is met with the alternative solution. Note, unless specifically tailored by Range Safety, these detailed text box paragraphs are required. These technical solutions are provided for the following reasons:
   (1) To aid the tailoring process between Range Safety and Range Users in evaluating a potential system against all performance requirements.
   (2) To aid Range Safety and Range Users in implementing lessons learned.
   (3) To provide benchmarks or a standard that demonstrate what Range Safety considers an acceptable technical solution/implementation of the performance requirement and to help convey the level of safety the performance requirement is intended to achieve.
   (4) The technical solutions in the text box paragraphs may be adopted, modified, or replaced with another solution to replace it. This process is done to:
      - Provide an appropriate level of detail necessary for contractual efforts
      - Promote efficiency in the design process.
      - Avoid contractual misunderstandings that experience has shown often occur if an appropriate level of detail is not agreed to. The level of detail in the text box paragraphs is necessary to avoid costly out-of-scope contractual changes and to prevent inadvertently omitting a critical technical requirement.
   (5) The Range User always has the option to propose alternatives to the solutions presented in the text boxes. Proposed alternative solutions by the Range User shall achieve an equivalent level of safety and must be approved by Range Safety.
   (6) Range Safety has final decision authority in determining whether Range User proposed detailed technical solutions meet any performance requirements.

1.2 Basis of Authority

The authority for this standard includes the following:

a. Department of Defense Directive (DODD) 3200.11 establishes the Major Range and Test Facility Base (MRTFB) and assigns safety responsibilities to the Range Commander.
b. NASA Procedural Requirement NPR 8715.5 establishes safety responsibility for all NASA activities. This document assigns the flight safety responsibility to the Center Director.

c. The FAA establishes its safety requirements for commercial launches through Part 417 of 14 CFR.

NOTE

The responsibilities identified in paragraph 1.2a through paragraph 1.2c above cannot be transferred to the Range User or to another test range. Consequently, while establishing common agreements and practices among all the test ranges, Range Safety personnel at each affected range are delegated with the responsibility to enforce the established safety policies of their respective commanders, even if the policies are unique to their range.

1.3 Scope

The scope of this document specifies minimum design, analysis, test, inspection, and data requirements for airborne and ground support equipment that have been shown to assure a minimally acceptable level of safety and reliability during installation, test, and flight of the airborne FTS. NASA, DOE, and FAA are considered MRTFB activities for purposes of this document. The following guidance applies:

a. There is no RCC commonality document for ground operations safety. Ground safety operations shall be determined uniquely by each range. The FTS design requirements established in this document do not negate, supersede, or include other range requirements such as ground or system safety.
b. Vehicle tracking and telemetry system requirements are contained in RCC Document 324, (Global Positioning and Inertial Measurements Range Safety Tracking Systems' Commonality Standard).
c. The FTS shall be effective throughout the portion of flight for which the Range Safety Office has safety responsibility.

1.4 Acceptability at any Range Within the Major Range and Test Facility Base (MRTFB)

1.4.1 This document is intended to provide a common set of FTS requirements that can be used at MRTFB ranges.

1.4.2 If a program intends to operate on multiple ranges, all affected ranges shall be involved in the tailoring of this document. A RCC 319 document tailored by one range, or group of ranges, will not be automatically approved on another range not involved in the tailoring process. A range not involved in the tailoring process may reinstate the original requirements.

1.4.3 Adherence to the requirements stated in this document will produce an airborne system that can be flown at any MRTFB without modification or retest provided the flight vehicle and environment are identical to those used for the initial qualification.

1.5 Lead Range Safety Office (LRSO)

For programs that launch from multiple ranges, the Range User is responsible for keeping each Range Safety Office informed about any changes that affect the FTS. The LRSO will be responsible for coordinating administrative functions such as schedules and meetings with the Range Safety personnel at other ranges. The LRSO does not have the authority to accept/reject a design, request, etc., for another activity Commander. In this document, "approval of Range Safety" implies that a coordinated approval of all participating ranges has been orchestrated by the LRSO.

1.5.1 LRSO Appointment. The ranges, not the Range User, shall designate the LRSO.

1.5.2 Responsibility. The responsibility of the LRSO is to coordinate a response to the Range User on a particular issue or question. The LRSO will seek to provide a joint response from among the ranges. However, each range is autonomous in the area of range safety. It may be the case that a particular issue or question will yield different answers or requirements especially in missile readiness checks and day-of-test operational requirements.

1.5.3 Authority. The LRSO does not have the authority to speak for all ranges without first obtaining a coordinated response.

1.6 Operational Constraints

Users are cautioned that ground and flight operational constraints may vary from range to range. Therefore, what is an acceptable operation on one range may not be permitted on another.

1.6.1 FTS Operational Control.

a. The control of the flight termination system (FTS) falls under the purview of each affected test range. Therefore, the control of the FTS will be the responsibility of affected Range Safety personnel unless specifically waived by the affected range.

b. Control of the FTS includes every aspect of powering up, powering down, activation of signals, and any form of real-time testing of the FTS during the on-range missile assembly and readiness process through final countdown and launch. The FTS control consoles will be controlled by Range Safety personnel to include key control (if applicable) and safety interlocks.

c. Range Safety personnel shall physically operate FTS control consoles during the launch countdown process at the prerogative of the affected test range. No actions involving the activation of the FTS may be taken by the Range User unless approved by Range Safety personnel.

1.6.2 Range Approval Process. The approval process includes the following:

a. Identification of program requirements.
b. Tailoring of RCC 319 (Chapter 2).
c. Design of FTS to the tailored requirements and support of design reviews (Chapter 3).
   (1) System Requirements Review (SRR) shall provide a program's system requirements.
   (2) Preliminary Design Review (PDR) shall provide detailed subsystem and component design. New components shall have an individual PDR.
   (3) Critical Design Review (CDR) shall provide the final subsystem and component design and test requirements. Design shall be placed under configuration control after CDR. New components shall have an individual CDR.
d. Testing of FTS components (Chapter 4).
e. Vehicle assembly, FTS subsystem/system testing, countdown and post-flight (see Chapter 5).
f. Final FTS approval through the Flight Termination System Report (FTSR) (Chapter 7), analysis (Chapter 6), and testing (Chapters 4 and 5).
g. Documentation and approval of waivers and conditional compliant requirements using the tailoring request form in Chapter 2, Figure 2.2-1. The tailoring requests shall be signed by the applicable range authority and Range User (e.g. program office and contractor).

1.6.3 FTS Frequencies.

a. General. The use of any frequency must be coordinated with the affected range.
b. Frequency Assignment. The ranges, not the Range User, shall specify the appropriate FTS frequency. The FTS operating frequency will be assigned by the LRSO after coordination with all the other affected ranges.

1.7 Procurement of FTS-Peculiar Test Equipment

1.7.1 The Range User shall provide any special instrumentation or hardware to test the FTS or fund for the procurement of the equipment.

1.7.2 The Range User shall provide any special FTS control panels and TM monitoring instrumentation if the test range does not have such instrumentation in place to support the program or fund for the procurement of the instrumentation.

1.8 Tailoring

Requirements shall be tailored by agreement between the Range User and all Range Safety Offices involved using the process in Chapter 2. The process will include the following:

a. It is the Range User's responsibility to ensure that the tailoring encompasses all of the participating ranges.
b. The tailoring is a continuing process throughout all phases of acquisition, including the Request For Proposal (RFP), pre-bid conferences with bidders, concept technical interchange meetings (TIMs), preliminary design reviews (PDRs), etc.
c. Tailoring agreements and the design/test/inspection concepts upon which the tailoring is based shall be formally documented including approval signatures. Compliance to the tailoring shall be mandatory.
d. It is the intent of the tailoring process to develop a document that is placed on the Range User's contract, where applicable. In the absence of any tailoring, all text box solutions as written shall be required. For contractual purposes, Range Safety determines whether a recommended solution meets a performance requirement. Text box solutions may be mandated by Range Safety.

1.9 Tailoring Disposition

1.9.1 Waivers. Waivers document noncompliance with one or more performance requirements. These noncompliance(s) pose significant risks to mission personnel or public safety.

a. Lifetime. Lifetime waivers are undesirable and shall be limited to those situations where it is practically impossible to meet the requirement. These waivers shall be reviewed for each launch to ensure that rationale for their acceptance remains valid.

b. Limited Effectivity. Time limited waivers are set for a limited period of time or a limited number of launches. The time constraint is normally determined as a function of cost, impact on schedule, and the minimum time needed to satisfactorily modify or replace the noncompliant item.

1.9.2 Compliant. This category documents performance requirements that meet or meet the intent of the requirement.

a. Fully. This category documents performance requirements that comply as written and are acceptable for the life of the program with no special rules or restrictions which require periodic review.

b. Conditional. This category documents performance requirements that pose low risk or require unique circumstances to maintain their safety. Conditional compliance may be required if procedural controls and personnel are required to maintain safety. These requirements shall be reviewed for each launch to ensure that rationale for their acceptance remains valid.

1.10 Waivers

1.10.1 All waivers must be approved by all Range Safety Offices involved. The Range User shall submit all waiver requests for review and approval separately. All approved waivers shall be included in the appropriate safety data package as an Appendix. Ranges that were not involved in the original process have the right to restore the requirements of this document for any program wishing to conduct test operations at these ranges.

1.10.2 Supporting data for a waiver request must include:

a. A statement of the technical or other requirements that make the waiver necessary.
b. A discussion of the effect on FTS performance functions if the waiver is granted.
c. A discussion of the effect on the program if the waiver is not granted.
d. A detailed description of the proposed flight tests or operations.
e. A detailed description of rationale for acceptance and any mitigating factors.
f. A get-well plan to eliminate “limited effectivity” waivers before their expiration.

1.10.3 Each Range Commander has the authority to deny or grant a waiver to any requirement in this document for a specific program or mission operating at their respective range; this authority only applies to the specific Commander’s range.

1.11 Grandfathering

1.11.1 Previously approved FTS components and systems are grandfathered and are not required to meet any subsequent versions of this document unless one (or more) of the following applies:

a. The Range User obtains a new component or system due to parts obsolescence or economic feasibility.
b. The launch vehicle system, FTS component location, or environment is modified to the extent that Range Safety considers it a new program.
c. A previously unforeseen or newly discovered safety hazard exists that is deemed significant enough to warrant the change. This category includes components and systems that were previously approved but the noncompliance was not identified.
d. Accident and incident investigations and reports dictate compliance to this document.

1.11.2 Grandfathering is only applicable to the range or ranges that originally approved the system.

1.12 Range User Provided Hardware

The Range User may be required to provide FTS components to Range Safety to support prelaunch and range activities. The requirement to provide this hardware will be determined by each individual range on a case-by-case basis. The Range User shall coordinate this requirement with each Range Safety Office.

CHAPTER 2

TAILORING

2.1 Tailoring Overview

A tailored version of RCC-319 shall be developed by the affected Range Safety Offices for a specific program. The ranges will develop this tailored document with Range User participation in the tailoring process. All original Range Commanders Council RCC-319 requirements shall be documented as being compliant, not applicable, or having a waiver during the tailoring process. The following actions are to be followed:

a. Delete requirements that are not applicable. Deleted requirements shall maintain the major paragraph numbering and title.
b. Develop new requirements or rewrite existing requirements for new technologies and unique applications.
c. Document in text boxes the specific solution that will be used to satisfy any performance requirement.
d. Identify waivers with mitigating solutions.
e. Begin new designs or tests for specific components only after applicable tailoring for that item has been completed.

2.2 Tailoring Process

2.2.1 Step 1. An initial technical interchange meeting (TIM) is required that describes in detail the type of test planned at each range, the vehicle configuration, and proposed FTS component and system design.

a. This TIM is necessary to identify the baseline for which tailoring can be performed and to identify all the ground rules.

b. The ground rules used for tailoring shall be included at the beginning of the tailored document.

c. Tailoring should begin at the earliest opportunity (preferably at the conceptual stage prior to contractual obligation), and finish before the system critical design review.

2.2.2 Step 2. A line-by-line assessment is performed with all applicable Range Safety organizations available. This assessment may include component vendors. Range Safety has final authority on disposition and interpretation of requirements. This process is often facilitated by the use of a computerized projection system where all parties can review and approve changes in real-time.

a. Each performance requirement is documented as compliant, not applicable, or waived.
   (1) Requirements that are not annotated shall be considered fully compliant. Requirements that are conditionally compliant shall be annotated with a (CC) after the paragraph number (e.g. 3.X.X (CC)).
   (2) Requirements that are not applicable shall be deleted and replaced with an N/A.
   (3) Requirements that require a waiver shall be annotated with the word "WAIVER" at the beginning of the paragraph.
   (4) Tailored text box requirements shall be annotated with a (T) after the paragraph number (e.g. 3.X.X (T)). Modifications to text box requirements shall be tracked. This can be performed by using the tracking/revisions feature in Word.

b. Text box paragraphs can be rewritten as necessary to document the specific technical solution that shall be used to meet the parent performance requirement. The technical solutions in the text box paragraphs may be adopted, modified, or replaced with another solution. Changing the text box requirements may not require justification as long as the rewritten solution meets the parent performance requirement.

2.2.3 Step 3. The tailored version of the document is denoted as RCC 319 [T-program name] and placed under Range Safety configuration control. The tailored document (see example pages at Figure 2.2-1 and Figure 2.2-2) is a "living document" and may change as the program matures.

a. Page headers shall incorporate the title of the program, version number, and date.

b. Often, the Range User may agree to certain requirements at the beginning of the program only to discover that conditions or assumptions have changed requiring a reassessment of the tailored requirement.

c. This process allows the Range User to develop some baseline requirements before detail knowledge is known about their system with the understanding that the requirements or solutions can be reassessed as conditions change or information becomes available.

d. Any change must be documented and approved by Range Safety.

2.3 Disposition of Tailored Requirements

Range users are responsible for identifying all noncompliances to Range Safety and obtaining an approved resolution.

2.3.1 Waivers. Waivers document noncompliances of performance requirements. These noncompliances pose significant risks to mission personnel or public safety. Waivers shall be documented and assigned a unique sequential tracking number on the tailoring request form in Figure 2.3-1.

a. Lifetime. Lifetime waivers are undesirable and shall be limited to those situations where it is practically impossible to meet the requirement. These waivers shall be reviewed for each launch to ensure that rationale for their acceptance remains valid.

b. Limited Effectivity. Time limited waivers are set for a limited period of time or a limited number of launches. The time constraint is normally determined as a function of cost, impact on schedule, and the minimum time needed to satisfactorily modify or replace the noncompliant item.

2.3.2 Compliant. This category documents performance requirements that meet or meet the intent of the requirement.

a. Fully. This category documents performance requirements that comply as written and are acceptable for the life of the program with no special rules or restrictions which require periodic review.

b. Conditional. This category documents performance requirements that pose low risk or require unique circumstances to maintain their safety. Conditional compliance may be required if procedural controls and personnel are required to maintain safety. These requirements shall be reviewed for each launch to ensure that rationale for their acceptance remains valid. Conditional compliance shall be documented and assigned a unique sequential tracking number on the tailoring request form in Figure 2.3-1.

No annotation on performance

Changes (blue text) can be tracked using "revisions mode"

Sample Tailoring Example 1

3.9.10. Self-Test. If an FTS component uses memory or a microprocessor, the component shall perform self-tests, detect errors, and relay the results through telemetry.

Added text documents Range User method for

~~Self test shall be performed upon power up or when commanded.~~

- The EFTS command receivers shall perform self-test at power-up or when command
- The electronic S&A shall perform a self-test of the communications circuit continuo
- ent of a failure

Details of waiver documented on the noncompliance

3.9.11 (Waiver-limited effectivity). Electromagnetic Interference and Compatibility Protection. The design of an FTS component shall eliminate the possibility of the maximum predicted electromagnetic interference emissions or susceptibilities, whether conducted or radiated, from affecting the component's performance. A component's electromagnetic interference susceptibility level shall ensure that the component satisfies all its performance specifications when subjected to the maximum predicted emission levels of all other vehicle components and external sources to which the component would be exposed.

1. FTS components shall be designed to meet the requirements of MIL-STD-461, ***REQUIREMENTS FOR THE CONTROL OF ELECTROMAGNETIC INTERFERENCE CHARACTERISTICS OF SUBSYSTEMS AND EQUIPMENT***. The following methods are required where applicable: CE102, CE106, CS101, CS103, CS104, CS105, CS114, CS115, CS116, RE102, RE103 and RS103. Other methods may be required for unique vehicle environments (T). Command receiver unable to meet RS103 at C-band. Transmitting sources will be limited to receiver C-band susceptibility with a 20 dB margin.
2. MIL-STD-461 tests, frequencies, limits and levels shall envelope electromagnetic operating environments or the default test environments, whichever is greater.
3. Radars an quenc ver levels greate

Explanation of waived requirement and mitigation. Must be reviewed for each mission to ensure justification remains valid

(CC) indicates a conditional compliance. There is no safety risk with procedural

3.9.18.1 (CC). There shall be a minimum 20 dB safety margin between the component leakage output and the minimum no-fire or degrading current of any downstream ordnance initiator.

1. The component shall not produce any outputs greater than 1 volt in amplitude for more than 200 microseconds into a 10k-ohm load during the voltage transient and shall meet its performance requirements after the application of the voltage transient. The command receiver outputs energy upon power up that only provides a 10 dB margin over the minimum no-fire level. The S&A will be in the SAFE position whenever the command receiver is powered up resulting in no energy being transmitted to the lo iver will not be connected to the S&A. No personnel will l to the S&A.

Explanation of conditions required to maintain conditional compliance. Conditions must be reviewed for each mission to ensure they remain

Not Applicable- indicates that no memory retention devices are used in the FTS. Title remains but text is deleted.

Figure 2.2-1. Sample tailoring example 1.

Sample Tailoring Example 2

Table 4.16.1: RF Receiving System Acceptance Test Requirements.

Test	Paragraph	Quantity Tested		
		Cable	Coupler	Antenna
Component Examination	4.11.1			
Visual Examination	4.11.2	100%	100%	100%
Dimension Measurement	4.11.3	100%	100%	100%
Identification Check	4.11.5	100%	100%	100%
Performance Verification	4.10.4	-		
VSWR	4.16.2	100%	100%	100%
Insertion Loss (1) (2)	4.16.3	100%	100%	-
Isolation (1)	4.16.4	-	100%	100%
Abbreviated Antenna Pattern	4.16.7	-	-	100%
Abbreviated Performance Verification	4.10.5			
VSWR(2) (1)	4.16.5	-	-	100%
Operating Environment Tests	4.15.1			
Thermal Cycling	4.15.2	100%	100%	100%
Thermal Vacuum (4)	4.15.3	-	~~100%~~	~~100%~~
Acoustic (3)	4.15.4	-	100%	100%
Humidity (5)				100%
Sinusoidal (3)	4.15.5		100%	100%
Random Vibration	4.15.6	-	100%	100%
Tensile Load	4.15.7	100%	-	-

(1) These tests shall be perfor[illegible]le fo[illegible] vacuum testing.
(2) These tests shall be performed during acoustic and random vibration testing.
(3) These tests to be demonstrated by analysis. Analyses will be included in the applicable qualification test report.
(4) Not applicable: Test not required. UHF system is low power and vented to prevent contained pressure buildup.
(5) CC: Test not required. Component will be maintained in an environmentally controlled area for all phases of prelaunch and launch operations.

(CC) indicates a conditional compliance. There is no safety risk with procedural controls

Deleted text indicates that no further analysis or testing is required

No annotation on performance requirement indicates full compliance

Figure 2.2-2. Sample tailoring example 2.

TAILORING REQUEST FORM

RCC 319 **Page 1 of ___**

TAILORING REQUEST ☐ **WAIVER** ☐ **CONDITIONAL COMPLIANCE**	**PROGRAM NAME:**
IMPACT ☐ **PUBLIC SAFETY** ☐ **PERSONNEL SAFETY** ☐ **RESOURCE PROTECTION**	**TRACKING NUMBER:** **(W-XXX for waiver or C-XXX for conditional compliance)**
EFFECTIVITY ☐ **LIFETIME** ☐ **LIMITED**	**REQUEST DATE: (YYMMDD):**
SUBJECT:	**RCC 319 REFERENCE PARAGRAPH:**
ORIGINATOR:	**ORIGINATOR'S ORGANIZATION:**
RECIPIENT:	**RECIPIENT'S ORGANIZATION:**
REQUIREMENT:	
ISSUE:	
JUSTIFICATION / DISCUSSION:	

DISPOSITION:		**APPROVAL AUTHORITY**	
		NAME/SIGNATURE/OFFICE SYMBOL	
		RANGES	**DATE**
☐ **APPROVED**			
☐ **APPROVED W/COMMENTS**			
☐ **DISAPPROVED**		**RANGE USER**	

Figure 2.3-1. RCC 319 Tailoring Request.

CHAPTER 3

COMMON FTS SYSTEM AND COMPONENT PERFORMANCE REQUIREMENTS

3.1 FTS Functional Requirements

When initiated (whether by command from a flight safety official, or other means such as automatically in the event of a vehicle failure) an FTS, where applicable, shall:

> In addition to disabling thrust, the goal of the FTS is to result in a termination action that minimizes the debris footprint. The FTS shall minimize significant lateral or longitudinal deviation in the impact point.

a. Ensure the flight-terminated vehicle's debris impact, resulting from residual lift or drift under worst-case wind conditions, will not endanger any protected area. When termination is initiated, it shall be irrevocable.
b. Render each propulsion system that has the capability of reaching a protected area, incapable of propulsion. This includes each stage and any strap on motor or propulsion system that is part of any payload.
c. Terminate the flight of any inadvertently or prematurely separated propulsion system capable of reaching a protected area.
d. Destroy the pressure integrity of any solid propellant system and terminate all thrust or ensure that any residual thrust causes the propulsion system to tumble without significant lateral or longitudinal deviation in the impact point.
e. Disperse any liquid propellant, whether by rupturing the propellant tank or other equivalent method. Shutdown and/or parachute systems may be used in lieu of rupturing propellant tanks if the risk posed by an intact impact is acceptable. Determination of shutdown-only systems will be range and vehicle dependent.

> The design goal is to initiate burning of any toxic liquid propellant.

f. Result in aerodynamic control surface manipulation that makes a vehicle unable to glide or auto-rotate. These types of termination systems shall demonstrate that any residual lift or drift under worst-case wind conditions will not result in the flight-terminated vehicle from endangering any protected area.

> For aeronautical systems, aerodynamic control surface manipulation may be more desirable than explosives.

g. FTS Requirements for Manned Vehicles.
   (1) The powered portion of a manned vehicle shall comply with all requirements of this document.

When the manned portion is an integral part of the vehicle, then the requirements for FTS will be handled on a case-by-case basis.

(2) If manned vehicles are flown unmanned, all requirements of this document shall be met.

Additional FTS requirements for manned vehicles:

1. The effect of abort action on engine shutdown shall be approved by Range Safety.
2. Time delays between engine shutdown and FTS action required for crew escape shall be provided by the Range in the ground equipment. The extent of these delays shall be determined by vehicle parameters, the type of escape system, and the degree of hazard presented to public safety.
3. Payloads and their booster stages transported on or within a manned portion of a vehicle will be evaluated by Range Safety to determine the need for an FTS.

h. Other FTS shall be determined on a case-by-case basis.
i. The FTS terminate action shall not detonate solid or liquid propellant.

For propellant formulations (double-base composites like DDP-70 and cross-linked poly ethylene glycol [PEG] high-energy formulations) that are sensitive to shock to the extent that impact at a velocity greater than 250 foot/second may result in detonation or explosion, FTS charges shall be designed to split the motor case and break up the propellant grain into fragments.

j. The termination action shall ensure that solid rocket motor propellant is fractured into small enough fragments to prevent unacceptable personnel risks due to blast effects upon ground detonation.
k. For multiple-stage vehicles, the flight termination of a propulsion system shall not interfere with the flight termination of any other propulsion system.

3.2 FTS Design

3.2.1 Margins. Design margins shall be sufficient to allow a component, subsystem or system to meet all required performance requirements when subjected to nominal/errant flight environments, worst-case test tolerances, aging effects, small sample sizes, unit-to-unit performance variability, flight environment uncertainty and vehicle monitoring system tolerances. Range Safety shall have final determination of the required margin for each vehicle application. Margins shall also include minimum workmanship screening levels to ensure that flight hardware is free of manufacturing defects.

1. Performance requirements or text boxes contain margins based on lessons learned from numerous nominal and errant vehicle flights from all MRTFB ranges. In general, meeting these RCC 319 margins satisfies the margin requirement.
2. The margins in the text box may be reduced or increased depending on the specific component and vehicle application.
3. The test margin shall account for test equipment and vehicle telemetry tolerances.
4. Qualification margin shall include vehicle monitoring system (e.g. telemetry) tolerances to account for launch go/no-go criteria.

3.2.2 Reliability Prediction. An FTS shall have a predicted reliability of 0.999 at a confidence level of 95 percent. A Range User shall establish the predicted reliability of the system by satisfying the requirements for system reliability analysis.

1. The number of FTS components and piece parts shall be kept to an absolute minimum.
2. The TERMINATE command output signal from the FTR shall be designed to go directly to FTS arming devices.
3. The flight termination system shall have a predicted reliability of 0.999 at a confidence level of 95 percent to be demonstrated through an analysis of the design. The reliability will be considered met through compliance with this document, which incorporates performance oriented design requirements for components coupled with comprehensive qualification and acceptance testing of components and preflight confidence tests of the entire system to ensure the system's reliability.

3.2.3 Redundancy. An FTS, including monitoring and checkout circuits, shall not have a single failure point that would:

a. Inhibit functioning of the system during the Range Safety responsibility portion of flight.

1. Single fault tolerance shall be met using redundancy except for:
   a. Any passive component such as an antenna or radio frequency (RF) coupler.
   b. Any destruct/terminate charge if it initiates at both ends and the initiation source for one end is not the same as the initiation source for the other end
2. There shall be one dedicated power source for each redundant leg of the FTS.
3. Single fault tolerance includes separate cables and connectors.

b. Produce an inadvertent initiation of the system that creates an unacceptable safety risk.

1. Single point failures for inadvertent termination must ensure initiation does not affect personnel safety or resource protection.
2. Single point failures for inadvertent termination must be formally accepted by the Range User for mission risk.
3. Inadvertent initiation of secondary explosives does not apply.
4. Inadvertent initiation of a primary explosive once FTS armed is acceptable.
5. A hazard analysis shall be performed on all software/firmware to ensure no single point failures for inadvertent initiation.

3.2.4 Survivability.

a. The FTS shall be designed to function at a reliability of 0.999 at a confidence level of 95 percent during nominal flight, errant flight, or vehicle breakup. This survivability includes protection against vehicle-induced environments plus a margin and vehicle events that could allow the vehicle to continue flight while disabling the FTS.

1. An FTS shall use physically redundant components that are structurally, electrically, and mechanically separated. The mounting of each redundant component on a vehicle, including location or orientation, shall ensure that any failure that will damage, destroy or otherwise inhibit the operation of one redundant component shall not inhibit functioning of the system.
2. Physically redundant components shall be mounted in different orientations on different axes where technically possible.
3. Tactical and aeronautical applications may not require physical redundancy depending on unique vehicle configurations and breakup modes.
4. The use of non-physically redundant FTS components for systems with limited space such as small vehicles shall be approved on a case-by-case basis.
5. Survivability requirements for Autonomous FTS (AFTS) systems include the tracking system and other supporting subsystems.
6. These survivability requirements are primarily met through the use of physical redundancy and design/testing to operating environmental margins required in this document.

b. Remotely Piloted Vehicles (RPVs) and Full-Scale Aerial Target Aircraft. RPVs and full-scale aerial targets shall incorporate an FTS that provides the control needed to protect the public in the event of a vehicle failure.

An FTS may include use of a dedicated FTS uplink, vehicle control uplink, autonomous onboard system or any combination.

1. Remotely Piloted Vehicles shall have redundant methods of terminating flight. FTS activation may use a combination of the following methods:
   a. The vehicle uplink command-control system shall have a command flight termination capability.
   b. For vehicles without an onboard autopilot, loss-of- vehicle control uplink shall result in an unstable vehicle, unable to glide or autorotate, such that its descent to the surface stays within the prescribed hazardous evacuation area.
   c. Autonomously piloted vehicles shall have a dedicated FTS uplink as one of the redundant methods of termination. Loss of the dedicated FTS uplink shall result in a condition that causes the vehicle to remain within the prescribed hazardous evacuation area.
2. Remotely Piloted Vehicles containing an onboard autopilot capable of maintaining vehicle stability in the event of loss-of-uplink command that operate within line of sight and a constant tactical command-control uplink are required to have an independent single path flight termination system independent of the tactical command-control system.
   a. The tactical command-control system shall have a command flight termination capability. The combination of the independent single path flight termination system and the tactical command-control system shall be considered to meet the FTS redundancy requirement.
   b. The independent FTS shall be the primary means of termination, with the tactical command-control system the secondary means.
   c. The independent system shall have priority over the secondary system, and the secondary system will not be able to override the independent system or cause failures in the independent flight termination system.
   d. The tactical command-control FTS components will be required to be qualified but not to overstress levels.
   e. Loss-of-RF fail-safe may be designed such that it only occurs if both the tactical command-control RF uplink and the independent flight termination system flight termination receiver lose uplink.
   f. A commanded flight termination signal or loss-of-RF fail-safe shall result in an unstable vehicle, unable to glide or autorotate, such that its descent to the ground or water surface stays within the prescribed hazardous evacuation area.
   g. Recovery of the vehicle by a parachute system is at the option of the Range User.
3. Full-Scale Aerial Target Aircraft. Full-scale manned aircraft converted into targets that have an onboard autopilot capable of maintaining vehicle stability that operate with a constant tactical command-control uplink are required to have an independent single path flight termination system independent of the tactical command-control system.
   a. The tactical command-control system shall have a command flight termination capability. The combination of the independent single path flight termination system and the tactical command-control system shall be considered to meet the FTS redundancy requirement.
   b. The independent FTS shall be the primary means of termination, with the tactical command-control system the secondary means.

c. The independent system shall have priority over the secondary system, and the secondary system will not be able to override the independent system or cause failures in the independent flight termination system.
d. The tactical command-control FTS components will be required to be qualified but not to overstress levels.
e. Loss-of-RF fail-safe may be designed such that it only occurs if both the tactical command-control RF uplink and the independent flight termination system flight termination receiver lose uplink.

A commanded flight termination signal or loss-of-RF fail-safe shall result in an unstable vehicle, unable to glide or auto-rotate, such that its descent to the ground or water surface stays within the prescribed hazardous evacuation area.

3.2.5 System Independence. An FTS shall operate independently of any other vehicle system. The failure of another vehicle system shall not inhibit the functioning of an FTS.

1. An independent power source for each of the redundant flight termination paths is required.
2. An FTS may share a connection with another system if the connection shall exist to satisfy an FTS requirement, such as any connection needed to:
   a. Accomplish FTS arming and safing.
   b. Provide data to the telemetry system.
   c. Accomplish any engine shutdown.
3. Other functions require specific approval.
4. An FTS may share a component with another vehicle system, only if Range Safety approves and the Range User demonstrates that sharing the component will not degrade FTS reliability.

3.2.6 Performance Specifications for Components and Parts. Each FTS component and each part that can affect the reliability of a flight termination component shall have written performance specifications that show, and contain the details of, how the component or part satisfies the requirements.

3.2.7 Ability to Test. The flight termination system, components, ground support, and monitoring equipment design must allow the required tests of Chapter 4 and Chapter 5 to be performed.

1. FTS components shall be designed to be functionally tested by ground test equipment before installation. Test equipment shall be designed to simulate input signals and to verify that FTS components are functioning within performance specifications.
2. The FTS and vehicle design shall accommodate easy replacement of FTS components. If replacement is not an option, the design shall allow verification of component performance through built-in-test (BIT) points or telemetry.
3. All ordnance initiators shall be testable.
4. High energy electrical ordnance initiation systems greater than 500 volts such as electronic arm and fire device (EAFD) (or electronic safe and arm device [ESAD]) or EBW firing units shall be testable such that the firing capacitor can be charged, and a measurement made of the deliverable energy by oscilloscope or other suitable method.
5. EAFDs (or ESADs) that incorporate g-activated switches or other components shall be designed such that these can be bypassed or otherwise activated for the purpose of performing electrical bench tests. Periodic certification of the entire mechanism by centrifuge testing shall be required.
6. Provisions shall be made in manually activated and lithium ion batteries design to permit OCV of each cell when assembled in the battery case. This testing shall take place at the range. Individual cell testing is not required for thermal or remotely activated batteries.
7. Batteries shall be easily accessible for inspection and replacement.
8. The system shall be designed to allow for performing “no-volt/no-current” or "stray energy" tests before ordnance connection.
9. The FTS shall be designed to provide for final electrical connections to the initiator to be made as late in the countdown as possible.
10. Explosive device such as a low voltage initiator (e.g., EED and SCB), booster charge, or rotor leads, contained in an S&A assembly, shall be designed to be individually subjected to qualification and acceptance testing.
11. Recyclable shutdown valves used as a primary termination shall be capable of being functioned with the FTS end-to-end test in their final flight configuration. Monitoring shall be available to verify valves meet performance requirements.
12. The AFTS shall have the capability to receive all simulated tracking data sources while remaining in its final flight configuration.
    a. A GPS based AFTS shall have antenna hats that can receive simulated trajectory data from a ground satellite simulator
    b. An INS based AFTS shall have inputs that can receive simulated trajectory data from a ground simulator. Note: only the INS electrical outputs need to be simulated to allow validation of software and termination sequences.

3.2.8 Software Safety Critical Functions. All software and firmware used in the FTS shall:

Software and firmware applicable to this requirement includes non-FTS systems used to control the FTS such as guidance computer safing

a. Be designed to eliminate the possibility of a single point software failure from inhibiting redundant FTS functions or initiating an inadvertent termination.
b. Software shall be subjected to independent verification and validation (IV&V) in accordance with an approved plan. Approval of the FTS for range usage will only be granted after the IV&V has been completed. The IV&V shall be completed before formal production of the FTS. Once approved, any modification shall also be validated in the same manner and approved through the LRSO before further production. These requirements apply to any computing system, software or firmware that is associated with an FTS and performs a software safety critical function.

Appendix A contains IV&V requirements.

3.2.9 Component Storage, Operating, and Service Life. Each FTS component shall have a specified storage life, operating life, and service life and shall satisfy all of the following:

a. Each component shall satisfy all its performance specifications when subjected to the full length of its specified storage life, operating life, and service life
b. The component storage, operating, or service life shall not expire before flight. A Range User may extend the service life of an ordnance component by satisfying the service life extension tests.

Electronic and ordnance components shall be designed to have a minimum shelf life of at least 10 years.

3.2.10 Consistency of Components. A Range User shall ensure that each flight component and system is manufactured using parts, materials, processes, quality controls, and procedures that are consistent with the manufacture of each qualification test sample. Subsystem and system level design shall be under configuration control.

1. All FTS components shall be manufactured in accordance with documented procedures and process control.
2. Manufacturer process controls shall provide a supplier-controlled baseline that assures subsequent production items can be manufactured that are equivalent in performance (in family), quality, and reliability to initial production items used for qualification and flight.
3. Modification to an approved FTS, to include modifications to or substitutions of associated equipment, components, component identification, test procedures, basic characteristics, and rating, or any changes affecting the configuration or integrity of the FTS will not be made without prior approval of each affected MRTFB activity. Such modification or substitution may result in an unapproved system and may require system or component level requalification. Approval of any proposed modification will be obtained in the same manner as the approval of the original FTS.
4. Second sources of FTS components shall undergo the same qualification process as the original suppliers. For purposes of this document, a second source is defined as another manufacturer building the same component or replacement component intended as a form-fit-and-function replacement for the original component All second source suppliers of any FTS component or major component subassemblies shall be qualified to the same specifications as the original source.
5. Break in Production or Change of Manufacturing Location. When the original manufacturer of a component experiences a change in manufacturing location or a break in production for more than 3 years then the component shall undergo requalification to the original environments. For batteries, the maximum allowable break in production shall be 1 year unless a very similar battery has been produced during the break period.
6. For electrical components that are in a continuous production process for more than 5 years after the original qualification, a verification shall be performed to demonstrate that new hardware and the qualification test unit are identical. This verification shall be performed as follows:
   a. A configuration audit that compares the original qualification test unit to new production units.
   b. Perform a requalification test of a new production unit.
7. When requested, the Range User and vendor shall support a Range Safety led configuration control audit of parts, materials and processes with a minimum 30 day notice.

3.2.11 FTS Functioning Time. The FTS activation time, from command initiation to airborne termination action, shall be specified and repeatable to ensure the FTS activates in sufficient time to terminate a vehicle prior to endangering a protected area.

For most ranges, a maximum of a 250 ms delay from commencing an FTS command or an automatic termination command to termination action is acceptable.

NOTE: When a terminate is issued, the vehicle can continue for a finite time towards a protected area until the FTS engages. This FTS reaction time must be factored into the total command destruct/terminate latency, including tracking data input, range ground systems/displays, RSO reaction time, ground transmission systems and airborne vehicle FTS. Additional FTS delay may affect allowable launch trajectory (limits mission profiles), launch availability (e.g. more conservative wind criteria) or mission assurance (not allow errant vehicle to continue to some usable mission).

3.3 Environmental Design

3.3.1 General. An FTS, including all of its components, mounting hardware, cables, and wires, shall satisfy all of its performance specifications when subjected to the maximum predicted operating and non-operating environment plus a margin.

1. FTS components shall be designed to meet all performance requirements when subjected to predicted combined environments, including combined environments (for example, thermal/vibration, thermal/shock or acceleration/thermal), that reflect the environments that will be experienced by the flight component during prelaunch and flight.
2. FTS components, that have been designed, qualified, and certified for use by the ranges for a specific vehicle and environment are not necessarily designed, qualified, or certified for use on any other vehicle or within the same vehicle at different locations or under different environments.
3. Modifications made to the vehicle that result in a harsher higher environment than the FTS was qualified for or that modify or interfere with FTS performance will require evaluation and possible requalification of the FTS.

3.3.2 Maximum Predicted Environments (MPE).

a. A Range User shall determine all maximum predicted non-operating and operating environments that an FTS, including each component, will experience.

1. Some vehicles may be soft-landing and/or recoverable that may allow the re-use of FTS components. The number of shock tests, the vibration test duration, and the acceleration test duration will depend on the number of times the vehicle is anticipated to be flown as mutually agreed upon by the ranges and the Range User.
2. MPE determination shall be based on analysis, modeling, testing, and/or monitoring.
3. Non-operating and operating environments include temperature (including number of cycles and thermal ramp rates), vibration, shock, acceleration, acoustic, and other environments that apply to a specific vehicle and launch site, such as humidity, salt fog, dust, fungus, explosive atmosphere, and electromagnetic energy.
4. MPE shall also include ship-and-shoot transportation environments.

b. Each maximum predicted vibration, shock, and thermal environment for an FTS component shall account for the uncertainty due to flight-to-flight variability and any analytical uncertainty.

1. For a vehicle configuration for which there have been fewer than three flights, the maximum predicted environment shall include an additional 4 dB for vibration and 4.5 dB for shock above the analytical predicted flight levels.
2. Once three flight data samples are obtained, the MPE will be defined by the maximum enveloped peak levels at each frequency from all flight data taken at the measurement location. This new predicted environment does not need to add any uncertainty margin for level.
3. The MPE used for determining acceptance and qualification margins shall already include the required variability margins.

c. A Range User shall monitor a minimum of three flights in all three mutually perpendicular axes at each location within the vehicle needed to verify the maximum predicted flight environments for each FTS component. An exception is that the Range User may obtain empirical shock environment data through ground testing. A Range User shall adjust each maximum predicted flight environment for any future launch to account for all data obtained through monitoring. Range Safety shall approve the locations of environmental monitoring devices.

1. Transportation environments shall be monitored for vehicles that are built at the factory (or partially) and transported to ensure that expected MPE levels are not violated.
2. Components that are sensitive to certain environments, such as battery temperature, shall be monitored to ensure that expected MPE levels are not violated.
3. Significant deltas between predicted and actual random vibration may warrant further analyses and qualification testing. The flight monitoring sample rates on actual data will be such that the data from 20 to 2000 Hz is definable.
4. Shock measurements from 100 to 10000 Hz may be performed on ground test set-ups that duplicate the flight configuration.
5. Flight random vibration data shall be analyzed using 1 sec time windows with a 5 Hz resolution.
6. A maxi-max approach shall be performed which envelopes the highest value within a frequency band throughout the preflight/flight trajectory. If this becomes too conservative, it may be possible to break the MPE into different phases of flight. This methodology will require unique acceptance and qualification and will be approved on a case-by-case basis.
7. Significant changes in vehicle configuration may require additional flight monitoring.

d. Maximum predicted environments include concurrent environments that represent the actual non-operating or operating environment such as vibration or shock at temperature.

e. Where applicable, the analysis shall include the environment for each different type of launch platform that will be used.

3.3.3 Thermal Environment. A component shall satisfy all its performance specifications when exposed to preflight and flight thermal environments including thermal cycle transition ramp rate that envelopes the worst-case thermal rate of change expected during the nonoperating and operating life of the component plus a margin.

1. The acceptance-number of thermal cycles for each component shall be the greater of eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing (including diurnal cycling) and flight, including all launch delays and recycling.
   Note: Thermally conditioned components that are subjected to a high number of thermal cycles such as components utilizing heaters shall be handled on a case-by-case basis. Fractional samples shall be rounded up to the nearest whole number.
2. Maximum predicted high temperatures shall include components that are temperature conditioned such as battery heaters.

a. Ordnance Thermal Design.
   (1) The thermal cycle temperature range shall be from the lower of -54 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C.

1. For components whose MPE exceed the 71 °C qualification level, a 3 percent °K margin shall be used in lieu of the + 10 °C margin.
2. For components whose MPE is less than the -54ºC qualification level, the lower temperature margin will be determined on a case-by-case basis. Where testing at temperatures colder than MPE is impractical, the number of thermal cycles may be increased to account for a reduced temperature margin.

(2) The number of thermal cycles shall be three times the acceptance-number of thermal cycles.

1. When an ordnance device is thermal cycle acceptance tested as part of a higher assembly, the ordnance device and any associated hardware shall satisfy all its performance specifications when subjected to the acceptance-number of thermal cycles.
2. For Safe and Arm devices, the minimum acceptance-number of thermal cycles is eight. Safe and Arm devices shall be designed to withstand 24 thermal cycles.
3. For ordnance systems not part of an electrical/electromechanical assembly, the ordnance device shall be designed to withstand 8 thermal cycles.

(3) The component shall be designed for a thermal ramp rate that envelopes the maximum expected prelaunch or flight thermal transition rate plus a margin.

The thermal cycle transition ramp rate of change shall be no less than 3 °C per minute.

b. Passive Components. A passive component shall satisfy all its performance specifications when subjected to the following:

(1) The minimum thermal cycle temperature range shall be from the lower of -34 °C or the predicted lowest temperature minus 10 , to the higher of 71 °C or the predicted highest temperature plus 10 °C.

1. For components with an MPE exceeding the 71 °C qualification level, a 3 percent °K margin shall be used in lieu of the +10 °C margin.
2. For components whose MPE is less than the -34 ºC qualification level, the lower temperature margin will be determined on a case-by-case basis. Where testing at temperatures colder than MPE is impractical, the number of thermal cycles may be increased to account for a reduced temperature margin.

(2) The number of thermal cycles shall be three times the acceptance-number of thermal cycles.

1. The minimum acceptance-number of thermal cycles is eight.
2. A passive component shall be designed to withstand a minimum of 24 thermal cycles.

(3) The component shall be designed for a thermal ramp rate that envelopes the maximum expected prelaunch or flight thermal transition rate plus a margin.

The thermal cycle transition ramp rate of change shall be no less than 3 °C per minute.

c. Electronic Components. An electronic FTS component, including any component that contains an active electronic piece-part such as a microcircuit, transistor, or diode shall satisfy all its performance specifications when subjected to:

(1) The minimum thermal cycle temperature range shall be from the lower of -34 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C.

1. For components whose MPE exceed the 71 °C qualification level, a 3 percent °K margin shall be used in lieu of the + 10 °C margin. 2. For components whose MPE is less than the -34ºC qualification level, the lower temperature margin will be determined on a case-by-case basis. Where testing at temperatures colder than MPE is impractical, the number of thermal cycles may be increased to account for a reduced temperature margin.

(2) The number of thermal cycles shall be three times the acceptance-number of thermal cycles.

1. The minimum number of acceptance-thermal cycles is eight. 2. An electronic component shall be designed to withstand a minimum of 24 thermal cycles. 3. The acceptance-number of thermal cycles for electronic boxes should not include the 10 burn-in thermal cycles.

(3) The component shall be designed for a thermal ramp rate that envelopes the maximum expected prelaunch or flight thermal transition rate plus a margin

The thermal cycle transition ramp rate of change shall be no less than 3 °C per minute.

d. Power Source. An FTS power source shall satisfy all its performance specifications when exposed to preflight and flight thermal environments. The power source shall satisfy the following:

(1) Power sources shall be designed to withstand the maximum and minimum predicted temperature and workmanship levels plus a margin.

1. Li-ion and Ni-Cd batteries qualification thermal levels shall be a minimum of -34 °C to +40 °C or the predicted temperature range, whichever is greater.
2. Thermal and remotely activated silver zinc batteries in an inactivated state shall satisfy all its performance specifications when subjected to eight qualification thermal cycles from 10 °C lower than its minimum predicted temperature to 10 °C higher than its maximum temperature or a minimum of -40 °C to +71 °C, whichever is more severe.
3. Manually activated silver-zinc batteries shall satisfy all its performance specifications when subjected to eight qualification thermal cycles. An exception is that each thermal cycle may range from 5.5 °C lower than the minimum predicted temperature to 5.5 °C higher than the maximum predicted temperature. To use this exception, the battery's operating temperature shall be monitored on the vehicle with an accuracy of no less than ± 1.5 °C.
4. Other power sources shall be a minimum of -34 °C to +71 °C or the predicted temperature range plus a +/- 10 °C margin, whichever is greater.
5. For power sources whose MPE exceeds the minimum -34 °C to 71 °C qualification levels, a 3 percent K margin shall be used in lieu of the +/- 10 °C margin.

(2) The number of thermal cycles shall be three times the acceptance-number of thermal cycles.

1. For rechargeable batteries, the minimum acceptance-number of thermal cycles is eight.
2. A rechargeable batteries shall be designed to withstand a minimum of 24 thermal cycles.
3. Non-rechargeable batteries shall be designed to withstand eight thermal cycles.
   Note: Non-rechargeable batteries are not acceptance thermal cycled.
   Note: This does not apply to silver-zinc batteries.

(3) The battery shall be designed for a thermal ramp rate that envelopes the maximum expected prelaunch or flight thermal transition rate plus a margin.

The thermal cycle transition ramp rate of change shall be no less than 3 °C per minute.

e. Mechanical devices**.** An electromechanical FTS device, including Safe and Arm devices, relays, valves, interrupters and safety switches shall satisfy all its performance specifications when subject to the following:
   (1) The minimum thermal cycle temperature range shall be from the lower of -34 °C or the predicted lowest temperature minus 10 °C, to the higher of 71 °C or the predicted highest temperature plus 10 °C.

1. For components whose MPE exceed the 71 °C qualification level, a 3 percent °K margin shall be used in lieu of the + 10 °C margin.
2. For components whose MPE is less than the -34ºC qualification level, the lower temperature margin will be determined on a case-by-case basis. Where testing at temperatures colder than MPE is impractical, the number of thermal cycles may be increased to account for a reduced temperature margin.

(2) The number of thermal cycles shall be three times the acceptance-number of thermal cycles.

1. The minimum acceptance-number of thermal cycles is eight.
2. A component shall be designed to withstand a minimum of 24 thermal cycles.

(3) The component shall be designed for a thermal ramp rate that envelopes the maximum expected prelaunch or flight thermal transition rate.

The thermal cycle transition ramp rate of change shall be no less than 3 °C per minute.

3.3.4 Random Vibration**.** A component shall satisfy all its performance specifications when exposed to a composite vibration level profile on each of three mutually perpendicular axes and for all frequencies from 20 Hz to 2000 Hz.

a. Acceptance. The acceptance random vibration level shall be no less than MPE and the minimum workmanship levels in Table 3.3-1. The duration shall be the MPE or 1 minute per axis, whichever is greater.

TABLE 3.3-1. MINIMUM WORKMANSHIP FOR ACCEPTANCE RANDOM VIBRATION

Frequency Range	Minimum Power Spectral Density
20	0.0053 g^2/Hz
20-150	3 dB/Octave Slope
150-600	0.04 g^2/Hz
600-2000	-6 dB/Octave Slope
2000	0.0036 g^2/Hz
Overall G_{rms} = 6.1	

b. Qualification. The component qualification random vibration level shall be 6 dB above acceptance workmanship and MPE levels. The qualification duration shall demonstrate margin over acceptance and flight.

TABLE 3.3-2. MINIMUM QUALIFICATION RANDOM VIBRATION TESTING	
Frequency Range (Hz)	**Minimum Power Spectral Density**
20	0.021 g^2/Hz
20-150	3 dB/octave slope
150-600	0.16 g^2/Hz
600-2000	-6 dB/octave slope
2000	0.014 g^2/Hz
Overall G_{rms} = 12.2	

1. For systems/components that will have long captive carry and/or flight times, test duration will be determined by the affected MRTFBs and approved through the LRSO. Longer low-level vibration duration times shall use a factor of 1.3 to 3 depending on application and vibration level.
2. The minimum duration shall be 3 minutes per axis or 3 times acceptance test duration, whichever is greater.
3. The MPE vibration duration shall also include a factor of 3 over each critical portion of the expected flight duration such as liftoff, maximum Q, and transonic. The critical vibration times are usually defined as the vibration exposure time that is included within 6 dB of the peak vibration level at each frequency throughout the entire flight.
4. If the MPE vibration duration is shorter than the required minimum duration, the vibration levels can be reduced to the minimum workmanship levels for the remainder of the required duration.

3.3.5 Sinusoidal Vibration. A component shall satisfy all its performance specifications when exposed to 6 dB above the maximum predicted flight sinusoidal vibration level. The qualification duration shall demonstrate margin over acceptance and flight.

The component shall satisfy all its performance specifications when exposed to:

a. Three times the maximum predicted sinusoidal vibration duration time on each of three mutually perpendicular axes.
b. The sweep frequencies shall be from 50 percent lower than the predicted lowest frequency to 50 percent higher than the predicted highest frequency.
c. The persistence at any sinusoidal frequencies shall be three times the MPE of the three axes.

3.3.6 Transportation Vibration. A component shall satisfy all its performance specifications when exposed to 6 dB above the maximum predicted transportation vibration level to be experienced when the component is in the configuration in which it is transported for the maximum predicted transportation exposure time, plus a margin.

1. The component shall satisfy all its performance specifications after being exposed to three times the maximum predicted transportation level.
2. At a minimum, design vibration profile shall be:
   a. 0.01500 g^2/Hz at 10 Hz to 40 Hz.
   b. 0.01500 g^2/Hz at 40 Hz to 0.00015 g^2/Hz at 500 Hz.
   c. If the component is resonant below 10 Hz, the test vibration profile shall extend to the lowest resonant frequency.
   d. The duration shall be 60 minutes per axis.

3.3.7 Operational Shock.

a. An FTS component shall satisfy all its performance specifications when exposed to prelaunch flight, landing and recovery environments at a force of 6 dB above the maximum predicted shock level to be experienced during flight with a shock frequency response range from 100 Hz to 10,000 Hz

1. For multi-stage vehicles, a component shall satisfy all its performance specifications when exposed to a 1300 G minimum shock.
2. The minimum breakup shock levels:

Frequency Range (Hz)	**Minimum Acceleration Spectral Density**
100	100 G
2000	1300 G
10000	1300 G
Q (Resonant Amplification Factor) = 10	

b. A component shall satisfy all its performance specifications after it experiences a total of three times the expected shock exposure in all three axes in both the positive and negative direction.

3.3.8 Transportation Shock. An FTS component shall satisfy all its performance specifications after being exposed to the packaged transportation shock environment.

3.3.9 Bench Handling Shock. An FTS component shall satisfy all its performance specifications after being exposed to the maximum predicted shock to be experienced during handling in its unpacked configuration.

3.3.10 Acceleration Environment. An FTS component shall satisfy all its performance specifications when exposed to vehicle breakup acceleration levels or twice the maximum predicted flight acceleration levels, whichever is greater. The component shall satisfy all its performance specifications when exposed to three times the maximum predicted acceleration duration for each of three mutually perpendicular axes.

The minimum duration for this environment shall be 5 minutes.

3.3.11 Acoustic Environment. The component qualification random vibration level shall be 6 dB above the maximum predicted sound pressure levels. The qualification duration shall demonstrate margin over acceptance and flight.

1. For systems/components that will have long captive carry and/or flight times, test duration will be determined by the affected MRTFBs and approved through the LRSO. Longer low-level acoustic vibration duration times shall use a factor of 1.3 to 3 depending on application and vibration level.
2. The minimum duration shall be 3 minutes per axis or 3 times flight duration, whichever is greater.
3. The MPE vibration duration shall also include a factor of 3 over each critical portion of the expected flight duration such as liftoff, maximum Q, and transonic. The critical vibration times are usually defined as the vibration exposure time that is included within 6 dB of the peak vibration level at each frequency throughout the entire flight.
4. If the MPE vibration duration is shorter than the required minimum duration, the vibration levels can be reduced to the minimum workmanship levels for the remainder of the required duration.
5. The frequency shall range from 50 Hz to 10000 Hz.

3.3.12 Electromagnetic Vulnerability. The design of a system shall eliminate the possibility of the maximum predicted electromagnetic interference emissions or susceptibilities, whether conducted or radiated, from affecting FTS performance. The electromagnetic interference susceptibility level shall ensure that subsystems and components satisfies all performance specifications when subjected to the maximum predicted emission levels of all other vehicle components and external sources to which the component would be exposed.

1. This requirement is often met by performing the system level range test in Chapter 5 and MIL-STD-461 component testing.
2. For electromagnetic flight environment not enveloped by the system range test, additional testing shall be performed.
   a. These environments can be a result of downrange transmitter or third-party transmitters.
   b. MIL-STD-464 provides additional system requirements for unique system conditions.
3. Component electromagnetic levels may be reduced to take into account shielding effectiveness of the vehicle.

3.3.13 Other Environments. An FTS component shall satisfy all its performance specifications and not create a hazardous condition after experiencing any environment that it could experience during transportation, storage, preflight processing, or preflight system testing.

1. Environments include storage temperature, temperature/altitude/humidity, humidity, thermal vacuum, salt fog, fine sand, fungus, explosive atmosphere, and electromagnetic energy environments.
2. Components, such as those using solenoids, relays, and motors in an explosive atmosphere, shall be designed to prevent ignition under all component operating conditions.

3.4 Command Terminate System

a. An FTS shall include a command terminate system that is initiated by radio command and satisfies the requirements of this section.

b. A command terminate system shall have its RF components on or above the last vehicle stage capable of reaching a populated or other protected area before the end of range safety responsibility occurs.

c. The initiation of a command terminate system shall result in accomplishing all the FTS functions.

d. For each launch, at any point along the nominal trajectory from liftoff/release until the no-longer-terminate time, a command terminate system shall operate with an RF input signal that has an electromagnetic field intensity of 12 dB below the intensity provided by the command transmitter system under nominal conditions over 95 percent of the radiation sphere surrounding the vehicle.

e. A command terminate system shall receive and process a valid FTS arm command before accepting an FTS terminate command.

f. For any liquid propellant vehicle, a command terminate system shall allow a flight safety official to non-destruct/terminative shut down any thrusting liquid engine as a command before terminate the vehicle.

3.5 Automatic, Inadvertent Separation, Fail-Safe, or Autonomous FTS

3.5.1 Automatic or Inadvertent Separation FTS.

a. An FTS shall include an automatic or inadvertent separation termination system for each stage or strap-on motor capable of reaching a protected area before the no-longer-terminate time for each launch if the stage or strap-on motor does not possess a complete command termination system, including all RF components. Any automatic or inadvertent separation termination system shall satisfy the requirements of this section.

b. The initiation of an automatic or inadvertent separation termination system shall result in accomplishing all FTS functions that apply to the stage or strap-on motor on which it is installed.

c. An inadvertent separation termination system shall include a device that senses any vehicle breakup or premature separation of the stage or strap-on motor on which it is located and activates the system.

d. A Range User shall locate an automatic or inadvertent separation termination system so that it will survive vehicle breakup until the system activates and accomplishes all its flight termination functions.

e. For any electrically initiated automatic or inadvertent separation termination system, each power source that supplies energy to initiate the termination ordnance shall be on the stage or strap-on motor with the system.

1. FTS Configuration for Orbital Inserted Stages and Payloads.
   a. When an FTS is required, orbital inserted stages and payloads shall contain actuating devices capable of flight termination.
   b. The FTS requirement for payloads may be met by locating the FTS for the payload at the vehicle/payload interface.
2. FTS Requirements for Propulsion Systems Other Than a Stage of the Vehicle. Propulsion systems such as staging system, retro-rockets, attitude control systems or escape rockets that are not considered a stage of the vehicle and present radiological, toxicological, explosive, or other hazards in the event of premature ignition or separation may require an FTS.

3.5.2 Fail-safe System.

a. The fail-safe system shall automatically terminate the flight of the vehicle if a failure of command uplink and/or failure of power source occur in both redundant paths.

1. A fail-safe system does not fulfill the redundancy requirement.
2. Range Safety will determine the need for a fail-safe system on a case-by-case basis.

b. The fail-safe system, once enabled, shall turn on the Arm and Terminate outputs when it experiences a Fail-Safe condition of either loss-of-command-link or low power.
   (1) The loss-of-command-link fail-safe.
   - An Arm and Terminate output shall occur when the fail-safe system has been enabled and a loss of the specified tone or RF carrier has occurred within a pre-programmable time.
   - Time duration for the loss-of-command-link fail-safe timer will be based on vehicle performance characteristics.
   - The Arm and Terminate output shall latch after the loss-of-tone timer times-out.
   - The loss-of-tone timer shall be reset if the tone is reacquired prior to timeout.

The loss-of-tone timer shall be reset if the tone is reacquired for at least 10 milliseconds.

1. Both redundant FTS sides shall be capable of being cross strapped together such that the Arm and Terminate outputs for the programmed Fail-Safe condition occurs only if both paths are Fail-Safe enabled and both paths experience a Fail-Safe condition.
2. When both redundant paths are cross strapped together, if only one of the redundant paths receives a fail-safe enable signal the path that received the fail-safe enable will ignore the input from the other path and output an ARM and TERMINATE if it experiences a fail-safe condition.

FAILSAFE CROSS STRAPPING LOGIC

FAILSAFE ENABLE FUNCTION		FAILSAFE EVENT		FAILSAFE INTERFACE LOGIC				COMMAND OUTPUT	
				FSI		FSO			
REC A	REC B	REC A	REC B	REC A	REC B	REC A	REC B	REC A	REC B
0	0	X	X	0	0	0	0	0	0
0	1	X	0	1	0	0	1	0	0
0	1	X	1	0	0	0	0	0	A/T
1	0	0	X	0	1	1	0	0	0
1	0	1	X	0	0	0	0	A/T	9
1	1	0	0	1	1	1	1	0	0
1	1	0	1	0	1	1	0	0	0
1	1	1	0	1	0	0	1	0	0
1	1	1	1	0	0	0	0	A/T	A/T

FAILSAFE ENABLE FUNCTION => 0 FAILSAFE NOT ENABLED
1 FAILSAFE ENABLED

FAILSAFE EVENT => 0 DOES NOT OCCUR
1 LOW VOLTAGE OR LOSS OF TONE OCCURS

FAILSAFE INTERFACE LOGIC => 0 LOW
1 HIGH

RECEIVER COMMAND OUTPUT =>0 ARM AND TERMINATE OUTPUT OFF
A/T ARM AND TERMINATE OUTPUT ON

FSI => FAILSAFE INPUT

FSO => FAILSAFE OUTPUT

(2) A loss-of-power fail-safe condition exists when the fail-safe system has been enabled for fail-safe and the power source voltage falls to a predefined level for a defined duration. This voltage level is set above the minimum specified operating voltage for all FTS components.

This fail-safe response shall occur within 5 ms after reaching the fail-safe voltage threshold.

c. A capability to enable and disable the fail-safe system shall be provided.

1. The fail-safe system shall contain a means to permanently deactivate the fail-safe system by either a plug or jumper.
2. The fail-safe system shall not be enabled until just prior to vehicle first motion or shortly after vehicle first motion.
3. If the fail-safe system is enabled prior to vehicle first motion a capability to disable fail-safe must be provided through an uplink command or other means.
4. The capability to command enable and disable fail-safe after first motion may be required on some vehicles.
5. Fail-safe enable can be generated by a pulsed or voltage level to the receiver.

1. FTRs with Loss-of-Tone and Low Voltage Fail-Safe.
   a. The fail-safe shall be enabled and latched by the application of voltage signal to a specified, agreed upon, pin at the FTR input connector. The fail-safe shall not be enabled with pulse durations less than 5 milliseconds but shall be enabled by pulse durations of 18 milliseconds. Application of a steady-state enabling signal shall not degrade the fail-safe enable circuit. The voltage amplitude may be as agreed upon by the ranges, the Range User, and the FTR manufacturer. Once enabled, the fail-safe shall not become disabled by the removal of the enabling signal from the specified FTR input connector pin.
   b. For laboratory testing purposes, the fail-safe latching feature shall be reset by removing the unit input power.
2. FTR with command loss-of-tone and low voltage fail-safe enable/disable.
   Note. FTRs have internal fail-safe capability.

Tone Logic For 4-Tone FTR With Fail-Safe (Commanded Fail-Safe Enable/Disable)

	TONE A	TONE B	TONE C	TONE D
MONITOR				
OPTIONAL				
ARM				
TERMINATE				
F/S ENABLE				
F/S DISABLE				

0 = Required ABSENCE of Tone.
1 = Required PRESENCE of Tone.
X = Do Not Care State.
-1 = Indicates that ARM command shall precede the TERMINATE command.

NOTE: If table above is required, please see your respective range.

3.5.3 Autonomous Flight Termination System (AFTS).

a. The AFTS shall only replace the command terminate system if specific approval is granted for each mission, vehicle, and range.

1. An AFTS uses on board decision making capability to terminate a mission when vehicle performance violates predetermined parameters.
2. The AFTS may supplement the existing command termination system.
3. An AFTS includes all associated software, hardware, and subsystems used to make termination decision such as GPS receivers, GPS antennas, batteries, and inertial navigation systems.

b. An AFTS shall terminate flight when a vehicle violates flight safety parameters, when the vehicle is performing erratically, or during breakup.
c. Tracking system and components needed to support the AFTS function shall meet both RCC 324 AND RCC 319 requirements.

1. RCC 324 performance requirements are not written to specifically address safety critical applications. RCC 324 requirements must be tailored using the more stringent criteria of RCC 319 FTS criteria.
2. Where a loss of tracking system components represents only a mission assurance risk, the tailoring may be reduced for those requirements related to loss of data. Specific approval shall be granted for each unique application and the Range User shall document risk acceptance of the lower reliability systems.
3. Requirements associated with accuracy, data latency, sample rate, quality indicators shall be tailored as critical FTS components.

4. Tracking systems used for the AFTS function shall not have single points of failure that would produce undetectable out of specification state vector data.
   Note: exceptions, such as Inertial Measurement Units (IMUs), may be granted on a case-by-case where IMU data is validated with another tracking source.

d. Two AFTS data transfer issues are:
   (1) The AFTS shall be capable of remotely verifying that the loaded software/firmware is correct.

1. The AFTS shall be capable of remotely outputting all software and firmware contents loaded after acceptance testing to ground support equipment to perform a bit-by-bit comparison against the required logic.
2. This requirement includes any memory or processing devices that require an internal load to boot such as FPGA and microprocessors.
3. Other high integrity data transfer verification algorithms may be used.

   (2) A minimum of two adequate and independent tracking sources shall be used as an input into the AFTS. These two tracking sources shall not be used for vehicle guidance control.

1. An adequate tracking source meets the requirements of RCC 324, including no single failures that would create undetectable false position data.
2. The tracking sources shall produce uninterrupted data to the end of Range Safety responsibility. Any expected dropouts must be evaluated to determine whether they are acceptable. Tracking dropouts shall not be longer than three (3) seconds.
3. Additional vehicle guidance tracking sources that exceed the two tracking sources may be used as an AFTU input. The weighting and mission rules for these additional tracking sources shall be determined on a case-by-case basis.

e. An AFTS shall have its components on or above the last vehicle stage capable of reaching a populated or other protected area before the end of range safety responsibility occurs.
f. Redundant systems shall have no common-cause software single point failures.

Where the same software and processing hardware are being used on both redundant systems, an independent terminate circuit shall be provided that automatically terminates flight if both processors stop processing data normally (i.e. heartbeat monitor). This monitor is not required to be redundant.

g. An AFTS shall provide for the required number of verifiable and independent inhibits depending on the termination system hazard.

1. For hazardous termination systems, the AFTS shall have a minimum of 3 inhibits for normal vehicle processing.
2. Two separate airborne power switching circuits shall be supplied to the AFTU. The following two independent power inputs shall be provided to the Autonomous Flight Termination Unit (AFTU):
   a. A remotely switchable power input to the AFTU logic for testing.
   b. A remotely switchable power input into the AFTU Master Arm.
   c. The two power inputs shall be controlled separately by ground support equipment.
3. Depending on unique vehicle applications and hazard levels, additional safety devices such as ordnance interrupters, mechanical power transfer switches or Safe/Arm plugs may be required.
4. Inhibits shall also ensure that there are no single failure or common-cause failure mode that could result in inadvertent initiation during prelaunch testing.

h. The AFTS, including tracking and supporting subsystems, shall be capable of being fully tested in its final flight configuration.

3.6 FTS Safing and Arming (S&A) Devices

Arming devices used on FTSs include electromechanical arm and fire devices (AFDs), S&A devices, high voltage EBW firing units, LFUs/ordnance interrupters, electronic arm and fire devices (EAFDs), and electronic S&A devices (ESADs).

3.6.1 General. An FTS shall provide for safing and arming of all FTS ordnance through the use of a mechanical barrier or other positive means of interrupting power to each of the ordnance firing circuits to prevent inadvertent initiation of ordnance.

For non-destruct termination systems that do not pose a hazard to personnel, arming devices that provide positive ordnance safing may not be required.

3.6.2 FTS Arming.

a. Arming Prior to First Motion. An FTS shall provide for each FTS ordnance initiation device or arming device to be armed and all electronic FTS components to be turned on before arming any vehicle or payload propulsion ignition circuits.
b. Arming After First-Motion.
   (1) For vehicles in which propulsive ignition occurs after first motion, the FTS shall contain an ignition interlock so that ignition cannot occur unless both FTS arming devices are armed. This arming requirement must be consistent with launch-crew safety.
   (2) For vehicles in which propulsive ignition occurs prior to first motion, arming of each independent FTS string shall contain no single point failures. The delay time for arming must be a minimum consistent with launch-crew safety. This

option shall only be used when there is no other means of supporting the mission.

(3) For non-propulsive guided vehicles, the arming of each independent FTS string shall contain no single point failures. The delay time for arming must be a minimum consistent with launch-crew safety.

When arming occurs after first motion, arming shall not require more than three independent events/environments. None of these events/environments may come from vehicle systems such as the guidance computer, control surfaces, whose failure may prevent the arming unless such systems are qualified to the same levels as the FTS and fall under the same configuration control as the FTS.

3.6.3 Preflight Safing. Vehicles armed prior to first motion, shall provide for remote and redundant safing of all FTS ordnance before launch and during any launch abort or recycle operation.

At least one safing system shall be routed to the vehicle via hard-line.

3.6.4 In-Flight Safing. Any safing of FTS during flight shall satisfy all of the following:

a. Any onboard vehicle hardware or software used to automatically safe the FTS shall be single fault tolerant against inadvertent safing. Any automatic safing shall satisfy all of the following:
   (1) Any automatic safing shall occur only when the flight of the vehicle satisfies the safing criteria for no less than two different safing parameters or conditions such as time of flight, propellant depletion, acceleration, or altitude. Safing criteria for each safing parameter or condition shall ensure that the FTS on a stage or strap-on-motor can only be “safed” once the stage or strap-on motor attains orbit or can no longer reach a populated or other protected area.
   (2) Any automatic safing shall ensure that all FTS system components remain armed during flight until the requirements of this section are satisfied and the system is safed.
   (3) If operation of the vehicle could result in meeting the safing criteria for one of the two safing parameters or conditions before normal thrust termination of the stage or strap-on motor to which the parameter or condition applies, then the Range User shall:
      - Demonstrate that the greatest remaining thrust, assuming a three-sigma maximum engine performance, cannot result in the stage or strap-on motor reaching a populated or other protected area.
b. If a radio command safes an FTS, the range command transmitter used for in-flight safing shall be single fault tolerant against inadvertent transmission of a safing command.

3.7 Liquid Propellant Shutdown

A liquid propellant shutoff system used as the primary means of Flight Termination System (FTS) shall be designed to ensure reliable termination within the required flight performance conditions.

1. A liquid propellant shutdown system is not required to meet the performance requirements of this section if it is a backup to a primary termination system.
2. The FTS valves may be shared with the vehicle propulsion system valves.

3.7.1 Shared shutdown valve control and activation circuits used for FTS and mission performance shall be electrically isolated from one another to prevent a vehicle system failure from affecting FTS performance.

3.7.2 Each FTS shutdown valve shall be capable of independently terminating vehicle thrust.

1. Thrust termination system shall consist of two or more valves.
2. Fuel and oxidizer feed lines shall have at least one FTS shutdown valve in each line.
3. A failure in one valve, such as a short-circuit, shall not inhibit the ability to function a redundant valve.

3.7.3 Recyclable FTS shutdown valves shall be capable of being tested in a flight installed configuration to ensure they meet their performance requirements.

Recyclable FTS shutdown valves shall be capable of being opened and closed for prelaunch testing

3.8 FTS Monitoring

1. Where applicable, electromechanical arming devices with a visual indication shall be accessible when the vehicle is totally assembled and provide a remote indication (i.e. a status indicator) of its SAFE/ARMED status.
2. The telemetry requirements specified below are not necessarily all-inclusive. The number and type of FTS parameters that may be required for telemetering will depend on the final configuration of the FTS.
3. The monitor circuit shall be designed to allow monitoring of the end-to-end FTS testing. This requirement may be accomplished either through telemetry or through a hard-line to the ground support equipment.

3.8.1 An FTS shall interface with the vehicle’s telemetry system to provide the data that the flight safety system personnel require in order to evaluate the health and status of the FTS before and during flight.

3.8.2 The telemetry data shall be provided to ensure the health, readiness, and functionality of the FTS.

1. Signal strength for each flight termination receiver.
2. Power status to each flight termination subsystem.
3. Status of output commands for each flight termination receiver and each automatic or inadvertent separation termination system.
4. Safe and arm status of each S&A device.
5. Voltage for each FTS battery or power source.
6. Current for each FTS battery or power source.
7. Status of any electrical inhibit at the system level that is critical to the operation of an FTS and is not otherwise identified by this volume.
8. Status of any firing unit, including arm input, power level, firing capacitor charge level, and trigger capacitor charge level.
9. Temperature of each FTS battery, whether monitored at each battery or in the immediate vicinity of each battery so that each battery's temperature can be derived.
10. Status of each switch used to provide power to an FTS, including any switch used to change from an external power source to an internal power source.
11. Shutdown valve position (OPEN/CLOSED/THROTTLE) where shutdown is the primary means of positive control.
12. Fail-Safe Status:
    a. Bypass. Data indicating the status of the fail-safe bypass.
    b. Fail-Safe Enable and Disable. Telemetry data indicating the enabled and disabled status of the fail-safe system.
    c. Fail-Safe Timer. Telemetry data indicating when the fail-safe time has started and reset.
13. Missile Separation Switch Status: Telemetry data indicating that the missile has separated from the launcher.

Range Safety may allow telemetry signals to be substituted for ground umbilical on a case-by-case basis.

3.8.3 Resolution, accuracies, and data rate for monitor circuit outputs shall allow determination that the FTS is functioning within its specification for all required measurements. Resolution, accuracies, and data rate specifications shall be submitted to Range Safety for review and approval.

For FTS outputs that can change continuously during flight such as SSTO, check channel, pilot tone, battery voltage and battery current, the minimum TM data rate shall be 100 samples per second.

3.8.4 FTS Parameter Channel Identification/Calibration Tape. The Range User shall provide a synthesized FTS parameter channel identification/ calibration magnetic tape. This tape is used to facilitate the setup of real-time recorders for missile test operations at that range. The Range

User shall contact each affected range for specific requirements in making the channel identification/calibration tape.

3.9 FTS Electrical Components and Electronic Circuitry

3.9.1 General. All FTS electrical components and electronic circuitry shall satisfy the requirements of this section.

3.9.2 Electronic Piece-Parts. Each electronic piece-part that can affect the reliability of an FTS electrical component or electronic circuitry shall be free of defects that would cause in-flight failure during environmental exposure. Technical justification showing qualification-by-similarity for any changes in parts between flight hardware and the original qualification test unit shall be approved by Range Safety.

1. Space and ballistic missiles shall meet the piece-part requirements of Appendix B.
2. All piece-parts shall meet the derating requirements in Appendix C.
3. Parts not directly associated with issuing FTS action or that do not degrade FTS performance, such as telemetry circuits, may be exempt from this requirement.
4. Parts used in flight components shall use the same design, form, fit, and function as the parts used during component qualification testing.

3.9.3 Over, Under, and Transient Input Voltage Protection. The component shall operate nominally after being subjected to any voltage from zero to the maximum power source voltage plus a margin including transients and reverse polarity.

1. Power Source OCV. FTS components shall be designed to withstand, without damage, up to 45V, or the OCV of the power source, whichever is greater.
2. An FTS electronic component shall satisfy all of its performance specifications after being subjected to a reverse polarity voltage that could occur before flight, for a duration of no less than five minutes.
3. The tolerance-to-transient voltages, as might occur during the application or removal of power, shall be specified for each connector pin. Amplitude, polarity, duty cycle, rise time, and duration shall be identified.
4. The component shall be tested from 0 volts to the minimum specified voltage back to 0 volts without damage or producing a spurious output regardless of the transition rate between the voltages present. The component shall function nominally after this test.

3.9.4 Series-Redundant Circuit. An FTS component that uses a series-redundant branch in a firing circuit to satisfy the prohibition against a single failure point shall possess one or more monitoring circuits or test points for verifying the integrity of each series-redundant branch after assembly and during testing.

3.9.5 Input Power. Components shall meet all performance requirements when power is applied.

a. Transient power dropout. In the event of an input power dropout during nominal and abnormal flight environments, a component shall not change state after experiencing the dropout plus a margin. Processors and memory devices shall be capable of returning to a fully functional configuration after the dropout plus a margin.

1. The minimum dropout shall be 50 millisecond.
2. The component does not need to function during the 50 millisecond dropout. However, it shall return to its last commanded state.
3. Processors or memory devices shall not reinitialize or require reloading unless the component will be fully functional within 50 millisecond upon power restoration.
4. Examples of components include, but are not limited to, power control, memory or switching circuit, solid-state power transfer switch and arm-and-enable circuit.

b. Component Power Up. A component shall power up in a safe, known and repeatable state.

A component shall power up in the safe condition after being powered-down for a minimum of three seconds.

3.9.6 Circuit Isolation, Shielding, and Grounding. The circuitry of an FTS component shall be shielded, filtered, grounded, or otherwise isolated to preclude any energy sources, internal or external to the vehicle, such as electromagnetic energy, static electricity, or stray electrical currents, from causing interference that would inhibit the FTS from functioning or cause an undesired output of the system.

1. If the design of an FTS component requires the use of electrostatic discharge sensitive circuitry and devices, the protection and handling requirements shall be specified and appropriate warning labels affixed to each unit and associated documentation. This protection requirement applies whether sensitivity is due to individual components, subassemblies, printed circuit boards, or open- or closed-box configuration.
2. Circuits, capable of building up static charge, shall be connected to the structure by static bleed resistors of between 10K and 100K ohms.
3. For low voltage initiator systems, the FTS firing circuit shall be isolated from vehicle ground except for static-bleed resistors. The static-bleed resistors shall be between 10K and 100K ohms.
4. Low voltage initiator firing and electronic component input power circuits shall have a single-point ground connection directly to the power source only.
5. The FTS wiring shields shall be grounded.
6. Electrical firing circuits shall be isolated from the initiating ordnance case, electronic case, and other conducting parts of the vehicle.
7. The DC bonding resistance between connection points of the shielded system, metallic enclosures, and structural ground shall be 2.5 milliohms or less.
8. The shielding for firing circuits shall provide a minimum 20-dB safety margin between worst-case electrical noise and the maximum NO-FIRE value.
9. The shielding for other FTS circuits shall provide a minimum 6-dB safety margin between worst-case electrical noise and circuit threshold levels.
10. Shielding shall provide a minimum of 85-percent optical coverage ratio. Optical coverage is the percentage of the surface area of the cable core insulation covered by a shield. A solid shield would have 100-percent optical coverage.
11. There shall be no gaps or discontinuities in the shielding including the termination at the back faces of the connectors. Shields terminated at a connector shall be electrically joined around the full 360o circumference of the shield.
12. Connectors and containers shall provide RF attenuation that will not circumvent the protection provided by the shielded cables.
13. The use of a wiring shield as a circuit return or ground is not permitted. Shields shall not be used as intentional current-carrying conductors.
14. Firing circuits and control circuits shall be shielded from each other.

3.9.7 Circuit Protection. Any circuit protection provided within an FTS shall satisfy all of the following:

a. FTS circuitry shall not contain protection devices, such as fuses, that would disable the FTS during out of specification conditions that can occur during nominal and errant vehicle flight. A termination circuit may employ current limiting resistors.
b. The design of an FTS output circuit that interfaces with another vehicle circuit shall prevent any vehicle circuit failure from disabling, degrading or inadvertently initiating the FTS.

1. An FTS electronic component's critical circuits shall satisfy all their performance specifications when any of its monitor outputs are subjected to a short circuit for a minimum of 5 minutes.
2. An FTS electronic component's critical circuits shall satisfy all their performance specifications when any of its monitor outputs are subjected to the forward and reverse polarity OCV of the vehicle system power source for up to 5 minutes. This requirement shall be met in both the powered-up and unpowered modes. The minimum OCV shall be 45V.
3. An FTS electronic component's shall satisfy all their performance specifications or be detectable after being subjected to a short circuit of any output for a minimum of 5 minutes. A component unable to pass required tests is considered a detectable condition.
4. All FTS and vehicle system interface components containing reactive elements, such as relays and electrical motors that are capable of producing voltages, shall be provided with suppression circuitry to prevent interference or damage to other FTS components.
5. Where liquid engine shutdown is not the primary means of flight termination, electronic FTS shutdown circuits shall contain protective devices such as current limiting resistors to prevent a short circuit from disabling the primary command terminate circuit.

3.9.8 Repetitive Functioning. Each circuit, element, component, and subsystem of an FTS shall satisfy all its performance specifications when subjected to repetitive functioning for the expected number required for acceptance, checkout, and operations, including re-tests caused by schedule or other delays plus a margin.

1. Each circuit, element, component, and subsystem of an FTS shall satisfy all its performance specifications when subjected to repetitive functioning for five times the expected number required for acceptance, checkout, and operations, including re-tests caused by schedule or other delays.
2. The power-on duty cycle shall be representative of 150 percent of nominal in-flight power consumption, at maximum temperature extremes, and shall include a 30 minute hangfire wait period for solid rocket motors. This cycle shall not be less than 45 minutes and shall be repeatable after a power-off period of not more than 2 minutes.
3. Firing units, without the initiators or ordnance, shall have an operating life of 1000 firings without degradation into an agreed upon test load.

4. If the firing unit cannot meet the required number of firings with a five times margin or 1000 firings, the ranges shall approve the total number of expected firings (acceptance test, bench test, prelaunch test and flight) based on the following:
   a. The firing unit shall be qualified for an operating life of at least two times the total expected firings into an agreed upon load that will include some firings into flight loads, but not to exceed the firing unit manufacturer guaranteed number of firings. The ranges shall also approve the actual load(s) used for testing.
   b. Data sheets shall accompany each firing unit that provides, at a minimum, the number of times the device has been fired, the load conditions, the date, a QA stamp (or initials of the person performing the test), and the results of the test. EAFDs (or ESADs) that exceed 50 percent of the qualification number of firings, at full load, will not be allowed for FTS applications. In addition, firing units that do not have an accompanying data sheet for review by Range Safety personnel will not be allowed for FTS applications.
   c. Spark-gap devices shall undergo piece-part level testing to ensure the expected operating life will exceed the EAFD (or ESAD) qualification number of firings by 50 percent.
5. Recyclable FTS shutdown valves shall function within their performance specifications when subjected to no less than 5 times the maximum number of open/closed cycles required for acceptance, prelaunch checkout and flight or a minimum of 500 cycles, whichever is greater. Valves shall be designed with a minimum pressure cycle life of 5X the maximum expected operating pressure cycles.
6. Connector Mate/Demate. Connectors shall meet all their performance requirements after being subjected to the following.
   a. All connectors shall be capable of being mated and demated five times the total expected number of cycles required for acceptance tests, preflight tests, and flight operations, including an allowance for potential retests due to schedule delays.
   b. The minimum number of mate/demates shall be 100.
7. Laser initiated fiber optic cable assemblies shall not degrade in performance when subjected to all of the following conditions concurrently:
   a. Repetitive functioning for 5 times the maximum expected number of firings, and
   b. Two times the maximum firing optical power for no less than 10 times the duration of the maximum firing pulse, with a minimum number of 100 firings.

3.9.9 Watchdog Circuits. An FTS or component that uses a watchdog circuit that automatically shuts down or disables circuitry during flight shall be specifically approved by Range Safety. The watchdog circuit shall not inhibit the intended processing function of the unit or cause any output to change.

1. Examples of acceptable applications are watchdog circuits for power-up resets and snap-on and snap-off circuits in power supplies for processor and logic circuits. The trigger parameter shall be specified in the component specification and included in testing.
2. For the initial power-up sequence, functional capability may be disabled.

3.9.10 Self-Test. If an FTS component uses memory, programmable logic/firmware, or a microprocessor, the component shall perform self-tests, detect errors, and relay the results through telemetry.

Self test shall be performed upon power up or when commanded.

3.9.11 Electromagnetic Interference and Compatibility Protection**.** The design of an FTS component shall eliminate the possibility of the maximum predicted electromagnetic interference emissions or susceptibilities, whether conducted or radiated, from affecting the component's performance. A component's electromagnetic interference susceptibility level shall ensure that the component satisfies all its performance specifications when subjected to the maximum predicted emission levels of all other vehicle components and external sources to which the component would be exposed.

1. FTS components shall be designed to meet the requirements of MIL-STD-461, "Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment." The following methods are required where applicable: CE102, CE106, CS101, CS103, CS104, CS105, CS114, CS115, CS116, RE102, RE103 and RS103. Other methods may be required for unique vehicle environments. 2. MIL-STD-461 tests, frequencies, limits, and levels shall envelope electromagnetic operating environments or the default test environments, whichever is greater.

3.9.12 Ordnance Initiator Circuits.

a. Low voltage ordnance initiators that function at less than 50 volts shall meet the following:
   (1) The firing circuit shall deliver a minimum operating current of the all-fire current level plus a margin. The current shall be delivered at the lowest battery voltage and under the worse case system tolerances allowed by the system design limits. The firing circuit shall deliver the required current for the worst-case initiator firing time plus a margin.

FTS firing circuits shall be designed to deliver 150 percent of the all-fire current for no less than 10 times the required duration.

   (2) The firing circuitry shielding shall limit the power at each associated initiator to an electromagnetic environment level at least 20 dB below the pin-to-pin direct current no-fire power.

b. High voltage ordnance initiators that function at greater than 500 volts shall meet the following:
   (1) The firing unit shall deliver the all-fire voltage to the initiator plus a margin.

The firing unit shall deliver a minimum of 150 percent of the all-fire voltage level.

   (2) The firing unit's power circuit shall include a positive means of interrupting the main initiator's charging circuits, such as the trigger and output capacitors.
   (3) Shielding circuitry shall maintain a 20 dB margin between the threshold firing level and the noise induced energy at the firing unit's command input.

3.9.13 Response Time. An FTS component's response time shall be specified and repeatable to ensure the FTS activates in sufficient time to terminate a vehicle prior to endangering a protected area and prior to loss of the FTS during vehicle breakup. Each component's response time shall be used as an input in meeting the overall FTS delay requirement in paragraph 3.2.11.

1. As a goal, the output of a commanded function should occur within 5 milliseconds of receipt of the completed command signal. However, the commanded output function shall occur no later than 50 milliseconds after receipt of the completed command signal. 2. Manned systems may use longer response times to account for crew escape. 3. An AFTS shall initiate a terminate output within 250 ms of a terminate criteria violation. 4. An FTR average response time of each function shall be between 4 and 25 milliseconds from the time the command is received by the FTR.

3.9.14 Memory Data Retention. An electronic component employing memory devices shall be tested to demonstrate that data stored in memory is accurate and retained in accordance with the specification. FTS memory devices shall retain the required data for the specified time interval while the component remains unpowered.

1. Any loaded parameter used in an airborne FTS component, such as the FTR and AFTS, shall remain in memory for a period of not less than 180 days without primary direct current (dc) power being applied. 2. Where software/firmware loading occurs after acceptance testing, a positive means to verify the integrity of the loaded memory device shall be provided.

3.9.15 Adjustment. An electronic component shall not require any adjustment after successful completion of acceptance testing.

3.9.16 Component Protection. FTS components shall be protected to withstand non-operating and operating environments.

1. Low voltage electronic components (less than 50 volts) shall be environmentally sealed to the equivalent of 10^{-4} standard cubic centimeters/seconds of helium at one atmosphere differential.
2. High voltage electronic components (greater than 500 volts) shall be hermetically sealed to the equivalent of 10^{-6} standard cubic centimeters/seconds of helium at one atmosphere differential.
3. FTS Component Case Finish and Construction. The FTS component case finish and construction shall provide protection against corrosion, cracking, peeling, and degradation of electrical connections and impedance paths necessary to insure performance within the requirements of the procurement specification under all environmental testing conditions.
4. Non-operating and operating environments shall include salt-fog and humidity, altitude, storage, explosive atmosphere, transportation, preflight and flight.

3.9.17 Power and Firing Circuits. Components used in an FTS power and firing circuits shall be capable of delivering the highest operating current and voltage at the required operating duration plus a margin.

1. The current and voltage margin shall be 150 percent of the highest operating current and voltage.
2. The duration margin shall be 10 times the worst-case operating time.

3.9.18 Leakage Current. The maximum leakage current through any commanded output port shall be at a level that cannot degrade performance of downstream electrical or ordnance initiation systems or result in an inadvertently triggered command. Leakage current shall meet the following requirements when the component is subjected to power-up, power-down, power dropout, and steady state operation:

a. There shall be a minimum 20 dB safety margin between the component leakage output and the no-fire or degrading current of any downstream ordnance initiator.

1. The component shall not produce any outputs greater than 1 volt in amplitude for more than 200 microseconds into a 10k-ohm load during the voltage transient and shall meet its performance requirements after the application of the voltage transient.
2. Leakage Current. The leakage current from the output port with no command output applied shall be 50 microamperes maximum unless otherwise agreed to by Range Safety.
3. The laser firing unit's optical output power while in the safe condition shall be 60 dB less than the guaranteed no-fire level at the main firing and BIT frequencies.

b. There shall be a minimum 20 dB safety margin between the component leakage output and the specified no fire trigger level for down-stream electronic circuits or ordnance initiation systems (for example, EBW and EFI firing units).

3.9.19 Warm Up Time. An electronic component shall meet all its performance requirements after being powered for the specified warm-up time.

3.10 FTS Monitor, Checkout, and Control Circuits

Monitor, checkout, and control circuits shall be designed as follows:

a. The actual status of critical parameters can be monitored directly during prelaunch and flight.
b. Any monitor and checkout current in a low voltage initiator system firing line shall not exceed one-tenth of the no-fire current of the low voltage initiator.
c. Resolution, accuracies, and data rate for monitor circuit outputs shall allow determination that the FTS is functioning within its specification for all required measurements. Resolution, accuracies, and data rate specifications shall be submitted to Range Safety for review and approval.

1. Monitor, control, and checkout circuits shall be completely independent of the firing circuits and shall use a separate and non-interchangeable electrical connector.
2. Monitor, control, and checkout circuits shall not be routed through safing and arming plugs.

3.11 FTS Ordnance Path

1. Ordnance items shall be assigned to the appropriate Department of Defense (DoD) or United Nations (UN) Hazard Classification and Storage Compatibility Group in accordance with DoD 6055.9-STD, Ammunition and Explosives Safety Standards.
2. Items that have not previously been classified and cannot be classified based on similarity with previously classified items shall be tested in accordance with Air Force Technical Order (AFTO) 11A-1-47 NAVSEAINST 8020.3/TB 700-2/DLAR 8220.1, Explosive Hazard Classification Procedures, and classified accordingly.
3. Ordnance items shall also have a Department of Transportation (DOT) classification.

3.11.1 Components. An ordnance path shall consist of all components responsible for initiation, transfer, and output of an explosive charge. Ordnance path components shall include, initiators, energy transfer lines, S&A rotor charges, boosters, explosive manifolds, and destruct/terminate charges.

3.11.2 Reliability. The reliability of an ordnance path to initiate ordnance, including the ability to propagate a charge across any ordnance interface, shall be 0.999 at a 95 percent confidence level.

1. Explosive paths containing cylindrical donor and receptor charges shall use the end-to-end detonation transfer mode where practicable. Designs that preclude use of the end-to-end transfer mode may use end-to-side or side-to-end, in that order of preference. Side-to-side detonation transfer shall not be used.
2. Where more than one input source occurs, such as a manifold or termination charge initiation block, either input shall be capable of initiation (propagation) independently from the other sources. The firing of simultaneous redundant initiators shall not prevent the proper propagation of the explosive path.
3. Detonation interconnects or crossovers shall not be used between redundant explosive paths unless approved by Range Safety.

3.11.3 Temperature Exposure. The decomposition, cook-off, sublimation, auto-ignition, and melting temperatures of all FTS ordnance shall be no less than 30 °C higher than the MPE temperature to which the material will be exposed during storage, handling, installation, transportation, and flight.

3.11.4 Safing. Ordnance systems shall be capable of being positively safed for ground processing operations.

1. An ordnance path shall include initiation devices that can be connected or removed from the destruct/terminate charge.
2. The design of an ordnance path shall provide for easy access to the initiation devices.
3. Fittings shall be designed to facilitate installation of the FTS ordnance components in the vehicle as late as possible in the prelaunch configuration.
4. All ordnance connections shall be capable of connection and disconnection for a minimum of 10 cycles or 5 times the number of planned cycles, whichever is greater, without causing any damage or degradation of performance.

3.11.5 Connections. All ordnance connections shall positively lock in place and provide for verification of proper connection through visual inspection.

1. Fitting design and placement on the vehicle shall not induce misalignment of ordnance components.
2. Fittings shall be designed so that reverse installation or interchanges are impossible.

3.12 RF Receiving System

3.12.1 General. An RF receiving system shall include FTS antennas, RF couplers, RF cables, or other passive devices used to connect an FTS antenna to a FTR. The system shall deliver range command transmitter system RF energy that satisfies all its performance specifications to each FTR when subjected to performance degradation caused by the command transmitter system variations, vehicle flight conditions, and FTS hardware performance variations.

1. Voltage Standing Wave Ratio (VSWR). Unless otherwise specified, FTS antenna system components shall be designed for a nominal 50-ohm impedance, and the antenna system shall have a VSWR of 2:1 or less across the specified bandwidth and over the operating environments.
2. Insertion Loss. The insertion loss shall have a design goal of no greater than 4 dB loss from the output port of any antenna to the input port of any FTR.
3. Deep nulls in the pattern shall be minimized both as to the number of nulls and angular width.
4. The FTS antenna systems for spinning vehicles shall also minimize the fluctuation of the received signals as the vehicle rolls.
5. The 3 dB bandwidth of the FTS antenna system shall be greater than ±180 kHz.

3.12.2 Sensitivity. An RF receiving system shall provide command signals to each FTR at an electromagnetic field intensity of no less than 12dB above the level required for reliable receiver operation. The system shall satisfy the 12-dB margin over 95 percent of the antenna radiation sphere surrounding the vehicle and shall account for range command transmitter system RF characteristics, airborne system characteristics including antenna gain, path loses due to plume or flame attenuation, and vehicle trajectory. For each launch, the system shall satisfy the 12-dB margin at any point along the nominal trajectory until the no-longer-terminate time for the launch.

3.12.3 Antennas. All of the following apply to each FTS antenna:

a. An FTS antenna shall have a 3 dB bandwidth that is no less than two times the total combined maximum tolerances of all applicable RF performance factors. The performance factors shall include frequency modulation (FM) deviation, range command transmitter inaccuracies, and variations in hardware performance during thermal and dynamic environments.
b. A Range User shall treat any thermal protection used on an FTS antenna as part of the antenna.
c. An FTS antenna shall be compatible with the range command transmitter equipment.

1. The FTS antenna system shall be fully compatible with the range command transmitter and their left-hand circular polarized antennae.
2. The 3 dB bandwidth of the FTS antenna system shall be greater than ±180 kHz.
3. Doppler effects do not require the two times margin.

3.12.4 RF Coupler. An FTS shall use a passive RF coupler to combine RF signals inputs from each FTS antenna and distribute the required signal level to each command receiver. An RF coupler shall satisfy all of the following:

a. An RF coupler shall prevent any single point failure in one redundant command receiver or antenna from affecting any other redundant command receiver or antenna by providing isolation between each port. An open or short circuit in one redundant command receiver or antenna path shall not prevent the functioning of the other command receiver or antenna path.
b. Each input port shall be isolated from all other input ports.
c. Each output port shall be isolated from all other output ports.
d. All input ports shall be isolated from all output ports.
e. An RF coupler shall provide for an RF bandwidth that exceeds two times the total combined maximum tolerances of all applicable RF performance factors. The performance factors shall include FM deviation of multiple tones, command control transmitter inaccuracies, and variations in hardware performance during thermal and dynamic environments.

1. Hybrid couplers that offset the phase (90° or 180°) between the outputs are preferred. Other types may be used but shall be technically justified and approved.
2. The 3 dB bandwidth of the FTS antenna system shall be greater than ±180 kHz.

3.13 Flight Termination Receiver

3.13.1 General. Each FTR shall:

a. Receive RF energy from the range command transmitter through the RF receiving system and interpret, process, and send commands to the FTS.
b. Be compatible with the range command transmitter equipment
c. Satisfy the requirements for all electronic components in 3.9
d. Satisfy all its performance specifications and reliably process a command signal when subjected to range command transmitter transmitting equipment tolerances and flight generated signal degradation. Margins added to nominal tolerances of this section must account for uncertainties associated with non-nominal RF performance.

At a minimum, range command transmitter transmitting equipment tolerances and flight generated signal degradation include:

a. Locally induced RF noise sources.
b. Vehicle plume.
c. The maximum predicted noise-floor including interference sources and high power pulse radars.
d. Range command transmitter performance variations.
e. Vehicle trajectory.
f. Flight hardware performance variations.

3.13.2 Tone-Based RF Processing. An FTR shall receive a range command under worst-case ground transmitter tolerances, flight hardware performance variations and RF signal degradation plus a margin. Each tone-based FTR shall satisfy all of the following for all preflight and flight environments:

The FTR threshold level is the minimum level where commands can be processed.

a. Decoder Channel Deviation. The FTR shall reliably process the intended tone deviated signal at the minimum and maximum number of expected tones using a nominal tone deviation plus a margin.

1. The margin shall be at least twice the maximum and minus half the minimum of the total combined tolerances of all applicable RF performance factors.
2. Current range command transmitter performance supports a tone deviation of plus and minus 30 KHz per tone.
3. The following are the requirements of the RF deviation threshold for each channel.
   a. The FTR shall meet all specifications when the input RF carrier is deviated over the range of plus and minus 27 to plus and minus 33 kHz per tone.
   b. Tone decoder operating threshold region shall be between 9 and 18 kHz.

RCC STANDARD DECODER TONES			
RCC TONE	**FREQUENCY (KHZ)**	**RCC TONE**	**FREQUENCY (KHZ)**

HIGH ALPHABET DECODER TONES	
SECURE TONE	**FREQUENCY (KHZ)**
1	
2	
3	
4	
5	
6	
7	
Pilot	

Range ground transmitter specification:
Tolerances: Frequency ±0.1%
Amplitude: ±1.0 dB
Distortion: <2 percent total harmonic distortion

NOTE: If the data above is required, please contact your respective range.

b. Operational Bandwidth. The FTR shall reliably process all tones and commands at the specified minimum operational bandwidth plus a margin.

1. The minimum operational bandwidth shall be +/- 45 KHz.
2. Threshold sensitivity shall not vary by more than 3dB across the bandwidth.
3. The operational bandwidth margin shall include the following:
   a. Twice the worst-case range command transmitter RF performance.
   b. Doppler shifts of the carrier center frequency.
   c. Shifts in flight hardware center frequency during flight at the manufacturer guaranteed receiver sensitivity.

c. RF Dynamic Range. The FTR shall satisfy all its performance specifications when subjected to the variations of the RF input signal level that will occur during checkout and flight. The FTR shall output all commands with input from the RF threshold level up to the maximum RF level that it will experience from the range command transmitter during checkout and flight plus a 3-dB margin.

The maximum RF level shall be 13 dBm.

d. Capture Ratio. The FTR shall meet all performance requirements and reject any interfering signal of less than 80 percent of the intended signal level.

The specific requirement for an interfering modulated signal will be determined on a case by case basis.

e. Signal Strength Telemetry Output (SSTO) Monitor.
   (1) The FTR shall include a SSTO monitoring circuit that accurately monitors and outputs the strength of the RF input signal during flight.
   (2) The SSTO output of the monitor circuit shall be directly related and proportional to the strength of the RF input signal from the receiver threshold SSTO to SSTO saturation.
   (3) The SSTO quiescent threshold level shall equate to a receiver with no RF input.

   (4) The dynamic range of the RF input from threshold to saturation shall be no less than 50 dB. The monitor circuit output amplitude from threshold to saturation shall have sufficient resolution to allow accurate determination of RF level.
   (5) The SSTO monitor output signal level shall be compatible with vehicle telemetry system interfaces and provide a response time that allows detection of RF interfering sources and dropouts.

The response time of the SSTO circuitry shall be 4 milliseconds or less.

   (6) The slope of the monitor circuit output shall not change polarity.

1. Signal Strength Telemetry Output (SSTO) Monitor. The receiver's SSTO voltage, while operating into a 10,000-ohm and flight representative TM load, shall be in accordance with the following requirements:
   a. The quiescent (no RF signal) condition shall be 0.5 ±0.25 Vdc.
   b. The measured command threshold sensitivity input condition shall be 0.1 Vdc minimum above the quiescent value.
   c. The SSTO output level shall reach 4.5 Vdc with no less than -60 dBm or no more than -50 dBm of RF input.
   d. The shape of the transfer function shall not exceed approximately 1 Vdc change in voltage for each 13-dB change in RF input signal over the range between threshold and saturation.
   e. The maximum SSTO voltage shall not exceed 5 Vdc under all conditions.
   f. The slope of the SSTO voltage shall not change polarity from measured threshold to a +13 dBm level. The slope shall be monotonic with no more than 50 millivolts of drop after saturation has been reached.
2. The SSTO voltage shall not be used as a command output monitor.

f. RF Input Characteristics.

(1) Threshold Sensitivity. The FTRs threshold sensitivity shall be repeatable to demonstrate in-family performance.

1. An FTRs threshold sensitivity shall be within a tolerance of plus and minus 3 dB throughout its service life.
2. The threshold sensitivity shall not be less than -116 dBm into a 50 ohm load.

(2) Guaranteed Sensitivity. The FTR shall meet all performance requirements at the guaranteed sensitivity. This specification shall include worst-case ground/airborne RF tolerances, operating environments and age-related degradation.

1. The RF guaranteed sensitivity shall be the value used for the RF link analysis.
2. The guaranteed sensitivity shall be derived using a margin above the threshold sensitivity level.
3. The guaranteed sensitivity of the receiver shall be between -107 dBm to -116 dBm across a 50-ohm impedance.
4. The guaranteed sensitivity shall have a minimum 3 dB margin above the noise floor. The noise-floor includes thermal noise, Range RF transmitting sources, interfering sources and vehicle generated noise.

g. Voltage Standing Wave Ratio. The RF impedance characteristics of the FTR shall match the antenna system adequately to support the required link margin and be repeatable to demonstrate in-family performance.

The FTR shall be tested for a VSWR of 2:1 or less into a 50-ohm impedance.

h. Decoder Channel Bandwidth. An FTR shall provide for reliable recognition of the command signal when subjected to combined variations in tone frequency and FM deviation plus a margin.

1. Standard RCC Tone:
   a. The decoder channel bandwidth shall be ±1 percent or greater of the assigned tone frequency at 2-dB above the threshold deviation.
   b. The decoder channel bandwidth shall be ±4 percent or less of the assigned tone frequency at 14-dB above the threshold deviation.
   c. The decoder channel bandwidth shall be ±4 percent or less of the assigned tone frequency at 20-dB above the threshold deviation. This test shall be performed at the decoder board level.
   d. Channel Filters. The channel filters shall be centered about the RCC tone center frequency within ±0.5 percent.
2. High Alphabet Decoder Channel Bandwidth. The decoder channel bandwidth shall be ±40 Hz minimum at 2 dB and ±600 Hz maximum at 20 dB.

i. High Alphabet Receiver Tone Balance. The FTR shall reliably decode a valid command at the worst-case ground transmitter amplitude tone imbalance plus a margin between tones within the same command sequence or message.

j. Message Timing. An FTR shall meet all performance requirements when subjected to the worst-case minimum and maximum ground generated command sequencing time plus a margin.

1. The FTR shall process commands at twice the maximum and one-half the minimum timing specification of the ground system.
2. High alphabet FTR shall meet performance requirements during timing variations between symbols.
3. A standard FTR shall produce command outputs when command tones are present for 25 ms or greater.

k. Check Channel. The FTR shall decode a tone, such as a pilot tone or check channel, and provide a telemetry output. The presence or absence of this tone signal shall have no effect on a FTR command processing and output capability.

l. Dynamic Stability. The FTR shall not degrade in performance or be damaged after being subjected to an RF input short-circuit, open-circuit, or changes in input voltage standing wave ratio.

m. Out of Band Rejection. The FTR shall meet all performance requirements when subjected to specified out-of-band RF sources.

Out of band RF sources include radiated emission from electronic components and ground/airborne transmitter sources.

(1) The FTR shall reliably process all tones and commands when subjected to interfering frequencies except at the receiver specified RF bandwidth plus a margin.

The FTR shall process commands when subjected to any interfering frequency from 10 MHz to 1000 MHz at a power level 60 dB above the guaranteed sensitivity signal level.

(2) The interfering frequencies shall include all expected transmitting sources using the maximum bandwidth of each transmitter, receiver image frequency and harmonics of the assigned center frequency plus a margin.

1. Continuous-Wave (CW) Bandwidth: The receiver shall have an intermediate frequency (IF) bandwidth of 180 kHz minimum at the 3-dB point and 360 kHz maximum at the 60-dB point, centered within 0.005 percent of the assigned RF center frequency.
2. Spurious-Response Rejection: The receiver shall provide at least 60 dB of rejection from 10 to 1000 MHz, excluding the frequency band within the 60-dB bandwidth at the assigned center frequency referenced to response at center frequency.
3. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.
4. Noise Immunity: The FTR shall be capable of processing all command outputs when the FTR is subjected to an RF input signal of -95 dBm that is FM modulated with white noise with a minimum bandwidth of 600 kHz and at an amplitude of 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.
5. Ranges typically have transmitting sources in the C-band, S-band, L-band and X-band frequencies. FTRs shall meet all performance requirements when subjected to all intended and unintended Range transmitting sources.

n. Adjacent Tone Decoder Channel Rejection. The FTR shall meet all performance requirements when subjected to the specified over-modulation of adjacent tones plus a margin.

1. The decoder shall not cause a keyed channel to drop out in the presence of adjacent-channel interference resulting from any combination of simultaneous tones with carrier FM deviation set at plus and minus 50 kHz per tone.
2. The tone decoder channels shall not respond to adjacent FM-modulated tone channels when they are modulated with a minimum of 150 percent of the expected tone deviation.

o. Termination Sequence. The FTR shall provide the required command output in accordance with the design specification. The FTR shall provide a terminate command only if preceded by an Arm command.

Tone Logic for the Standard FTR. The following standard receiver command sequences should be used unless otherwise approved.

1. ARM Command
2. Flight TERMINATE Command.

LOGIC SEQUENCE	DECODER OUTPUT

RCC Standard Tone Combinations for Multiple Missiles.

VEHICLES	CHECK CHANNEL	OPTIONAL	ARM	TERMINATE
A	*See Note*			
B	*See Note*			
C	*See Note*			
D	*See Note*			
E	*See Note*			
***Note*:** Check channel shall be the same for all vehicles				

. NOTE: If information above is required, please see your respective range.

Tone Logic for the High Alphabet FTR. The following high alphabet receiver command sequences should be used unless otherwise approved:

a.
b.
c.
d.

Typical Secure Command Message Format

NOTE: If information above is required, please see your respective range..

3.13.3 Inadvertent Command Output. To ensure that it does not provide an output other than when it receives a valid command, an FTR shall satisfy all of the following:

a. Dynamic Stability. The FTR shall not produce an inadvertent output when subjected to an RF input short-circuit, open-circuit, or changes in input voltage standing wave ratio.
b. RF Rejection. The FTR shall not produce an inadvertent output to any out-of-band vehicle or ground transmitter source that could be encountered from launch to the end of Range Safety responsibility.
   (1) The FTR shall provide sufficient rejection for any out of band interfering frequency that it could experience during prelaunch and flight plus a margin.

1. The FTR shall provide 60 dB of rejection for any out of band interfering frequency from 10 MHz to 1000 MHz.
2. Special attention should be given to other command terminate frequencies used on a Range.

(2) The interfering frequencies shall include all expected interfering transmitting sources using the maximum bandwidth of each transmitter, receiver image frequency and harmonics of the assigned center frequency plus a margin.

1. Continuous-Wave (CW) Bandwidth: The receiver shall have an intermediate frequency (IF) bandwidth of 180 kHz minimum at the 3-dB point and 360 kHz maximum at the 60-dB point, centered within 0.005 percent of the assigned RF center frequency.
2. Spurious-Response Rejection: The receiver shall provide at least 60 dB of rejection from 10 to 1000 MHz, excluding the frequency band within the 60-dB bandwidth at the assigned center frequency referenced to response at center frequency.
3. Image Rejection: The FTR shall provide at least 60 dB of RF rejection at the image frequency.
4. Noise Immunity: The FTR shall not produce command outputs when the FTR is subjected to an RF input signal of -95 dBm that is FM modulated with white noise with a minimum bandwidth of 600 kHz and at an amplitude of 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.
5. Ranges typically have transmitting sources in the C-band, S-band, L-band and X-band frequencies. FTRs shall be meet all performance requirements when subjected to all intended and unintended Range transmitting sources.

c. Tone Channel Output. The FTR shall not trigger any tone channel outputs at the specified FM deviation noise plus a margin.

The decoder shall not provide any output at deviation levels of less than plus and minus 9 kHz per tone.

d. Adjacent Tone Decoder Channel Rejection. The FTR shall not inadvertently output any tones or commands when subjected to any over-modulation of adjacent tones plus a margin.

1. The tone decoder channels shall not respond to adjacent FM-modulated tone channels when they are modulated with a minimum of 150 percent of the expected tone deviation.
2. The decoder shall not produce an output on un-keyed channels in the presence of adjacent-channel interference resulting from any combination of simultaneous tones with carrier FM deviation set at plus and minus 50 kHz per tone.

e. Receiver Abnormal Logic. The FTR shall not respond to any combination of tones or tone pairs other than the correct command sequence(s). The FTR shall not output a command when one tone in the sequence is dropped or missing.

f. Noise Immunity.

(1) FM White Noise. The FTR shall reject the specified RF FM white noise generated by the range command transmitter or other sources plus a margin.

1. The FTR shall not respond to a frequency modulated white noise RF input that has a minimum frequency modulated deviation of 12 dB above the measured threshold deviation.
2. The FTR shall not produce command outputs when the FTR is subjected to an RF input signal of -95 dBm that is FM modulated with white noise with a minimum bandwidth of 600 kHz and at an amplitude of 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.

(2) Quiescent Response. The receiver shall not produce an inadvertent output when no RF input is applied.

The FTR threshold sensitivity shall be greater than -116 dBm.

g. Power Cycling. The FTR shall not produce an inadvertent output of a tone or command when the receiver is repeatedly powered up and powered down.

h. AM Rejection. The FTR shall not output a tone or command when subjected to the specified amplitude modulated signals and noise that can be generated by the range command transmitter or other sources.

The FTR shall not produce an output at 100 percent AM.
Note: This requirement addresses an AM signal modulated on the range transmitted FM signal.

3.14 Wiring and Connectors

3.14.1 Reliability. Wiring and connectors that can affect an FTS component's reliability during flight shall satisfy the electronic parts requirements of paragraph 3.9.

3.14.2 FTS Component Interface. All wiring, including any cable and all connectors, that interface with any FTS component shall provide for the component, wiring, and connectors to function without degradation when exposed to storage, preflight, flight and reuse environments.

3.14.3 Shielding. All wiring and connectors shall have shielding that ensures the FTS satisfies all its performance specifications and will not experience an inadvertent termination output when subjected to electromagnetic interference levels 20 dB greater than the greatest electromagnetic interference induced by vehicle and launch site systems.

1. Splicing of firing circuit wires or over braid shields is prohibited.
2. The use of single-wire firing lines is prohibited.
3. Outer shells of connectors shall be made of conductive metal. The shell of connectors shall provide attenuation at least equal to that of the shield.
4. All firing circuit harnesses shall be isolated from other harnesses.
5. There shall be no gaps or discontinuities in the shielding including the termination at the back faces of the connectors. Shields terminated at a connector shall be electrically joined around the full 360o circumference of the shield.
6. The FTS wiring shields shall be grounded.
7. The use of a wiring shield as a circuit return or ground is not permitted. Shields shall not be used as intentional current-carrying conductors.
8. All shields of the FTS shall be bonded with a dc resistance of less than 5 ohms.
9. Firing circuits and control circuits shall be shielded from each other.

3.14.4 Insulation. The dielectric withstanding voltage between mutually insulated portions of any component part shall provide for the component to function at the component's rated voltage and satisfy all its performance specifications when subjected to any momentary over-potentials that could normally occur, such as due to switching or surge.

3.14.5 Insulation Resistance. The insulation resistance between mutually insulated portions of any component shall provide for the component to function at its rated voltage plus a margin. Any insulation material shall satisfy all its performance specifications when subjected to workmanship, heat, dirt, oxidation, or loss of volatile material plus a margin.

1. For low voltage circuits, the insulation resistance between the shield and conductor shall be greater than 2 megohms at 500 volts, direct current (Vdc) minimum.
2. For high voltage circuits, the insulation resistance between the shield and conductor shall be greater than 50 megohms at 150 percent of the rated output voltage or 500 Vdc, whichever is greater.

3.14.6 Dielectric Strength. The dielectric withstanding voltage between mutually insulated portions of wires or connectors shall satisfy all performance specifications at its rated voltage plus a margin and withstand any momentary over-potential due to switching, surge, or any other similar phenomena plus a margin.

1. Dielectric Strength testing shall be taken at a minimum of 500 VDC or 150 percent of the operating voltage, whichever is greater. Measurements shall be taken between mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application.
2. The voltage used for this test shall not damage or degrade the component.
3. The measurement error at the required insulation resistance value shall not exceed 10 percent.

3.14.7 Wiring Capacity. If any wiring or connector will experience loads with continuous duty cycles of 100 seconds or greater, that wiring or connector, including each connector pin, shall have a capacity of 150 percent of the design load. If any wiring or connector will experience loads that last less than 100 seconds, all wiring and insulation shall provide a design margin greater than the wire insulation temperature specification.

3.14.8 Test Pull Force. All wiring, including any cable or connector, shall satisfy all its performance specifications when subjected to the required qualification test pull force and any additional handling environment that the component could experience.

The mated connectors shall not degrade in performance with an axial pull on the cable or harness of at least 30 pounds for a minimum of 1 minute.

3.14.9 Redundant Circuits and Reliability. Redundant circuits that can affect FTS reliability during flight shall not share any wiring harness or connector with each other.

3.14.10 Connectors. For any connector or pin connection that is not functionally tested once connected as part of an FTS or component, the design of the connector or pin connection shall eliminate the possibility of a bent pin, mismating, or misalignment.

Electrical connections that cannot be subjected to a continuity or functional test following the final mate shall be designed to meet the following criteria.

a. A straight pin within specifications cannot be misaligned during the mating process so that the circuit is no longer functional.
b. A connector with a bent or misaligned pin out of specification will prevent the connector from mating.
c. A qualification test program shall be developed by the Range User to demonstrate compliance with these requirements.
d. The qualification test plan and test results shall be submitted to the affected ranges for review and approval.

3.14.11 Detecting Component Pin Damage. The design of an FTS component shall prevent undetectable damage or overstress from occurring as the result of a bent connector pin.

3.14.12 Hazardous Event. A hazardous event such as inadvertent initiation or completely disabling the FTS shall not occur if a bent connector pin:

a. Makes unintended contact with another pin.
b. Makes unintended contact with the case of the connector or component.

1. Source circuits shall terminate in a connector with female contacts.
2. Connectors shall be selected to minimize spare pins and eliminate the possibility of mismating.

3.14.13 Electrical Continuity. Each connector that interfaces with an FTS component shall protect against electrical dropout and ensure electrical continuity as needed to ensure the component satisfies all its performance specifications.

1. Plug- and socket-type connectors are required.
2. Connectors relying on spring contact shall not be used.
3. Chatter on ordnance firing circuits shall be no more than 0.1 milliseconds. All other connectors shall be limited to no more than 5 milliseconds.

3.14.14 Connector Locking. All connectors shall positively lock to prevent inadvertent disconnection during vehicle processing and flight.

3.14.15 Wiring and Cable Protection. Wiring and cables shall be protected against abrasion and crimping during installation, ground processing and flight environments.

3.14.16 Connector mate-demate requirements. All connectors shall be capable of being mated and/or demated at least five times the number of planned cycles and still be within the performance requirements of the connector specification.

All connectors shall be capable of being mated and/or demated for no less than 100 cycles.

3.14.17 Demated Connector Protection. Connectors that demate and are exposed to environments during flight shall be protected to prevent pin-to-pin shorting that could disable or degrade FTS performance.

1. These connectors include umbilical and staging connectors.
2. Environments that can cause pin-to-pin shorting include rocket motor plasma and condensation.
3. Dead-face connectors may be an acceptable solution.

3.15 Laser Initiated Ordnance Fiber Optic Cable Assembly

3.15.1 General. A fiber optic cable assembly, including connectors, shall be capable of transmitting the required optical power and spectral characteristics necessary for reliable LID functioning when subjected to stressing conditions such as aging, operating environments, non-operation environments and repeated function for checkout and flight. A Range User shall ensure that the design of each cable and connector is qualified as part of the component qualification testing performed according to Chapter 4 of this volume.

3.15.2 Transmission Characteristics. The transfer function characteristics such as pulse spreading and attenuation shall be designed to be repeatable with no optical dropouts, or changes in attenuation or optical characteristics when subjected to stressing conditions.

3.15.3 Repetitive Functioning. The fiber optic cable assembly shall satisfy all its performance specifications for the maximum number of operating outputs at the maximum optical power output and duration expected throughout its life plus a margin to account for performance variability.

1. The design of the fiber optic cable assembly shall withstand, without degradation in performance, repetitive functioning for five times the total expected number of cycles required for acceptance tests, preflight tests, and flight operations, including an allowance for potential retests due to schedule delays.
2. The fiber optic cable assembly shall have the capacity to output at least 1.5 times the maximum firing optical power for no less than 10 times the duration of the maximum firing pulse.

3.15.4 Bend Radius. The fiber optic cable assembly shall meet all performance requirements at the worst-case installed and tested bend radius plus a margin.

3.15.5 Shielding. The fiber optic cable assembly shall be shielded to prevent that could result in firing, degrading or “dudding” of the LID.

Shielding design shall ensure that any external optical source is a minimum of 20 dB below the no-fire level of the LID.

3.15.6 Handling. All cables and connectors shall not degrade in performance when subjected to the greatest pull force that could be experienced during manufacturing and installation.

Unless otherwise specified, a 30 pound minimum pull shall be used.

3.15.7 Connector Verification. For any connector that is not functionally tested (i.e. BIT) once connected as part of an FTS or component, the design of the connector shall eliminate the possibility of a bent pin, mismating, or misalignment.

3.15.8 Connector Locking. All connectors shall positively lock to prevent inadvertent disconnection during vehicle processing and flight.

3.15.9 Contamination Sensitivity. All optical connectors and interfaces shall be meet their performance requirements when subjected to worst case optical misalignment, contaminants or condensation plus a margin.

3.15.10 BIT Performance. The BIT shall verify that it can detect any degradation that could prevent the required optical power from being input into the LID. The BIT shall determine the type of inspection necessary before field optical connections. If BIT testing is used to validate an interface, a correlation shall be established between BIT pass/fail criteria and the main laser firing pulse.

3.16 Batteries

3.16.1 Batteries. Batteries shall be designed to meet the applicable performance requirements of paragraph 3.9 and the manufacturer's performance specification.

3.16.2 Capacity. An FTS battery shall have a manufacturer-specified capacity of no less than the required operational capacity. Operational capacity shall be calculated using the following requirements:

1. A 0.5 AH minimum capacity margin shall be required.
2. Batteries shall have a lifetime of at least 150 percent of the required mission time from transfer to internal power to end of Range Safety responsibility.
3. Amp-hour capacity shall be based on a voltage level before the "knee" in the discharge curve or above the minimum FTS component voltage requirement.
4. Batteries and cells shall have repeatable performance.

a. Any self discharge plus margin.

1. The minimum margin shall be 50 percent.
2. Worst-case high temperature self discharge at the maximum preoperational and operational temperature shall be specified.
3. Except remotely activated batteries, a battery or cell must retain a minimum of 90 percent of its fully charged total capacity after 72 hours at ambient temperature

b. All load and activation checks
c. All launch countdown checks including any potential number of preflight re-tests due to potential schedule delays including the number of potential launch attempts that the battery could experience before it would have to be recharged or replaced plus a margin.

1. The minimum margin for capacity and time shall be 50 percent.
2. At a minimum, the battery shall deliver energy for two arm and two terminate commands.

d. Any potential hold time or launch abort plus a margin.

The minimum margin shall be 50 percent.

e. Flight capacity from launch to the end of Range Safety responsibility plus a margin.

There are two requirements:
1. Flight capacity of at least 150 percent of the time and capability needed to support a normal flight from launch until the time in which FTS is no longer required.
2. Two terminate functions.

f. For a vehicle that uses solid propellant the flight capacity shall include an additional 30-minute hang-fire hold time.

The 30 minute requirement may not be required for systems that demonstrate they will not create a safety hazard if the solid propellant inadvertently ignites and becomes mobile. Examples include vehicles that can be restrained on the launcher.

Capacity Summary:

C = Manufacturer's Specified Capacity. This is a reference number only.

C_T = Total Actual Capacity, Amp-Hrs. Actual measured capacity of a fully charged battery or cell.

C_P = Prelaunch Testing Capacity, Amp-Hrs. Battery capacity consumed by any prelaunch testing conducted between final battery charging/activation and final transfer to internal power during countdown.

C_S = Self-Discharge, Amp-Hrs. Battery capacity lost due to self-discharge due to temperature and humidity between final battery charging and beginning of the final launch countdown procedure.

C_{fs} = Flight Self-Discharge, Amp-Hrs. Battery capacity lost due to self-discharge due to flight temperature between launch and end of Range Safety responsibility.

C_L = Launch Countdown Capacity, Amp-Hrs. Battery capacity consumed during the final countdown procedure, which includes all normal launch activities, testing, abort procedures and contingency checklists within the final countdown procedure. This also includes any capacity consumed during potential hold times during the countdown.

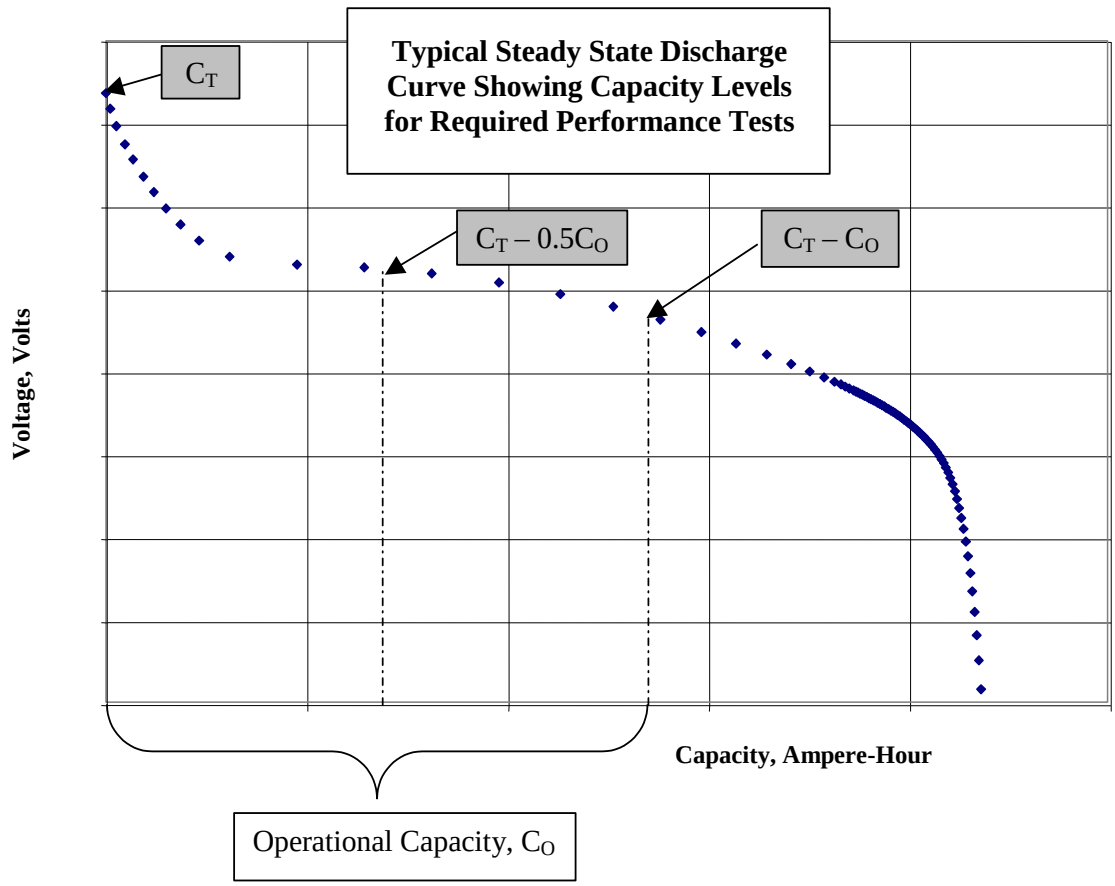
N = Countdown Recycles. Number of recycle attempts planned as contingencies within the final launch countdown procedure.

C_F = Flight Capacity, Amp-Hrs. Battery capacity consumed during a normal flight from lift-off to the no longer to endanger time plus the energy consumed from two arm commands and two terminate commands.

C_H = Hang-Fire Capacity (Solid Propellants Only), Amp-Hrs. The battery capacity consumed during a 30-minute hang-fire hold.

C_O = Operational Capacity, Amp-hrs. The battery capacity needed to meet Range Safety requirements (with margin).

$$C_O = C_P + C_H + 1.5\,[(N \times C_L) + C_F + C_S + C_{fs}]$$



3.16.3 Electrical Characteristics. An FTS battery, under all load conditions, including line loss, shall have all the following electrical characteristics:

a. The minimum specified battery voltage during worst-case operational loading shall be no less than the minimum acceptance test voltage that satisfies the electrical component acceptance tests.
b. The Electrical Capability of the battery will conform to the following:
   (1) The battery shall maintain its minimum specified voltage while delivering the worst-case steady-state operational high current plus a margin at low and high qualification temperatures. The battery shall deliver the required current at the minimum battery operating voltage. This requirement shall be met throughout the specified battery lifetime and capacity.

1. The steady state load is the worst-case current for an FTS without a terminate output. This includes changes in load profile versus time.
2. The margin shall be 50 percent of the worst-case operating current.
3. Minimum component voltage can be specified for transient voltage events. For example, receivers that can maintain a terminate during pulse load may be acceptable even if it cannot process RF commands.
4. The criteria for maintaining the required voltage regulation shall account for voltage line losses predicted or measured in the system. For example, if a receiver's minimum qualification voltage is 22 volts and there is 0.5 volt line loss due to resistance in the cable/connectors from the battery, then the minimum criteria would be 22.5V.

   (2) The battery shall maintain its minimum specified voltage while delivering the qualification operating current pulse level at the worst-case termination event duration plus a margin. This requirement shall be met throughout the specified battery lifetime and capacity.

1. The minimum pulse width workmanship screening level for silver zinc batteries shall be 100 milliseconds.
2. The current pulse shall be ten times longer than the duration required to initiate ordnance or other termination event.
3. The current shall be a minimum of 150 percent of the current pulse at the lowest system battery voltage, using the worst case system tolerances.
4. Minimum component voltage can be specified for transient voltage events. For example, receivers that can maintain a terminate during pulse load may be acceptable even if it cannot process RF commands.

   (3) The battery shall function within specification after exposure to no less than twice the expected number of arm and terminate command sets planned to occur during vehicle processing, preflight FTS end-to-end tests, and flight commands including load checks, conditioning, and functioning of terminate mechanisms.

The worst-case operating current shall also take into account prelaunch testing using any type of termination device simulator.

c. The design of a battery, including any activation procedures or cell conditioning, shall ensure uniform cell voltage.

1. Minimum soak time for manually activated silver-zinc batteries shall be specified for both vacuum fill and gravity fill of electrolyte.
2. Absorption devices shall be provided to accommodate electrolyte release. This device shall not provide a conductive path between cell terminals, or the cell terminals and the battery box.
3. Activation shall include any battery conditioning needed to ensure uniform cell voltage, such as peroxide removal or nickel-cadmium preparation.

d. The design of a battery or the system using the battery shall protect against reverse polarity, shorting, overcharging, thermal runaway, or overpressure.

1. Plug or receptacle connectors shall be designed to prevent reverse polarity.
2. Diodes shall be used to prevent reverse current due to transfer of external power to/from internal power or during end-to-end checkout.
3. If a battery is not connected to the system, the battery terminals or connector plug shall be taped, guarded, or otherwise given positive protection against shorting.

e. Continuity, Isolation and Insulation Resistance.
   (1) Design of the battery and wiring interconnections shall not contribute to self-discharge, open, or low impedance short-circuits.
   (2) The resistance from each pin-to-pin, pin-to-return and/or case ground shall be specified.

1. For pins that electrically connected, pin-to-pin continuity shall be 0.05 ohms or less
2. For pins that are isolated, pin-to-pin and pin-to-case shall be 2 megaohms or more.
3. Pin-to-case insulation resistance shall be 2 megaohms or greater when measured at a potential of 500 ±25 Vdc. Insulation resistance is before activation.

   (3) Positive and negative terminals and other measurement points that are polarity sensitive shall be identified.

f. The battery and cells shall have repeatable capacity, self discharge, and voltage performance.

1. Manually activated batteries shall consist of cells assembled from electrode plates that are manufactured together and without interruption.
2. The design of a battery and any activation or charging procedures must ensure uniform cell voltage.
3. Capacity for rechargeable cells shall be repeatable within one percent for each charge and discharge cycle.
4. Manually activated primary (non-rechargeable) batteries shall be validated by comparing qualification test data with coupon cells.

3.16.4 Monitoring. The monitoring system shall provide the status of health for each battery. Monitoring accuracy shall be consistent with the minimum and maximum limits used for launch countdown. A battery that requires heating or cooling to sustain performance shall provide for monitoring the battery's temperature with a resolution that indicates the battery remains within its specified operating temperature range.

1. A battery or the system that uses a battery shall provide for voltage and current monitoring.
2. For manually activated silver zinc batteries, the qualification temperature margins can be reduced from 10 ^{o}C to 5.5 ^{o}C if a temperature sensor and telemetry combined measurement tolerance is less than ± 1.5 °C.
3. Batteries requiring heating or cooling to sustain performance shall have a telemetry channel indicating the temperature of each battery with a resolution of 0.5 °C. The telemetry channel temperature indicators shall be provided during prelaunch and flight.
4. Monitoring accuracy and display precision must be consistent with the minimum and maximum temperature limits used for launch constraints during countdown operations to ensure flight batteries do not violate design limits.
5. Battery voltage and current monitoring output to Ground Support Equipment (GSE) and telemetry system must have accuracy tolerances of ± 0.05 volts and ± 0.05 amps.
6. Battery temperature monitoring output to GSE and telemetry systems must have an accuracy tolerance of ± 0.25 °C.
7. The thermostat tolerances must ensure that the battery remains within its thermal design limits.
8. Lithium Ion batteries shall have individual cell voltage monitoring.

3.16.5 Identification. Identification requirements include:

a. Each battery shall have an attached permanent label with the component name, type of construction (including chemistry), manufacturer identification, part number, lot and serial number, date of manufacture, and expiration date.
b. Each cell or major subassembly shall have traceability.

Each cell shall be serialized with indelible markings that will not damage the structural or electrical integrity of the cells. The serialization shall be a unique number for each cell and include or be traceable to the lot date code of the cell.

3.16.6 Battery Temperature Control. Any battery heater shall ensure even temperature regulation of all battery cells.

3.16.7 Battery Cases and Cells.

a. Battery cases and cells shall be designed to prevent catastrophic failure that could lead to personnel injury or property damage when subjected to handling, electrical discharge, charging and short-circuit conditions.

1. Sealed batteries and sealed cells shall have pressure relief capability to protect the structural integrity of the case in the event of over pressurization.
2. Cell vents shall open within + 10 percent of the relief pressure average. The maximum vent pressure shall be no higher than 67 percent of case yields.
3. Battery cases and sealed cells shall be designed to a minimum 3:l ultimate safety factor with respect to worst-case pressure build-up for normal operations.
4. The battery case pressure build-up shall take into account hydraulic and temperature extremes.
5. Unless otherwise specified, pressure relief devices for sealed batteries and cells shall be set to operate at a maximum of 1.5 times the operating pressure and sized such that the resulting maximum stress of the case does not exceed the yield strength of the case material.
6. Batteries and cells shall not create a hazardous condition when completely discharged.
7. Batteries not connected to the system shall have terminals or connector plugs that are taped, guarded, or otherwise given positive protection against shorting.

b. Battery cells or batteries shall be sealed to prevent electrolyte leakage that could affect battery and other FTS component performance.

1. For any cell that may vent electrolyte mist as part of normal operations, the battery shall satisfy all its performance specifications for pin-to-case and pin-to-pin resistances after the battery experiences the maximum normal venting.
2. Any vented products, such as hydrogen, shall not create a hazardous condition.
3. Cells with liquid electrolyte shall be designed not to leak when exposed to qualification environments.

3.16.8 Battery and battery flight cells shall use the same parts, materials and processes as the qualification test unit.

1. To be considered a "lot", non-configuration controlled (COTS) cells shall have a manufacturing code indicating that they are from a large continuous automated production run, materials from the same source, and manufactured without interruption.
2. To be considered a "lot", limited production cells (non-automated) shall use personnel that are trained, qualified, and experienced in a continuous production run.
3. Regardless of manufacturing code, a new procurement of commercial cells will be designated as a new lot.
4. All cells in a battery shall be from the same lot.

3.16.9 Service, Storage Life and Transportation.

a. FTS batteries and cells shall meet all performance requirements including capacity, electrical characteristics and environmental survivability, at the beginning, middle and end of their activated service life.
b. FTS batteries and cells shall have their activated and unactivated, where applicable, storage life specified. The battery shall satisfy the activated service life requirements after experiencing its storage life in an activated or inactivated state.
c. Storage and transportation environments for FTS batteries and cells shall be specified and support storage life requirements.

1. Batteries and cells shall be stored long-term at less than 5 °C in a humidity controlled environment.
2. Storage and transportation temperature shall not exceed 35°C for short-term exposure.
3. Loss of capacity and charge retention at the specified storage conditions shall be specified.

3.16.10 Manually Activated Batteries. Manually activated batteries shall be designed to ensure repeatable electrical performance, which meets component and system performance requirements. Manually activated batteries shall be designed to ensure no workmanship deficiencies are introduced as a result of parts, materials, and process deficiencies during manufacturing.

1. Manually activated batteries shall allow activation of each individual cell after all the cells are installed in the battery.
   Note: Manually activated batteries shall be subjected to a high level of materials, production, and process scrutiny since workmanship deficiencies cannot be screened by acceptance testing.

Note: Manually activated batteries with multiple cells shall permit voltage monitoring of each cell during OCV and load tests of the battery.

3.16.11 Rechargeable Cells and Batteries. Rechargeable batteries shall be designed to provide repeatable electrical performance that meets system performance requirements for each required charge-discharge cycle. Any rechargeable battery or cell shall satisfy all the requirements of this section for each charge-discharge cycle.

Cell matching for Nickel Cadmium batteries is required at 0 degrees C and 20 degrees C. Note: Cell matching at 0 degrees C and 20 degrees C provides sufficient data to characterize capacity at all operating temperature ranges (including below 0 degrees C and above 20 degrees C).

a. Cycle Life. The battery shall satisfy all its performance specifications for the number of operating charge and discharge cycles expected of the battery throughout its life plus a margin to account for cell production variability, electrical performance variations and aging degradation. Cycle life includes all acceptance testing, preflight testing, and flight.

1. With the exception of any silver-zinc battery, a rechargeable battery design specification shall allow for five times the number of operating charge and discharge cycles expected of the battery throughout its life, including all acceptance testing, preflight testing, and flight.
2. A silver zinc rechargeable battery shall satisfy all its performance specifications for each operating charge-discharge cycle expected of the battery throughout its life, including all acceptance testing, preflight testing, and flight.
3. Silver-zinc batteries used in the secondary mode shall have:
   a. A maximum number of secondary cycles specified.
   b. A charge retention life for each charge/discharge cycle specified.
   c. An activated service life (total activated time) specified.

b. The charging and electrical conditioning methods, equipment and parameters shall ensure repeatable charging and reflect the same charge process used for qualification. Charging systems shall have protection to prevent failures in the charging circuit or battery from creating a hazardous condition that could adversely affect personnel safety or lead to property damage.

1. Battery charging shall be designed to prevent a runaway battery temperature.
2. The temperature-based control shall be in addition to other methods of charge control.
3. The temperature and current used to charge the battery shall result in repeatable performance and not result in damage or degradation.
4. The battery shall not be damaged or degraded when overcharged. The percentage of acceptable overcharge shall be specified. This shall include a maximum time limit based on the nominal charging rate.
5. For Li-Ion batteries and cells, the end of charge voltage shall be specified.
6. For Li-Ion batteries and cells, a minimum end-of-discharge voltage shall be specified.
7. The equipment and configuration used for qualification and prelaunch charging shall be the same.

3.16.12 Remotely-Activated Battery Requirements. Remotely-activated batteries, including silver-zinc and thermal batteries, shall be designed to ensure reliable activation and repeatable electrical performance, which meets component and system performance requirements.

1. Battery initiators shall be designed to the applicable initiator requirements of this document.
2. Activated batteries shall meet all applicable performance requirements when activated in any orientation.
3. For batteries activated by application of an external electrical current, the minimum voltage, current, and applied duration shall be at least 10 percent greater than the manufacturer ALL-FIRE rating.
4. An FTS battery initiator and electrolyte distribution system shall be designed to support mission reliability requirements for each vehicle application.
5. The battery rise time after activation shall be specified and shall support mission and safety timelines.
6. A visual indicator shall be provided that will permanently change color after the battery has been activated.

Note: Batteries must be subjected to a high level of materials, production and process scrutiny since workmanship deficiencies cannot be screened by acceptance testing. Battery workmanship is also demonstrated through lot acceptance testing required in Chapter 4.

Note: The battery rise time after activation to specified voltage levels shall be specified and shall support mission and safety timelines.

3.16.13 Generator-Powered Missiles. An FTS using vehicle generator power shall have a redundant backup power source not using a vehicle generator to prevent any single point failures that result in loss of FTS capability. Vehicle generators shall not create a fault condition that results in damage to FTS components such as undervoltage, overvoltage, or rectification.

The backup power source shall be capable of providing twice the capacity required for nominal FTS power to initiate a terminate action.

3.17 Electromechanical Safe and Arm (S&A) Devices With a Low Voltage Initiator

This section applies to any electromechanical S&A device that has an internal low voltage initiator and is part of an FTS. An S&A device shall provide for safing and arming of the FTS ordnance in accordance with the requirements of this chapter.

3.17.1 S&A in Arm Position During Environmental Tests. An S&A device in the arm position shall remain in the arm position and satisfy all its performance specifications when subjected to the design environmental levels.

Mechanical Latching: The S&A shall remain mechanically latched in the selected position under all operational environments. This condition shall be maintained without the application of any electrical signal.

3.17.2 Wiring and Connector Requirements. All wiring and connectors used in an S&A device shall satisfy the wiring and connector requirements of paragraph 3.14.

3.17.3 Electronic Component Requirements. The S&A device shall satisfy the applicable electronic component requirements of paragraph 3.9.

3.17.4 Low Voltage Initiator. An S&A device's internal low voltage initiator shall satisfy the requirements for an ordnance initiator requirements of paragraph 3.21.

3.17.5 S&A Adjustment. An S&A device shall not require any adjustment throughout its service life.

3.17.6 Firing Pulse. An S&A device shall deliver a firing pulse to the internal low voltage initiator without any dropout that could affect low voltage initiator performance when subjected to the design environmental levels.

3.17.7 Drop Qualifications. An S&A device shall satisfy all its performance specifications after being exposed to the handling drop required during qualification testing and any additional transportation, handling, or installation environment that the device could experience.

The S&A shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.

3.17.8 Worst-Case Abnormal Drop. An S&A device shall not initiate and shall allow for safe disposal after experiencing the worst-case abnormal drop that could occur during transportation, handling, or installation.

The S&A shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The device is not required to function after this test.

3.17.9 S&A Device Body (No Fragmenting). When an S&A device's low voltage initiator is initiated, the safe-and arm-device's body shall not fragment, regardless of whether the ETS is connected or not.

S&As shall be designed such that when the device is functioned in either the ARM or SAFE condition, the body shall not fragment.

3.17.10 Dual Initiators. When dual initiators are used within a single S&A device, the design shall ensure that one low voltage initiator does not affect the performance of the other initiator.

Dual low voltage initiators shall be capable of being functioned serially or simultaneously without degrading the performance of the explosive path.

3.17.11 S&A Performance Testing. An S&A device shall satisfy all its performance specifications when subjected to no less than five times the total number of S&A cycles required for the combination of all acceptance tests, preflight tests, and flight operations, including an allowance for potential re-tests due to schedule changes.

All S&A devices shall be designed to withstand repeated cycling from SAFE to ARM and return to SAFE for at least 1,000 cycles without any malfunction, failure, or deterioration in performance.

3.17.12 S&A Device in Safe Position. An S&A device in the safe position shall satisfy all of the following:

a. While in the safe position, an S&A device shall protect each internal low voltage initiator from any condition that could degrade its performance and prevent inadvertent initiation when subjected to any external energy source, such as static discharge, RF energy, or firing voltage during transportation, storage, preflight testing, and any preflight fault conditions.

When the S&A device is in the SAFE position, it shall provide mechanical isolation of the low voltage initiator from the explosive path and electrical isolation of the firing circuit from the initiators by means of: a. The power and return lines of the firing circuit shall be disconnected. b. The bridge wire shall be shorted and grounded through a resistor having a resistance value between 10 and 100 kilohms. c. The explosive path shall be interrupted by a mechanical barrier capable of containing the output energy of the low voltage initiator without initiating the explosive.

b. While in the safe position, an S&A device shall prevent the propagation of the ordnance path, with a reliability of 0.999 at a 95 percent confidence level if the low voltage initiator is initiated.
c. An S&A device shall satisfy all its performance specifications when in the safe and locked position and subjected to the worst-case operational arming voltage that could be applied during prelaunch processing.

The S&A devices shall be designed to meet all performance requirements after applying maximum operational arming voltages continuously for periods of up to 5 minutes with the safing pin installed.

d. An S&A device shall not initiate its low voltage initiator, or any other ordnance path component when locked in the safe position and subjected to the continuous operational arming voltage.

Stalling shall not create a hazardous condition when arming voltages are applied continuously for 1 hour with the safing pin installed.

e. An S&A device shall have a visual display of its status on the device and remote display of the status when the device is in the safe position. When transitioning from the arm to safe position, the safe indication shall not appear unless the position of the S&A device has progressed beyond the .999 @ 95 percent no-fire transition position.

1. The electrical continuity of one status circuit of the electromechanical S&A device (SAFE or ARM) shall completely break before the time that the electrical continuity is established for the other status circuit (ARM or SAFE).
2. The safe indication shall not appear unless the position of the S&A device has progressed more than 50 percent beyond the .999 @ 95 percent no-fire transition position.

f. An S&A that is Armed prior to vehicle first motion shall be capable of being remotely safed.

An S&A device shall have a remote means of moving its rotor or barrier to the safe position from any rotor or barrier position.

g. An S&A device shall have a manual means of moving its rotor or barrier to the safe position.
h. An S&A device shall have a safing interlock that prevents movement from the safe position to the arm position while operational arming current is being applied. The interlock shall have a means of positively locking into place and shall allow for verification of proper functioning. The interlock removal design or procedure shall eliminate the possibility of accidental disconnection of the interlock.

Electromechanical S&A Safing Pins.

1. Rotation and/or transition of the mechanical barrier to the aligned explosive path and electrical continuity of the firing circuit to the low voltage initiator shall not be possible with the safing pin installed.
2. The safing pin shall be accessible through final launch complex clear.
3. When inserted and rotated, the safing pin shall manually safe the device.
4. The force required for safing pin insertion for an Armed S&A shall be between 20 and 40 pounds and/or 20 to 40 inch-pounds of torque.
5. Removal of the safing pin shall not be possible if the arming circuit is energized. The retention mechanism of the safing pin shall be capable of withstanding an applied force of at least 100-pounds tension or a torque of 100 inch-pounds without failure.
6. Removal of the safing pin shall not cause the device to automatically arm.
7. Removal of the safing pin shall be inhibited by a locking mechanism requiring 90° rotation of the pin. The removal force shall be 3 to 10 inch-pounds of torque.
8. A safing pin shall be used in the S&A device to prevent movement from the SAFE to the ARM position when arming power is applied.

i. For S&As armed after launch, the interrupter shall be mechanically locked in the SAFE position with two but not more than three independent safety interlocks.

3.17.13 <u>S&A Device in Arm Position</u>. An S&A device in the Arm position shall satisfy all of the following:

a. When an S&A device is in the arm position, the S&A shall connect power and return line of the firing circuit and align all ordnance interfaces, such as initiator, rotor charge, and ETS components with one another to ensure propagation of the explosive charge with a reliability of 0.999 at a 95 percent confidence level.
b. An S&A device shall have a visual display of its status on the device and remote display of the status when the device is in the Arm position. When transitioning from the safe to arm position, the Arm indication shall not appear unless the position of the S&A device has progressed beyond the .999 @ 95 percent all-fire transition point and the S&A is locked in the Armed position.

The electrical continuity of one status circuit of the electromechanical S&A device (Arm or Safe) shall completely break before the time that the electrical continuity is established for the other status circuit.

c. An S&A device shall provide for remote arming of the device.
d. For S&As armed after first motion, the forces removing the interlock inhibits shall be derived from different environments. Operation of at least one of the interlocks shall depend on sensing an environment after first motion or sensing a post-launch environment.
e. An S&A device shall satisfy all its performance specifications after transitioning to the arm position and being subjected to the continuous operational arming voltage that could be applied during prelaunch processing.

The S&A devices shall be designed to meet all performance requirements after the application of maximum operational arming voltages continuously for periods of up to 5 minutes.

3.18 High Energy Electronic Initiator Firing Unit

3.18.1. General. This section applies to any firing unit that is part of an FTS that uses voltages higher than 500V to directly initiate a secondary explosive. A firing unit shall provide for safing and arming of the FTS ordnance in accordance with the requirements of this chapter. A firing unit shall satisfy the requirements for applicable requirements of this document including paragraph 3.9.

Approval may be granted on a case-by-case basis for non-physically redundant systems used for small systems. If a single housing is approved, both initiators shall be completely redundant including redundant high voltage firing capacitors, trigger circuitry, charging circuits and initiators.

a. The functioning of one side of initiator shall not inhibit or cause the functioning of the other side.
b. The status of initiator shall be individually made available for monitoring.
c. The firing unit output shall be capable of being functioned serially or simultaneously without degrading the performance of the explosive path.

3.18.2 Charging and Discharging. A firing unit shall have a remote means of charging and discharging of the unit's firing capacitor.

3.18.3 Input Command Processing. A firing unit's electrical input processing circuitry shall satisfy all of the following:

a. The firing unit's 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 20 dB above the worst-case noise or current leakage environment.

The firing unit's command and firing circuits shall not trigger when a 5 volt signal is applied for 5 minutes.

b. A firing unit's input firing threshold sensitivity shall operate within its performance requirements at a margin in amplitude and duration of the worst-case operational trigger signal that the unit would receive during flight.

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

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

3.18.4 High Voltage Output. A firing unit's high voltage discharge circuit shall satisfy all of the following:

a. A firing unit shall include circuits for capacitor charging, charge interruption, triggering and single fault tolerant capacitor discharge capability.

1. All high voltages shall be generated internally within the firing unit.
2. The firing (high voltage) capacitor circuit shall have a dual-bleed system with either system capable of independently discharging the capacitor charge.

b. A firing unit shall deliver a voltage to the initiator with a margin greater than the initiator's minimum all-fire voltage, including transmission losses, at the unit's worst-case high and low arming voltages.

1. The all-fire energy shall be a minimum energy delivered to an initiator to yield a firing reliability of 0.999 at a 95-percent confidence level. The energy (in terms of voltage, current and time) specified above is the minimum ALL-FIRE energy for the EFIs and shall apply at the lowest system battery voltage using the worst-case system tolerances.
2. An EBW firing unit design shall incorporate a high voltage capacitor adequate to store and deliver the required ALL-FIRE voltage, plus a 50 percent margin.
3. An EFI firing unit or EAFD (or ESAD) design shall incorporate a high voltage capacitor adequate to store and deliver the required ALL-FIRE voltage, plus an agreed upon margin not less than 100 volts greater than the ALL-FIRE voltage.
4. 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 percent voltage margin above the nominal voltage threshold level.

c. The design of a firing unit shall prevent corona and arcing on internal and external high voltage circuitry.

1. The firing unit high voltage system shall not arc (pin-to-pin, pin-to-chassis, or internal component-to-chassis) at any atmospheric pressure up to the highest altitude the missile system is capable of attaining.
2. The isolation resistance between each firing unit circuit and any other circuit shall not be less than 50 megohms at 500 Vdc.
3. The firing unit shall be hermetically sealed to the equivalent of 10^{-6} standard cubic centimeters/seconds of helium at one atmosphere differential.

3.18.5 Output Monitors. The monitoring circuits of a firing unit shall provide the data for real-time checkout and determination of the firing unit's acceptability for flight.

1. The monitor circuits shall, as a minimum, provide the status of the high voltage firing capacitor(s), trigger capacitor (if used), any inhibits, SAFE/ARM status (if different from high voltage capacitor status), BIT results (if applicable), ARM and SAFE separation status, and TERMINATE command status. The monitor circuit for the firing (high voltage) capacitor(s) shall provide an output voltage that is proportional to the voltage on the capacitor(s) to within an accuracy of + 5 percent.
2. ARM indication - The firing unit shall be considered armed when the monitoring circuit indicates a capacitor bank voltage at least 95 percent of the nominal operating voltage value of the device but not less than 100 volts above the minimum ALL-FIRE voltage level for the initiators.
3. SAFE indication - The firing unit shall be considered safe when the capacitor bank voltage is one-fifth of the maximum NO-FIRE voltage for the EFIs or 200 Vdc, whatever is less.

3.18.6 Inhibit/Safing Circuitry. A firing unit shall provide for a minimum of two verifiable and independent inhibits. These inhibits shall also ensure that there are no single failure or common-cause failure mode that could result in inadvertent initiation or arming.

1. The firing unit shall provide a master Arm/Safe command for a positive, remotely controlled means of interrupting the power to the firing circuit and is independent of other inhibits.
2. The firing unit shall provide for inhibits that remove continuity to the high voltage firing circuit power.
3. The output firing capacitor shall have a bleed resistor between the high and return side of the firing circuit.
4. Any logic device, such as an FPGA, used in the implementation of safety features shall:
   a. Be permanently programmed for its final flight configuration
   b. Not load any data
   c. Not be reconfigured at power-up.
   d. Not use microprocessor based controls.
5. At least two of the safety features will be implemented with dissimilar logic devices.
6. Safety timing features, implemented within logic, shall not be susceptible to common cause failures resulting in premature arming.
7. A firing unit shall power-up in the safe condition.
8. Safing and Arming plugs shall be designed to be manually installed to provide electrical isolation of the input power.
9. Depending on unique vehicle applications and hazard levels, additional safety devices such as ordnance interrupters or remotely safe/arm ordnance interrupters may be required.

3.19 Low Voltage Laser Diode Firing Unit

3.19.1 General. The design of a laser firing unit (LFU) shall meet the requirements for electronic components in paragraph 3.9.

3.19.2 Command Processing. The firing unit's input trigger circuitry shall function within its performance specifications when subjected to any variation in input that it could experience during flight. The test shall demonstrate all of the following:

a. The firing unit's 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 20 dB above the worst-case noise or current leakage environment.

The firing unit's command and firing circuits shall not trigger when a 5 volt signal is applied for 5 minutes.

b. The firing unit command and firing circuits shall function at a margin over the worst-case signal that could be delivered on the vehicle.

1. The firing unit's command and firing circuits shall trigger at 75 percent of the amplitude and 50 percent of the pulse duration of the lowest firing signal that could be delivered during flight.
2. The firing unit's command and firing circuits shall trigger at 125 percent amplitude and 150 percent of the pulse duration of the highest firing signal that could be delivered during flight.

3.19.3 Output Firing Circuit. A laser firing unit shall deliver an optical output to the initiator, including frequency, power and pulse duration, with a margin greater than the initiator's minimum all-fire voltage, including transmission losses, at the unit's worst-case high and low arming voltages.

1. The all-fire energy shall be a minimum energy delivered to an initiator to yield a firing reliability of 0.999 at a 95-percent confidence level. The energy (in terms of amplitude, frequency, pulse width and spot size) specified above is the minimum ALL-FIRE energy for the LIDs and shall be applicable at the lowest system battery voltage and using the worst-case system tolerances.
2. An LFU design shall deliver the required ALL-FIRE optical energy plus a 50 percent margin.

a. The design of a firing unit shall be sealed to prevent optical degradation as a result of non-operating and operating environments, such as salt-fog and humidity, altitude experienced during storage, transportation, preflight, and flight.

The firing unit shall be hermetically sealed to the equivalent of 10^{-6} standard cubic centimeters/seconds of helium at one atmosphere differential.

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

c. The pulse duration delivered by the LFU shall be a minimum of twice the pulse duration used to determine the all-fire level during qualification.

3.19.4 Inhibit/Safing Circuitry. An LFU shall provide for a minimum of two verifiable and independent inhibits. These inhibits shall also ensure that there are no single failure or common-cause failure mode that could result in inadvertent initiation.

1. The LFU shall provide a master Arm/Safe command for a positive, remotely controlled means of interrupting the power to the firing circuit and is independent of other inhibits. A fire command shall not be processed while the unit is safed.
2. The LFU shall provide for inhibits that remove continuity to the laser diode 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.
3. The laser diode shall have a bleed resistor between the high and return side of the firing circuit.
4. An LFU shall power-up in the safe condition.
5. Safing and Arming plugs shall be designed to be manually installed to provide electrical isolation of the input power.
6. Depending on unique vehicle applications, BIT, and hazard levels, additional safety devices such as ordnance interrupters or remotely safe/arm optical interrupters may be required.
7. Any logic device, such as an FPGA, used in the implementation of safety features shall:
   a. Be permanently programmed for its final flight configuration.
   b. Not load any data.
   c. Not be reconfigured at power-up.
   d. Not use microprocessor based controls.
8. At least two of the safety features will be implemented with dissimilar logic devices.
9. Safety timing features, implemented within logic, shall not be susceptible to common cause failures resulting in premature arming.
10. Depending on unique vehicle applications and hazard levels, additional safety devices such as ordnance interrupters or remotely safe/arm ordnance interrupters may be required.

3.19.5 Output Monitors. The monitoring circuits of a firing unit shall provide the data for real-time checkout and determination of the firing unit's acceptability for flight.

At a minimum, the following measurements shall be provided:

a. The 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 termination firing output.
d. The status of the master arm/safe circuit.
e. The status or result of a bit.

3.19.6 Built-In-Test. The BIT shall detect any condition that could prevent a specification-level firing pulse from reaching the LID ordnance plus a margin. The BIT energy pulse shall not degrade LID performance or result in initiation as a result LFU piece-part failures.

1. The power used for the BIT test shall ensure a minimum 20 dB margin between the LID no fire level and the maximum BIT power output from the LFU. No single point failure in the BIT circuitry shall result in a violation of this requirement.
2. Two BIT piece-part circuit failures shall not result in an LFU output of 1/10 the LID no-fire level.
3. The BIT shall be capable of detecting any foreign debris, condensation, or optical misalignment that could prevent the required optical power from being input into the LID.
4. The BIT power and control circuitry shall be routed through a dedicated connector.
5. The LID reflective coating used for the BIT shall provide for a minimum of 10 dB of attenuation to the BIT laser frequency. This margin is not included as part of the 20 dB safety margin required above.
6. The BIT is optional.

3.20 Ordnance Interrupter

3.20.1 This section applies to any ordnance interrupter that does not have an internal low voltage initiator and is part of an FTS. An ordnance interrupter shall provide for safing and arming of the FTS ordnance in accordance with the requirements of this chapter.

3.20.2 An ordnance interrupter in the arm position shall remain in the arm position and satisfy all its performance specifications when subjected to the design environmental levels.

Mechanical Latching. The interrupter shall remain mechanically latched in the selected position under all operational environments. This condition shall be maintained without the application of any electrical signal.

3.20.3 All wiring and connectors used in an ordnance interrupter shall satisfy the wiring and connector requirements of paragraph 3.14.

3.20.4 The ordnance interrupter shall satisfy the applicable electronic component requirements of paragraph 3.9.

3.20.5 An ordnance interrupter shall not require any adjustment throughout its service life.

3.20.6 An ordnance interrupter shall satisfy all its performance specifications after being exposed to the handling drop required during qualification testing and any additional transportation, handling, or installation environment that the device could experience.

The interrupter shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.

3.20.7 An ordnance interrupter with an internal rotor lead shall not initiate and shall allow for safe disposal after experiencing the worst-case abnormal drop that could occur during transportation, handling, or installation.

The interrupter shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The device is not required to function after this test.

3.20.8 When the interrupter is initiated, the body shall not fragment, regardless of whether the ETS is connected or not.

Interruptors shall be designed such that when the device is functioned in either the ARM or SAFE condition, the body shall not fragment.

3.20.9 When dual initiation paths are used within a single interrupter device, the design shall ensure that one ordnance path does not affect the performance of the other ordnance path.

Dual initiation shall be capable of being functioned serially or simultaneously without degrading the performance of the explosive path.

3.20.10 An ordnance interrupter shall satisfy all its performance specifications when subjected to no less than five times the total number of interrupter cycles required for the combination of all acceptance tests, preflight tests, and flight operations, including an allowance for potential re-tests due to schedule changes.

All Ordnance interrupter shall be designed to withstand repeated cycling from SAFE to ARM and return to SAFE for at least 1,000 cycles without any malfunction, failure, or deterioration in performance.

3.20.11 An ordnance interrupter in the safe position shall satisfy all of the following:

a. While in the safe position, an ordnance interrupter shall prevent the propagation of its the ordnance path, with a reliability of 0.999 at a 95 percent confidence level if the low voltage initiator is initiated.

The explosive path shall be interrupted by a mechanical barrier capable of containing the output energy from the input donor to the output receptor.

b. An ordnance interrupter shall satisfy all its performance specifications when in the safe and locked position and subjected to the worst-case operational arming voltage that could be applied during prelaunch processing.

The Ordnance interrupter shall be designed to meet all performance requirements after the application of maximum operational arming voltages continuously for periods of up to 5 minutes with the safing pin installed.

c. An ordnance interrupter using a rotor charge shall not initiate the rotor charge when locked in the safe position and subjected to the continuous operational arming voltage.

Stalling shall not create a hazardous condition when arming voltages are applied continuously for 1 hour with the safing pin installed.

d. An ordnance interrupter shall have a visual display of its status on the device and remote display of the status when the device is in the safe position. When transitioning from the arm to safe position, the safe indication shall not appear unless the position of the ordnance interrupter has progressed beyond the .999 @ 95 percent no-fire transition position.

1. The electrical continuity of one status circuit of the electromechanical ordnance interrupter (SAFE or ARM) shall completely break before the time that the electrical continuity is established for the other status circuit (ARM or SAFE).
2. The safe indication shall not appear unless the position of the ordnance interrupter has progressed more than 50 percent beyond the .999 @ 95 percent no-fire transition position.

e. An interrupter that is Armed prior to vehicle first motion shall be capable of being remotely safed.

An ordnance interrupter shall have a remote means of moving its rotor or barrier to the safe position from any rotor or barrier position.

f. An ordnance interrupter shall have a manual means of moving its rotor or barrier to the safe position.
g. An ordnance interrupter shall have a safing interlock that prevents movement from the safe position to the arm position while operational arming current is being applied. The interlock shall have a means of positively locking into place and shall allow for verification of proper functioning. The interlock removal design or procedure shall eliminate the possibility of accidental disconnection of the interlock.

Electromechanical interrupter Safing Pins.

a. Rotation and/or transition of the mechanical barrier to the aligned explosive path shall not be possible with the safing pin installed.
b. The safing pin shall be accessible through final launch complex clear.
c. When inserted and rotated, the safing pin shall manually safe the device.
d. The force required for safing pin insertion for an Armed interrupter shall be between 20 and 40 pounds and/or 20 to 40 inch-pounds of torque.
e. Removal of the safing pin shall not be possible if the arming circuit is energized. The retention mechanism of the safing pin shall be capable of withstanding an applied force of at least 100-pounds tension or a torque of 100 inch-pounds without failure.
f. Removal of the safing pin shall not cause the device to automatically arm.
g. Removal of the safing pin shall be inhibited by a locking mechanism requiring 90° rotation of the pin. The removal force shall be 3 to 10 inch-pounds of torque.
h. A safing pin shall be used in the ordnance interrupter to prevent movement from the SAFE to the ARM position when arming power is applied.

h. For interrupter's Armed after launch, the interrupter shall be mechanically locked in the SAFE position with two but not more than three independent safety interlocks.

3.20.12 An ordnance interrupter in the Arm position shall satisfy all of the following:

a. When an ordnance interrupter is in the arm position, the interrupter shall align all ordnance interfaces including rotor charges and ETS components with one another to ensure propagation of the explosive charge with a reliability of 0.999 at a 95 percent confidence level.
b. An ordnance interrupter shall have a visual display of its status on the device and remote display of the status when the device is in the Arm position. When transitioning from the safe to arm position, the Arm indication shall not appear unless the position of the ordnance interrupter has progressed beyond the .999 @ 95 percent all-fire transition point and the interrupter is locked in the Armed position.

The electrical continuity of one status circuit of the electromechanical ordnance interrupter (Arm or Safe) shall completely break before the time that the electrical continuity is established for the other status circuit.

c. An ordnance interrupter shall provide for remote arming of the device.

d. For interrupter's armed after first motion, the forces removing the interlock inhibits shall be derived from different environments. Operation of at least one of the interlocks shall depend on sensing an environment after first motion or sensing a post-launch environment.
e. An ordnance interrupter shall satisfy all its performance specifications after transitioning to the arm position and being subjected to the continuous operational arming voltage that could be applied during prelaunch processing.

The Ordnance interrupter shall be designed to meet all performance requirements after the application of maximum operational arming voltages continuously for periods of up to 5 minutes.

3.21 Ordnance Initiators

3.21.1 General.

a. An ordnance initiator shall have a manufacturer-specified all-fire energy level. When the all-fire energy level is applied, the ordnance initiator shall fire with a reliability of no less than 0.999 at a 95 percent confidence level. Ordnance initiators shall be designed to reliably initiate at a high energy level at a margin above operating levels.

1. Low voltage initiators shall be designed to reliably function at 200 percent of the operating current level.
2. High voltage initiators shall be designed to reliably function at 150 percent of the operating energy level.
3. Percussion primers shall be designed to reliably function at 200 percent of the operating impact energy.

b. An ordnance initiator shall have a specified no-fire energy level. An ordnance initiator shall not fire or degrade in performance when exposed to the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level. An electrical or optical ordnance initiator shall satisfy all its performance specifications when subjected to continuous application of the no-fire energy level.

c. The lowest temperature at which an ordnance initiator would experience auto-ignition, sublimation, or melting or in any other way experience degradation in performance shall be no less than 30 °C higher than the highest temperature that the initiator could experience before or during flight.

Auto-ignition temperature shall not be less than 150°C.

d. An ordnance initiator shall not fire, and shall satisfy all its performance specifications when subjected to the maximum expected electrostatic discharge that it could experience from personnel or conductive surfaces.

An ordnance initiator shall not fire, and shall satisfy all its performance specifications when subjected to no less than a 25-kV, 500-picofared pin-to-pin discharge through a 5-kΩ resistor and a 25-kV, 500-picofared pin-to-case discharge with no resistor.

e. An electrical or optical ordnance initiator shall not initiate and shall satisfy all performance specifications when exposed to stray electrical or optical energy that is at a 20-dB margin greater than the greatest stray energy that the ordnance initiator could experience before or during flight. When determining the 20-dB margin, a Range User shall account for all potential sources of stray electrical energy, including leakage current from other electronic components and RF induced electrical current.

1. Low voltage initiators shall be shorted and connected to case ground through a static-bleed resistor(s) having a resistance of 10 to 100 kilohms.
2. The outer case of the low voltage initiator main body shall be made of conductive material.

f. An ordnance initiator shall satisfy all its performance specification after being exposed to the tensile loads, compression loads and the handling drop during and transportation, handling, or installation environment that the device could experience.

1. All connector pins shall withstand the tension and compression loads initiator pins (terminals) of at least 18 pounds for not less than 1 min or meet an alternate specification acceptable to Range Safety.
2. For initiators that are contained within an assembly, such as a low voltage initiator within an S&A, this requirement applies only before installation. The S&A and PAD are tested as an assembly after installation.

g. An ordnance initiator shall satisfy all its performance specifications after being exposed to the handling drop required during qualification testing and any additional transportation, handling, or installation environment that the device could experience.

The ordnance initiator shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.

h. An ordnance initiator shall not initiate and shall allow for safe disposal after experiencing any handling or worst-case abnormal drop that can occur during and transportation, handling, or installation environment that the device could experience.

1. Initiators shall not fire or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The initiator is not required to function after a 40-foot drop.
2. The initiator main body shall not rupture or fragment when the device is fired. Displacement or deformation of the connector and main housing is permissible.
3. For initiators that are contained within an assembly, such as a low voltage initiator within an S&A, this requirement applies only before installation. The S&A and PAD are tested as an assembly after installation.

i. An ordnance initiator shall be sealed to prevent degradation during non-operating and operating environments, such as salt-fog and humidity, altitude experienced during long-term storage, transportation, preflight, and flight.

An ordnance initiator shall be hermetically sealed to the equivalent of 5×10^{-6} standard cubic centimeters/second of helium at one atmosphere pressure differential.

j. The insulation resistance between mutually insulated points of an electrical ordnance initiator shall ensure that an ordnance initiator satisfies all performance specifications when subjected to the greater of twice the maximum applied voltage during testing and flight. The insulation material shall satisfy all its performance specifications when exposed to heat, dirt, oxidation, and any additional expected environment.

1. The insulation resistance for high voltage initiators between conductors and the outside of the initiator shall not be less than 50 megohms at 500 Vdc.
2. Insulation resistance for low voltage initiators between pin-to-case shall not be less than 2 megohms at 500 Vdc.

k. All internal ordnance interfaces within an ordnance initiator shall have a minimum reliably ordnance transfer of .999 @ 95 percent confidence.

3.21.2 <u>Low Voltage initiators</u>.

a. This section applies to any low voltage initiator that is part of an FTS. An initiator shall use electrical energy of less than 50 volts to trigger an explosive charge that initiates the FTS ordnance.

Carbon bridgewires and conductive mixes without bridgewires are prohibited.

b. An initiator shall have a specified no-fire energy level. An initiator shall not fire when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level. An initiator shall satisfy all its performance specifications when subjected to continuous application of the no-fire energy level.

1. Initiators shall be designed to withstand a constant direct current firing pulse of 1-ampere minimum and 1-watt power minimum for a period of 5-minutes minimum duration without initiation or deterioration of performance.
2. The RF induced no-fire level shall be specified for all applicable frequency ranges and used in the 20 dB RF environmental analysis.

3.21.3 Exploding Bridgewire (EBW).

1. Only explosives listed in MIL-STD-1316 for in-line use or that are approved by the associated safety evaluation board as stipulated in MIL-STD-1316 will be allowed in the initiator and explosive path.
2. If modified secondary (composition) explosives are used, their sensitivity characteristics shall be established by test in accordance with MIL-STD-1751, Allied Ordnance Publication AOP-7, ADA 086259, or the equivalent. Approval of any modified secondary explosive shall be approved by Range Safety on a case-by-case basis.

a. An EBW shall use high voltage electrical energy of 500 volts or greater to trigger an explosive charge that initiates the FTS ordnance.

b. The EBW connectors, pins, wiring, and header assembly shall withstand the maximum operating voltage plus a margin. This shall include allowances for effects such as corona and arcing of a flight configured EBW exposed to altitude, thermal vacuum, salt-fog, and humidity environments.

Connectors, pins, wiring and header assembly shall withstand 150 percent of the maximum operating voltage delivered by the EBW firing unit.

c. An initiator shall have a specified no-fire energy level. An initiator shall not fire or degrade in performance when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level. An initiator shall satisfy all its performance specifications when subjected to continuous application of the no-fire energy level.

1. Spark gap protection circuitry internal to an EBW can be used to meet the no-fire requirement. Spark gaps shall not degrade bridgewire performance or reliability when exposed to the qualification environments. The design shall allow for testing all internal devices, including the bridgewire, to ensure they are functioning within their performance specifications.
2. The RF-induced no-fire level shall be specified for all applicable frequency ranges and used in the 20 dB RF environmental analysis.
3. The bridgewire degradation current shall be the dc current level that will not damage or degrade the initiator at the highest system temperature or +71 °C, whichever is greater, for a minimum of five minutes shall be specified.
4. The initiator shall be capable of exposure to 50 percent of the bridgewire degradation current for five minutes and one 45-volt firing pulse without dudding or degrading.

d. Safety No-Fire**.** The initiator shall not fire when exposed to the worst-case voltage from ground support equipment or vehicle systems plus a margin.

The initiator shall be exposed to 500 VDC for 5 minutes without firing.

3.21.4 Exploding Foil Initiators. Exploding foil initiators (EFIs), also called "slapper" detonators, are used in EAFDs and ESADs.

1. Only explosives listed in MIL-STD-1316 for in-line use or that are approved by the associated safety evaluation board as stipulated in MIL-STD-1316 will be allowed in the initiator and explosive path.
2. If modified secondary (composition) ex-plosives are used, their sensitivity characteristics shall be established by test in accordance with MIL-STD-1751, ADA 086259, or the equivalent. Approval of any modified secondary explosive shall be approved by Range Safety on a case-by-case basis.

a. An initiator shall have a specified no-fire energy level. An initiator shall not fire or degrade in performance when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level. An initiator shall satisfy all its performance specifications when subjected to continuous application of the no-fire energy level.

1. Bridgewire Degradation Current. The dc current level that will not damage or degrade the EFI at the highest system temperature or +71°C, whichever is greater, for a minimum of five minutes shall be specified.
2. The EFI shall be capable of being exposed to 50 percent of the bridge degradation current for five minutes and one 45-volt firing pulse without degrading in performance.
3. The RF induced no-fire level shall be specified for all applicable frequency ranges and used in the 20 dB RF environmental analysis

b. Safety No-Fire. The initiator shall not fire when exposed to the worst-case voltage from ground support equipment or vehicle systems plus a margin.

The initiator shall be exposed to 500 VDC for 5 minutes without firing.

3.21.5 Laser Initiated Detonator.

1. Only explosives listed in MIL-STD-1316 for in-line use or that are approved by the associated safety evaluation board as stipulated in MIL-STD-1316 will be allowed in the initiator and explosive path. 2. If modified secondary (composition) ex-plosives are used, their sensitivity characteristics shall be established by test in accordance with MIL-STD-1751, ADA 086259, or the equivalent. Approval of any modified secondary explosive shall be approved by Range Safety on a case-by-case basis.

a. The laser initiated detonator (LID) shall be designed to function normally when subjected to the worst-case operational firing energy plus a margin.

The laser initiated detonator (LID) shall be designed to function normally when subjected to twice the worst-case operational firing energy.

b. LIDs containing an integral fiber optic cable (pigtail) shall ensure that the worst-case handling and installation environment will not damage the LID or fiber optic cable.

Fiber optic cable pigtails shall withstand a minimum 30 pound pull of the pigtail without degradation in performance.

c. An LID system, using a Built In Test (BIT), shall locate the optical reflector in a location that validates LID connector and performance integrity.

The reflective coating shall be located just prior to the LID initiation ordnance.

d. An initiator shall have a manufacturer-specified all-fire energy level. When the all-fire energy level is applied, the initiator shall fire with a reliability of no less than 0.999 at a 95 percent confidence level.

The LID all-fire specification shall include all parameters necessary for reliable operation such as spot size, pulse width, energy density, and wavelength. These specifications shall include tolerances that have been derived by test or analysis.

e. An initiator shall have a specified no-fire energy level. An initiator shall not fire when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level. An initiator shall satisfy all its performance specifications when subjected to continuous application of the no-fire energy level.

1. LIDs in-flight configuration shall be designed to not initiate nor degrade in performance when subjected to any stray energy sources such as strobes, sunlight, arc welders, flash-lamps, lightning, RF, and ac and dc electrical energy present during prelaunch processing and in the flight environment.
2. At a minimum, statistical testing shall include spot size, pulse width, energy density, and wavelength.
3. The LID NO-FIRE energy shall be 20 dB greater than any credible stray energy source.
4. LIDs shall have a capability to dissipate heat faster than single failure conditions can input into the device without initiating or dudding. An analysis shall be provided to demonstrate compliance with this requirement.
5. LIDs shall be designed to prevent any differential voltage potential from occurring across the LID ordnance.

3.21.6 Percussion Primers.

a. This section applies to percussion primers that are used within Percussion Activated Devices (PAD) to initiate an ordnance output.

b. An initiator shall have a specified no-fire energy level. An initiator shall not fire when exposed to continuous a no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level.

3.22 Percussion-Activated Devices

This section applies to any percussion-activated device (PAD) that is part of an FTS. A PAD shall use mechanical energy to trigger an explosive charge (percussion primer) that initiates the FTS ordnance.

3.22.1 A percussion primer within the PAD shall meet the applicable initiator requirements of paragraph 3.21.

3.22.2 A PAD shall not fragment upon initiation.

3.22.3 A PAD shall have a guaranteed no-fire pull force where the unit shall not initiate. The guaranteed no-fire pull distance/force shall ensure the PAD cannot be inadvertently initiated due to a prelaunch installation/checkout accidental pull or flight hardware forces plus a margin.

1. The minimum NO-FIRE pull force level shall be 50 pounds.
2. The minimum pull distance shall be .25 inches.

3.22.4 A PAD shall not initiate when pulled with its maximum no-fire pull force then released.

1. The firing pin mechanism shall be designed such that it does not come in contact with the primer unless it is pulled to the ALL-FIRE distance.
2. After the firing pin mechanism is pulled the ALL-FIRE distance, the mechanism shall automatically release and allow the firing pin to strike the primer.

3.22.5 A PAD shall deliver an operating energy to the percussion primer of no less than twice the primer guaranteed all-fire energy level.

PAD energy is a function of spring constant and pull distance.

3.22.6 A PAD primer shall satisfy all its performance specifications when subjected to two times the operational impact energy.

3.22.7 A PAD lanyard pull system shall have a protective cover or other feature that prevents inadvertent pulling of the lanyard.

3.22.8 A PAD shall satisfy all its performance specifications after experiencing any handling drop and additional transportation, handling, or installation environment that the device could experience.

1. The PAD shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.
2. The PAD shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The device is not required to function after this test.
3. The PAD mechanical mechanisms shall be sealed. The leak rate through the PAD seal shall not be greater than 1×10^{-4} standard cc/sec of helium.

3.22.9 A PAD shall reliably initiate when pulled at the worst-case vehicle separation angle that could occur during a vehicle failure.

The PAD shall reliably function when pulled at a $\pm 45^{o}$ in two perpendicular planes.

3.22.10 PAD structural and firing components shall withstand largest pull or jerk force that the device could experience during breakup of the vehicle plus a margin. The PAD shall withstand the qualification pull at any angle.

The pull/jerk margin shall be a minimum of 5 times the maximum expected pull force during vehicle breakup.

3.22.11 A PAD shall include a safing interlock, such as a safing pin, that provides a physical means of preventing the PAD assembly from pulling more the guaranteed no-fire pull distance plus a margin. The following apply to a safing interlock:

The PAD assembly shall not move more than 50 percent of the guaranteed no-for pull distance when pulled at the worst-case expected accidental prelaunch pull force.

a. A safing interlock shall positively lock into place and shall have a means of verifying proper function of the interlock.
b. A safing interlock shall eliminate the possibility of removal of the interlock should a pre-load condition exist on the lanyard.

The force required for safing pin removal shall be a minimum of 10 pounds when the lanyard is pulled with the no-fire pull force or greater.

c. With the safing interlock installed, the PAD shall not fire when exposed to a lanyard pull force representing the greatest possible inadvertent pull force that could be experienced during launch processing plus a margin.

The PAD shall not fire when exposed to a minimum lanyard pull force of 200 lbs with the safing interlock installed.

d. The safing interlock shall have a positive means of locking into the PAD assembly to prevent accidental disengagement.
e. The safing pin shall have a red warning streamer.

3.23 Cartridge-Activated Devices

3.23.1 The CAD initiator shall meet the applicable requirements of paragraph 3.21 for ordnance inititators.

3.23.2 The firing of either one or both initiators in a single CAD system, or the firing of either one or both CADs in a dual CAD system, shall provide operational success. The firing of the first low voltage initiator or CAD shall have no detrimental effect on the second low voltage initiator or CAD.

3.23.3 All CADs shall be capable of performing their end function when actuated by a single cartridge containing an explosive charge that is 80 percent or less of the minimum specified charge weight. The requirement applies to both single and dual CADs.

3.23.4 All CADs shall be capable of performing their end function when actuated by an explosive charge that is at least 120 percent of the maximum specified charge weight and with no increase in the initial free volume without rupture.

3.23.5 All CADs that are required to function under a load of either tension, compression, or shear shall have the ability to operate satisfactorily both unloaded and loaded to at least 150 percent of the maximum predicted operating load.

3.23.6 FTS applications using a cartridge-activated device (CAD) shall require redundancy. If the use of a single CAD to perform a function is approved, dual initiators shall be used.

3.23.7 A CAD shall satisfy all its performance specifications after experiencing any handling drop and additional transportation, handling, or installation environment that the device could experience.

1. The CAD shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.
2. The CAD shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The device is not required to function after this test.
3. The CAD mechanical mechanisms shall be sealed. The leak rate through the CAD seal shall not be greater than 1×10^{-4} standard cc/sec of helium.

3.23.8 A CAD shall not fragment upon initiation.

3.24 Explosive Transfer System (ETS)

3.24.1 An ETS shall transmit an explosive charge from an initiation source, such as an ordnance initiator, to other FTS ordnance such as a destruct/terminate charge.

Note: ETSs are used to transmit the initiation reaction from the initiator to the termination charge. Most ETS harnesses contain flexible confined detonating cord, mild detonating cord, or mild detonating fuse terminated by end booster caps or manifolds.

3.24.2 ETS explosives shall not inadvertently initiate when exposed to potential anomalous conditions. ETS shall be designed to interface with hazardous ordnance without adversely affecting personnel safety.

1. ETSs shall use only explosives listed in MIL-STD-1316 for in-line use or that are approved by the associated safety evaluation board as stipulated in MIL-STD-1316.
2. Ordnance used in an ETS shall consist of a secondary explosive. An exception to this is any transition component that contains a primary explosive that is fully contained within the transition component. Any transition component that contains a primary explosive shall be no more sensitive to inadvertent detonation than a secondary explosive.
3. Anomalous conditions include static discharge, drop, high temperature exposure, shock, and vibration.

3.24.3 An ETS shall satisfy all its performance specifications with the smallest bend radius that it is subjected to when installed in its flight configuration.

3.24.4 All explosive transfer connectors shall positively lock in place to prevent movement during flight and provide for verification of proper connection through visual inspection.

1. All ETS interconnections shall provide for safety wiring to ensure retention under the required environmental conditions.
2. All ETS interconnections shall be capable of connection and disconnection for a minimum of 10 cycles or 5 times the number of planned cycles, whichever is greater, without causing any damage or degradation of performance.
3. Fittings that must not be reversed or interchanged shall be designed so that reverse installation or interchange is not possible.

3.24.5 An ETS shall satisfy all its performance specifications after experiencing transportation, handling, or installation environments that the system could experience.

1. Exposed end fittings shall be fitted with protective caps.
2. The ETS shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.
3. Each ETS component shall satisfy all its performance specifications when subjected to the greater of twice the tensile load that can occur during installation and handling or a minimum axial pull of at least 100 pounds for not less than 1 minute.

3.24.6 An ETS shall not initiate and shall allow for safe disposal after experiencing the worst-case drop that could occur during transportation, handling, or installation.

The ETS shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The device is not required to function after this test.

3.24.7 ETS ordnance shall be sealed to prevent degradation during non-operating and operating environments such as salt-fog and humidity, altitude experienced during long-term storage, transportation, preflight, and flight.

An ETS shall be hermetically sealed to the equivalent of 5×10^{-6} standard cubic centimeters/second of helium at one atmosphere pressure differential.

3.25 Destruct/Terminate Charge

3.25.1 This section applies to any destruct/terminate charge that is part of an FTS. A destruct/terminate charge shall sever or penetrate a vehicle component or payload, such as a propellant tank or motor casing, to accomplish a flight termination function.

Tactical warheads may be used as destruct/terminate charges.

3.25.2 Initiation of a destruct/terminate charge shall result in an FTS action in accordance with the FTS functional requirements of this document.

3.25.3 Explosives shall not inadvertently initiate when exposed to potential anomalous conditions. Destruct/Termination Charges shall not adversely affect personnel safety.

1. Destruct/Termination Charges shall use only explosives listed in MIL-STD-1316 for in-line use or that are approved by the associated safety evaluation board as stipulated in MIL-STD-1316.
2. Ordnance used in a Destruct/Termination Charges shall consist of a secondary explosive.
3. Anomalous conditions include static discharge, drop, high temperature exposure, shock, and vibration.

3.25.4 A destruct/terminate charge shall completely sever or penetrate the flight material plus a margin to account for performance variability. A destruct/terminate charge, when initiated to terminate the flight of a vehicle, shall not detonate any vehicle or payload propellant.

1. A destruct/terminate charge shall completely sever or penetrate 150 percent of the thickness of the flight material.
2. It may be acceptable to fracture 150 percent of the flight material thickness instead of completely severing it. However, the destruct/terminate charge shall completely sever a minimum 100 percent of the flight material thickness. Approval of this methodology will depend on the terminate charge target and destruct action.
3. Severance margin shall be designed for the worst-case flight operating temperature.

3.25.5 A Destruct/Terminate Charge shall satisfy all its performance specifications after experiencing transportation, handling, or installation environments that the system could experience.

1. Exposed end fittings shall be fitted with protective caps.

2. The Destruct/Terminate Charge shall be required to perform to specifications after being subjected to a 6-foot drop onto a steel plate.
3. Each Destruct/Terminate Charge component shall satisfy all its performance specifications when subjected to the greater of twice the tensile load that can occur during installation and handling, or a minimum axial pull of 50 pounds for not less than 1 minute.

3.25.6 A destruct/terminate charge shall not initiate and shall allow for safe disposal after experiencing the worst-case drop that could occur during transportation, handling, or installation.

The destruct/terminate charge shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 40-foot drop onto a steel plate. The device is not required to function after this test.

3.25.7 Destruct/terminate ordnance shall be sealed to prevent degradation during non-operating and operating environments, such as salt-fog and humidity, altitude experienced during long-term storage, transportation, preflight and flight.

A destruct/terminate charge shall be hermetically sealed to the equivalent of 5×10^{-6} standard cubic centimeters/second of helium at one atmosphere pressure differential.

3.26 Parachute Systems

3.26.1 Ordnance Devices. Ordnance devices used for deploying a parachute system shall be redundant such that either one of the redundant devices will accomplish the desired action. Ordnance devices used in approved recovery or FTSs will meet all the requirements specified in the appropriate section of this chapter.

3.26.2 Parachutes. Depending on the size and weight of the vehicle to be recovered, the parachute system may be single or dual. Dual-chute systems require a drogue chute and a main chute. Parachute systems shall be capable of recovering the vehicle up to the maximum weight, speed, and corresponding altitude.

3.26.3 Normal and Emergency Deployment Modes. During normal operations, the parachute system shall not deploy above an agreed upon altitude and vehicle speed. For the emergency mode, the parachutes shall deploy at any altitude and speed. Analyses showing maximum recovery impact patterns based on vehicle weight, parachute size, drop speed, and wind velocity are required.

3.26.4 Surface Impact Release Switch. Systems using parachutes shall incorporate a surface impact release switch.

3.27 Thrust Termination Valves

Liquid propellant shutoff valves used as the primary means of Flight Termination System (FTS) shall be designed to ensure reliable termination within the required flight performance conditions.

1. Recyclable shutdown valves shall allow repeated opening, and closing and throttling of liquid commodities. Cyclable shutdown valves shall respond to signals from a controlling system to an actuator that supplies force and motion to a valve closure member.
2. One-shot shutdown valves shall have only two positions, open or close, and cannot change positions after initiation. One-shot valves are usually pyrotechnically actuated.

3.27.1 General. This section applies to any shutdown valves and associated hardware that is part of a the primary means of providing flight termination system, including the mechanism for actuation, whether it is electromechanical, hydraulic, pneumatic, pyrotechnic or any combination thereof. These requirements also apply to valve systems (valves and valve systems including fittings, connectors, and plumbing).

1. The types of valves described in this section are as follows:
   a. Electromechanical valves. These valves are actuated by an electrical input resulting in direct interruption or venting of fluids.
   b. Pneumatically actuated valves. These valves are actuated by a pressure input resulting in direct interruption or venting of fluids.
   c. Electro-pneumatic valves. These valves are actuated by an electrical input and output a corresponding change in pneumatic pressure. These valves are typically used to actuate pneumatically actuated valves (pilot valves).
2. Supplemental valves, used for mission assurance, that provide an additional system level of redundancy that exceeds RCC 319 requirements may allow reduction in testing for the primary FTS valves. Tailoring shall include these non-primary valves, but only to document Range User planned tests and not levy RCC 319 requirements.
3. If critical to FTS functionality, supporting hardware such as fluid transfer lines must meet also meet the valve requirements. Note, where failure of a fluid transfer line results in a fail-safe condition, the requirements of this section can be reduced or eliminated.

3.27.2 FTS shutdown valves and associated subsystems shall satisfy the applicable requirements of paragraph 3.9.

3.27.3 Valves and associated subsystems shall be designed to meet all performance specifications when exposed to the worst-case Maximum Expected Operating Pressure (MEOP) plus a margin.

1. Pressurized lines shall not leak and shall meet all performance specifications at operational pressures from 0 to 1.25 x MEOP.
2. Pressurized lines shall not burst at less than 4 times Maximum Expected Operating Pressure (MEOP).
3. Valve and valve systems shall be designed to withstand, without leakage, the water hammer effect from the minimum valve closure time during maximum flow velocity plus margin with a representative upstream pipe length.
4. External leakage shall be sufficient to prevent explosive atmosphere, hazards to personnel or potential FTS failure conditions such as propellant compatibility with FTS components or freezing the valve closed.

3.27.4 Valve position shall be capable of being remotely determined.

1. Valves shall be designed to provide the valve position (OPEN/CLOSED/THROTTLE) to be used for remote monitoring.
2. Use of pressure transducers on the input and output of valves to determine position are acceptable.
3. Electrical indication positions outputs shall be provided to GSE and telemetry.

3.27.5 Valves and valve support systems shall function within their performance specification when subjected to the design high and low system inputs.

3.27.6 Valves shall be marked with sufficient information to allow installation technicians and quality assurance to easily verify the proper component configuration.

1. Valves shall be marked with an arrow indicating the direction of fluid flow.
2. The minimum following information shall be marked on the valve.
   a. Name of Component.
   b. Manufacturer's Part No.
   c. Manufacturer's Serial No.
   d. Manufacturer's Name or Trademark.
   e. Date of Manufacture.
   f. Service Life.

3.27.7 Valve parts shall be compatible with other materials, fuels, or oxidizers that come in contact with the valve parts.

3.27.8 Valve specifications shall include all operating and performance parameters required to determine electrical and mechanical performance. As appropriate, each parameter shall include a minimum and maximum performance values for a specified range.

The following applicable valve specifications shall be included:

a. Operating time @ minimum, nominal, and maximum operating voltage.
b. Operating voltage.
c. Operating current.
d. Operating pressure.
e. Flow rate.
f. Proof pressure.
g. Burst pressure.
h. Solenoid temperature rise.
i. Dielectric strength.
j. Cycle life (endurance).
k. Service life.

3.27.9 External Leak. A valve and associated systems shall meet its leak rate requirements when exposed to Maximum Expected Operating Pressure (MEOP) plus a margin.

1. The maximum leak rate shall meet performance requirements at 1.25 times the MEOP.
2. External leakage shall not create:
   a. An explosive atmosphere environment.
   b. Hazards to personnel.
   c. FTS failure due to propellant incompatibility with FTS components.
   d. Cryogenic freezing that damages FTS components.
3. At a minimum, the specified leakage rate shall be determined using 1.25 times the MEOP.
4. The external leak rate shall be met with valve in the static position and while cycling.

3.27.10 Closed valves shall be designed to meet leakage performance requirements to the valve output when continuous Maximum Expected Operating Pressure (MEOP) plus a margin without external or internal leakage. Any leakage through a closed actuated FTS valve shall result in no residual thrust.

Internal leakage through a closed valve shall not allow propellant to come in contact with downstream propulsion systems that could result in performance degradation or personnel safety hazards including downstage components that could degrade due to fuel/oxidizer incompatibility over time.

3.27.11 Valves shall not create fratricide that could disable the FTS or a hazardous condition to ground personnel when exposed to the MEOP plus a margin.

Valves shall be designed to not burst when subjected to pressure of 4 times MEOP.

3.27.12 A valve shall satisfy all its performance specifications after experiencing transportation, handling, or installation environments that the system could experience plus a margin.

3.27.13 Electromechanical valves shall not degrade in performance nor create a hazardous condition when subjected to the worst-case input current that could occur during prelaunch and launch environments.

1. An electrically recyclable valve shall not degrade in performance after an extended stall at worst-case system high current for 5 minutes.
2. Stalled or mechanically inhibited electrically recyclable valves shall not create a hazardous condition when the maximum actuation voltage, power, or pressure is applied continuously for 1 hour.

3.27.14 Pressure Cycle Life. A valve and associated systems shall function within all performance parameters without degradation after being exposed to the worst-case pressure cycles at its fluid inlet that it would experience for prelaunch and launch plus a margin.

1. Valves shall withstand 5 times the worst-case checkout and operational pressure cycles.
2. Pressure cycles shall are from ambient pressure to 1.25 MEOP at a pressure rate of change that envelopes flight pressure application.

3.27.15 Insulation Resistance. Electrically initiated valves shall be designed to withstand an insulation resistance test from mutually insulated pin-to-pin and pin-to-case points using maximum operating voltage plus a margin.

1. Insulation resistance shall be a minimum of 500 VDC between the mutually-insulated points or between insulated points The voltage shall not damage or degrade the valve or solenoid.
2. The insulation resistance between all insulated parts shall be greater than 2 megohms.

3.28 Vibration and Shock Isolators

A vibration or shock isolator shall ensure the environmental survivability of an FTS component during applicable nonoperating and operating environments.

1. A vibration or shock isolator shall have repeatable natural frequency and resonant amplification parameters when subjected to flight environments.
2. An isolator shall account for all effects that could cause variations in repeatability, including acceleration preloads, temperature, component mass, and vibration level variations.
3. A vibration or shock isolator shall satisfy all of its performance specifications when subjected to the qualification test environments for each component that is mounted on the isolator.
4. All components mounted on a vibration or shock isolator shall withstand the environments introduced by isolator amplification. In addition, all component interface hardware, such as connectors, cables, and grounding straps, shall withstand any added deflection introduced by an isolator.

3.29 Autonomous Flight Termination Unit (AFTU)

This AFTS component processes the tracking data, makes a determination of whether to initiate a terminate output command. Individual tracking component requirements are addressed in RCC 324.

3.29.1 General. The design of an AFTU shall meet the requirements for electronic components in paragraph 3.9.

3.29.2 Processing.

a. AFTU processors shall have a margin to ensure the processors function within their performance requirements during non-nominal vehicle flight.

Processors shall have a 25 percent processing speed and memory margin over that required for worst-case processing.

b. No mission or tracking sensor simulation test software shall reside in memory in the final flight configuration.

This does not include self-test of microprocessors, FPGA, and other internal circuits.

3.29.3 Output Firing Circuit. The AFTU shall provide an output to a termination initiation component that meets the requirements of this document.

3.29.4 Arming/Safing Circuitry.

a. An AFTU shall be capable of being functionally tested on the vehicle.

1. For hazardous systems, the AFTU shall have a minimum of two independent inputs that are used to both remotely Arm and Disable the AFTU. The unit shall not be capable of producing a terminate output unless all Arm inputs have been enabled.
2. The two AFTU Arm inputs are logic Arm and Master Arm:
   a. The logic Arm input shall enable only the logic and processors for ground checkout. This power input may be controlled from within the box or through external power switching circuits.
   b. The Master Arm command enables or provides the power used for the terminate output.
3. The AFTU shall power-up in the safe condition after power has been removed for greater than 1 second.

b. Input Arming commands shall latch and not require a continuous command to remain latched.
c. Input commands shall maintain a minimum 20 dB margin between the threshold trigger level and the worst-case noise environment.

Any Arming and Safing circuits shall trigger at no less than 5 volts.

3.29.5 Output Monitors. The monitoring circuits of an AFTU shall provide the data for real-time prelaunch checkout and flight.

1. The status of all inhibits.
2. Results of processor built in test.
3. Indication of termination firing output.
4. The status of the master arm/safe circuit.
5. Processor “heartbeat” output.
6. Integrity indicators of each tracking source as tailored in RCC 324.
7. The number tracking sources being used for AFTS decision criteria.
8. Minimum time to endanger (green time) counter start flag.

3.29.6 AFTU Data Input/Output. The AFTU shall be capable of verifying that the loaded software/firmware is correct.

1. The AFTS shall be capable of remotely outputting all software and firmware contents loaded after acceptance testing to ground support equipment to perform a bit-by-bit comparison against the required logic.
2. This requirement includes any memory or processing devices that require an internal load to boot such as FPGA and microprocessors.
3. Other high integrity data transfer verification algorithms may be used.

3.29.7 AFTU Terminate Decision Criteria. An AFTU shall initiate a termination action prior to a flight vehicle posing an unacceptable risk to property. Requirements will be determined on a case-by-case basis but shall include, at a minimum, the following:

a. AFTU terminate logic shall initiate before any powered stage, debris, focused distance overpressure or toxics can violate a Range Safety protected areas.

1. The impact limit lines shall be generated by each Range's safety office and provided to the Range User.
2. The Range User and Range Safety must determine the required format for the data product.

b. The AFTU shall process a minimum of two adequate and independent tracking inputs for determining vehicle state vector and termination logic.

1. When two INS tracking sources are used, there shall be no common-cause failures that could cause both sources to produce false position data (e.g. alignment).
2. The AFTU shall provide adequacy of each tracking source. Note: For launch commit, two adequate and independent tracking inputs are required.

c. The AFTU shall initiate a termination command if all required adequate tracking sources are lost before the vehicle can hazard a Range Safety protected area.

When tracking source data is lost, the terminate logic shall assume the vehicle has taken a worst-case stable turn towards a termination boundary. The AFTU shall calculate the time (minimum time to endanger) it takes to reach this boundary and terminate flight prior to reaching the boundary.

d. Termination Scenario. The AFTU shall initiate a terminate output when all valid tracking sources violate terminate criteria. The AFTU shall initiate a terminate output when one valid source is on the nominal trajectory and the other valid source violates terminate criteria.

Non-nominal vehicle trajectories include:

a. Ground launched/non-programming (straight up).
b. Rapid turn towards impact limit line.
c. Slow turn towards impact limit line.
d. For space launch, inability to make orbit.

e. Loss of one tracking source. The AFTU shall initiate a terminate output when one tracking source fails (no data) with an *inadequate* second tracking source. The AFTU shall NOT initiate a terminate output and process data normally when one tracking source fails (no data) with a second adequate tracking source.

1. Examples of inadequate source test conditions for GPS are as follows:
   a. Loss of all data.
   b. DOP exceeds specification.
   c. GPS is in a "coast' mode.
   d. Filter residuals that indicate errors exceed specification.
   e. Other indicators will be included on a case-by-case basis that indicate GPS may not be producing the required specification state vector output.
2. Examples of inadequate source test conditions for INS are as follows:
   a. Loss of all data.
   b. INS has not been validated by another source after each vehicle shock event.
   c. Any discrepancies such as unrealistically large jumps in state vector or diverging data with GPS.
   d. Where two INS tracking sources are used to validate one another, there shall be no common-cause failures that could cause both sources to produce false position data (e.g. alignment).
   e. Other indicators will be included on a case-by-case basis that indicate INS may not be producing the required specification state vector output.

f. Diverging tracking source. The AFTU shall NOT initiate a terminate output and process data normally when all valid tracking sources diverge but do not violate terminate criteria. The AFTU shall initiate a terminate output when one adequate tracking source violates a terminate criteria and the other does not.
g. Nominal Trajectory. The AFTU shall NOT initiate a terminate output and process data normally during a nominal flight trajectory including any allowable deviation due to nominal vehicle performance variability.
h. The AFTU shall initiate a termination command if the vehicle trajectory is sufficiently off course to prevent accomplishment of the mission.

AFTU shall terminate a space vehicle if it is unable to achieve orbit due to a flight anomaly.

i. The AFTU shall initiate a termination command if the vehicle is performing erratically such that it may degrade FTS component reliability.

A GPS based tracking source can detect tumbling by showing that the instantaneous impact point has stopped moving.

j. The AFTU shall initiate a termination command when its processor and the other AFTU processor cease functioning including the loss of connectivity between the units. The AFTU shall initiate a terminate command in a timeframe that prevents errant vehicle violation of Range Safety protected areas.

1. A "heartbeat monitor" shall be included in each AFTU that monitors its processing status as well as the other redundant AFTU at a rate not less than 10 sps. If the status of both processors fails, then the AFTU shall initiate a terminate output.
2. The number of missed samples before the heartbeat monitor terminates flight will be determined on a case-by-case basis. At a minimum, this time shall be set to the worst-case minimum time to endanger number calculated in paragraph 3.29.7b above.

3.30 Miscellaneous Components

Range Safety shall identify any additional requirements in conjunction with the Range User that apply to any new or unique component and demonstrate that those requirements ensure the reliability of the component during non-operating and operating environments.

Range Safety personnel will determine whether any component or technology not identified in this document can be used. Depending on configuration and usage, not all new components may be allowed.

CHAPTER 4

FTS COMPONENT TEST AND ANALYSIS REQUIREMENTS

4.1 Scope and Compliance

This chapter contains requirements for tests and analyses that apply to all components that make up each FTS.

4.2 Component Tests and Analyses

A component shall satisfy each test or analysis required by an applicable table of this chapter to demonstrate that the component satisfies all its performance specifications when subjected to non-operating and operating environments. Range Safety shall identify any additional test or analysis requirements in conjunction with the Range User for any new technology or any unique application of an existing technology.

4.3 Test Plans and Procedures

4.3.1 Each test shall follow a written procedure that specifies the test parameters, including pass/fail criteria, and a testing sequence that satisfies the requirements of this chapter.

4.3.2 For any component that is used for more than one flight, the test procedure shall provide for component reuse qualification, refurbishment, and acceptance.

4.3.3 The ranges shall review and approve all plans and procedures. The Range User shall not deviate from or change an approved procedure unless specifically approved by the ranges. This includes software for automated checkout, test equipment, pass/fail criteria, etc.

1. The Range User shall notify the range 30 days before the start of testing, at which time the range will determine if a representative will be sent to witness the test. The range shall have the prerogative of witnessing any test.
2. Testing shall not begin until the test plan and/or procedure has been approved.
3. Components whose test data reflect the unit is out-of-family when compared to other units shall be considered out of specifications.
4. Plans and procedures shall be submitted for review and approval 45 days prior to the start of the procedure.

4.4 Test Anomalies and Failures

Each of the following constitutes a condition that requires resolution with Range Safety approval:

a. Any test that does not satisfy a performance specification or pass/fail criteria.
b. Any failure to accomplish a Range Safety test objective.

c. Any test result that indicates an out-of-family condition when compared to other tests even if it satisfies other test criteria.
d. Any unexpected change in the performance occurring at any time during testing.
e. Examination showing any defect that could adversely affect the performance.
f. Any discontinuity, dropout, or change in amplitude in a measured performance parameter.
g. Any inadvertent output.
h. Any sign that a part is stressed beyond its design limit, such as a cracked circuit board, bent clamps, worn part, or loose connector or screw, even if the component passes the final functional test

4.5 Failure Analysis

In the event of a test failure or anomaly, the test item, procedures, and equipment shall undergo a written failure analysis. The failure analysis shall identify the cause of the failure, the mechanism of the failure, and isolate the failure to the smallest replaceable item or items and ensure that there are no generic design, workmanship, or process problems with other flight components of similar configuration.

4.5.1 In the event of a test anomaly, the test configuration shall be frozen until a Range Safety representative can be contacted. The Range shall have the prerogative of participating in any failure analysis and corrective action. Invasive troubleshooting or corrective action shall not begin without Range Safety approval.

A failure investigation plan shall be submitted that describes the detailed approach to resolve the anomaly or failure.

4.5.2 The failure or anomaly of an FTS test shall be reported verbally or electronically to the Range Safety representative within 24 hours. Data shall be provided in a timely manner that allows Range Safety sufficient time to review documentation, which supports program schedule.

Detailed description with any supporting data shall be provided in writing within 14 calendar days of the date the failure is noted.

4.5.3 This requirement includes failure of tests conducted at the supplier plant, contractor plant, or at the range.

4.5.4 Flight approval will not be granted until Range Safety approves the failure analysis and corrective action.

4.5.5 Test Failure Reports.

a. This requirement includes failure of tests conducted at the supplier plant, contractor plant, or at the range.
b. A formal report containing a description of the failure, an analysis of the failure, and planned corrective actions shall be submitted to Range Safety in a timely manner that allows Range Safety sufficient time to review documentation, which supports program schedule.

Failure analyses shall be submitted to Range Safety for approval within 30 days of the failure.

4.6 Test Tolerances

4.6.1 The tolerance of any measurement taken during a functional test shall provide the accuracy needed to detect any out-of-family or out-of-specification anomaly.

4.6.2 The test tolerance level shall account for any test equipment tolerance to ensure that the component experiences the required margin for acceptance and qualification levels. These levels are shown at Table 4.6-1.

TABLE 4.6-1.TEST TOLERANCES

Test (Note: The following tests shall be used as applicable)	**Tolerance**
Temperature	±3 C
Pressure	
Above 1.3×10^{2} Pascals (1 Torr)	±10%
1.3×10^{-1} to 1.3×10^{2} Pascals, (≡ 0.001 Torr to 1 Torr)	±25%
Less than 1.3×10^{-1} Pascals, (≡ 0.001 Torr)	±80%
Relative Humidity	±5%
Acceleration	±10%
Vibration Frequency	±2%
Sinusoidal Vibration Amplitude	±10%
Random Vibration Power Spectral Density (G^2/Hz)	
20 to 100 Hz (5 Hz or narrower bands)	±1.5 dB
100 to 500 Hz (25 Hz or narrower bands)	±1.5 dB
500 to 2000 Hz (50 Hz or narrower bands)	±1.5 dB
Sound Pressure Level	
1/3 Octave Band	±3.0 dB
Overall	±1.5 dB
Shock Response Spectrum (Q = 10)	
1/6 Octave Band Center Frequency Amplitude	+6 dB/-3dB
Static Load	±5%

4.7 Test Equipment

4.7.1 Environmental Testing. All equipment used during environmental testing shall provide for the test item to experience the required environmental test levels. Environmental monitoring devices shall be placed to ensure accurate representation of the actual test environment. Any difference between the pre-qualification acceptance of the qualification unit and acceptance of the flight unit test fixture or cable(s) shall undergo an evaluation to ensure that flight hardware is not subjected to stresses greater than that which the unit experienced during pre-qualification acceptance testing.

1. A component's dynamic test input shall be validated by the use of accelerometers on at least two diagonal corners of the component input.
2. Any test fixture used to simultaneously test multiple component samples shall ensure that each component sample, at each mounting location on the fixture experiences each required environmental test level.
3. Flight hardware acceptance testing shall use the same configuration used during the pre-qualification acceptance testing.
4. For components that generate heat, sensors used to monitor thermal testing temperature levels shall be placed on the component and in a location to monitor ambient air temperature.
   a The air temperature shall be a minimum of the MPE for acceptance testing and MPE plus margin for qualification testing.
   b The component temperature (as measured on the component) shall meet the minimum required workmanship levels.

4.7.2 Automated Test Equipment. Automated test equipment used to perform functional testing shall be validated to ensure it performs the required tests within the specified test limits. This includes validation of pass/fail criteria if included in the test sequence. The test sequence plan and procedure used to write the software shall be submitted to Range Safety for review and approval. Once the automated test system is approved and used for qualification and acceptance testing, software changes (e.g. revision changes) shall not be made without Range Safety approval.

4.8 Rework and Repair of Components

Reworked components shall undergo all required tests to ensure the component meets all its performance requirements.

1. The component manufacturer shall make all repairs or reworks to FTS components.
2. A component that undergoes rework and repair shall complete the test that it failed and each remaining test. If a repair requires disassembly of the component or soldering operations, the component shall repeat any test necessary to demonstrate that the repair corrected the original anomaly and did not cause other damage.

3. The total number of acceptance tests experienced by a repaired flight component shall not subject the component to any environment for longer than the total duration that the component experiences during qualification testing.

Note: Qualification test methodology allows for 3 complete acceptance tests for flight hardware. Use of a component that has been acceptance tested more than 3 times requires specific Range Safety approval.

4.9 Test and Analysis Reports

The Range User shall provide a written report demonstrating compliance to all required component performance and environmental requirements.

As a minimum, the reports shall:

a. Describe all component test results and test conditions.
b. Describe any analysis performed instead of testing.
c. Identify, by serial number or other identification, each test result that applies to each system or component.
d. Describe any family performance data to be used for comparison to any subsequent test of a component or system.
e. Describe all performance parameter measurements made during component testing for comparison to each previous and subsequent test to identify any performance variations that may indicate potential workmanship or other defect that could lead to a failure of the component during flight.
f. Identify any test failure or anomaly, including any variation from an established performance baseline, with a description of the failure or anomaly, each corrective action taken, and all results of additional tests.

4.10 Component Test and Analysis Tables

4.10.1 General. This section applies to the component tables of this chapter. Each test requirement identified in the component tables shall be satisfied by test or analysis as determined by Range Safety.

1. Determination whether analysis or testing is required will be determined by Range Safety as part of the tailoring process.
2. When applicable to flight environments, combined tests (for example, thermal/vibration or thermal/shock) shall be performed to reflect the environments that will be experienced by the flight component during prelaunch and flight.

The following represents component-level testing categories:

a. Development Tests. Development tests validate hardware design concepts and assist in the evolution of designs from the conceptual to the operational phase. The objective of these tests is to identify hardware problems early in their design evolution, so any required actions can be taken before beginning formal qualification testing and production hardware fabrication. Significant component or system design changes dictated by development test results shall also be approved by the ranges. The ranges have the option of witnessing these tests.

b. Qualification Tests. Qualification tests are functional tests of flight representative hardware system or component designs. Performed during exposure to physical stress, these tests ensure adequacy and suitability of the design to reliably operate during and after exposure to certain physical environments in excess of flight predictions by a prescribed margin. Test articles subjected to qualification testing are considered expended and shall not be used for flight termination applications.

c. Delta-Qualification Tests. Delta-Qualification tests are additional functional tests conducted on hardware that have previously passed a prior qualification test program. Delta-qualification test hardware is exposed to additional physical stress to ensure the prescribed margin is maintained or to expand the operating envelope of the hardware.

d. Acceptance Tests. Acceptance tests are conducted to demonstrate that each production end item meets the requirements of the specification and to reveal production inadequacies. The acceptance test shall be performed on 100 percent of all FTS components and systems. The acceptance test performance data will be used to evaluate "in-family" performance and item life cycle performance degradation. Acceptance test environmental levels shall be at the maximum predicted levels or workmanship levels, whichever are greater, unless otherwise approved by the ranges through the LRSO.

e. Lot Acceptance Tests. Lot acceptance tests are destructive tests that are conducted on FTS components that are "one-shot" devices. Lot acceptance testing necessitates performance of tests that are destructive in nature. For this reason, this type of testing will be done on a specified number of randomly selected units. Lot acceptance tests are performed at qualification test levels on a specified number of specimens that have previously undergone individual item acceptance tests. Failure of any specimen to meet the lot acceptance test does not necessarily invalidate the qualification test for that component but will cause rejection of the particular lot for flight termination purposes.

f. Surveillance Testing. Surveillance testing is testing that is conducted to extend the shelf life for a particular FTS component. Such tests are performed to ensure components have not degraded over time. The Lead Range Safety Office will determine the frequency and type of surveillance testing.

Continued on next page

g. Reuse Testing. Reuse tests are conducted to recertify an FTS component for another flight. Approval for reuse of an FTS component shall be obtained from the Range Safety Office of the affected test range. Approval will be based on the component design and on the flight and recovery environments experienced on previous flights. Design margins, environments, and reuse/refurbishment plans shall be addressed early in the design cycle when reuse is desired. Reuse testing is expected to be accomplished by the same facility that performed the certification tests and is under the same time constraints. The test data shall correlate with the ATP baseline data and any previous certification test data.

h. Special Tests. Special tests are those deemed by the ranges as necessary to prove a unique performance specification. The need for special tests will be determined by the ranges. At a minimum, a RF compatibility test of the airborne system and range equipment shall also be conducted in the flight configuration.

4.10.2 An analysis used in lieu of testing shall demonstrate one of the following:

a. The test environment does not apply to the component.
b. The test environment does not degrade the component's performance.
c. Another test or combination of tests that the component undergoes places equal or greater stress on the component than the test in question.

4.10.3 Quantity of Sample Components Tested.

a. For a new component, each table identifies the quantity of component samples that shall undergo each test identified by the table.

b. A Range User may test fewer samples than the quantity identified for a new component if the Range User demonstrates one of the following:
(1) That the component has experienced comparable environmental tests
(2) The component is similar to a design that has experienced comparable environmental tests.

c. Any component that a Range User uses for any comparison to a new component shall have undergone all the environmental tests as those required for the new component to develop cumulative effects.

4.10.4 Performance Verification Tests. Each performance verification test identified by any table of this chapter shall satisfy all of the following:

a. Each performance test shall demonstrate all component performance parameters. At a minimum, the performance verification tests required in the component test matrix shall be performed for each component.
b. All performance verification tests required by the component test matrix shall be performed prior to the start of testing and after completion of the final test.

A subset of performances tests may be required to verify component functionality between environmental tests. The intent is to determine which environment caused a failure.

c. An electronic component shall undergo each performance verification test at low operating voltage, nominal operating voltage and high operating voltage that the component could experience during preflight and flight operations.
d. Monitoring and recording shall have a resolution and sample rate that will detect any component performance degradation.

4.10.5 Abbreviated Performance Verification Tests. Each abbreviated performance verification test required by any table of this chapter shall satisfy all of the following:

Abbreviated performance verification tests are performed when there is insufficient time or access to a component during testing to perform all required performance tests. Abbreviated performance tests are typically performed during operating acceptance and qualification testing.

a. Each test shall demonstrate a sampling of the component's critical performance parameters while the component is subjected to each test environment. At a minimum, the abbreviated performance verification tests required in the component test matrix shall be performed for each component

Any additional performance measurements will be determined based on the unique design, testing and operational usage of a specific component.

b. Monitoring and recording shall have a resolution and sample rate that will detect any component performance degradation.

1. Electronic components shall have input current monitored at a minimum sample rate of 1 millisecond during dynamic environments.
2. FTS components that are part of an ordnance firing circuit, such as batteries, safe & arm devices, command receiver outputs, shall be monitored at a minimum sample rate of 0.1 milliseconds during dynamic environments.

4.10.6 Status-of-Health Tests. Status-of-health tests shall satisfy all of the following:

a. Each test shall measure performance parameters that act as an indicator of an anomaly that a functional performance test might not detect.
b. Each test shall compare the results to any previous test results to identify any degradation in performance.
c. Monitoring and recording shall have a resolution and sample rate that will detect any component performance degradation.

d. Status of health tests include any indication that the unit under test may have been stressed beyond its design limit.

Status of health indications are not necessarily tied to a measurable test and include the following conditions:

a. Overheating.
b. Loose screws, connectors or attaching hardware.
c. Unit rattles when shaken.
d. Bent, worn or deformed parts.
e. Electrical burning smell.
f. Unusual sounds during vibration.

4.10.7 Margins. The component test matrices levy margins for numerous parameters such as environments, voltages, currents and time. These margins shall ensure components meet all performance requirements when subjected to nominal/errant flight environments, worst-case test tolerances, small qualification sample size, unit to unit performance variability, inability to fully recreate the combined flight environment and vehicle monitoring system tolerances.

1. Text boxes following each performance requirement may contain margins based on lessons learned from numerous nominal and errant vehicle flights from all MRTFB Ranges.
2. The margins in the text box may be reduced or increased depending on the specific component and vehicle application.
3. The test margin shall account for test equipment and vehicle telemetry tolerances.
4. Qualification margin shall include vehicle monitoring system (e.g. telemetry) tolerances to account for launch go/no-go criteria.

4.10.8 Test Sequence. A component or system shall undergo each test in the same order as the table identifies the test. A Range User may deviate from the test sequence if the Range User demonstrates that another order will detect any component anomaly that could occur in the required test sequence.

4.11 Component Examination

4.11.1 General. This section applies to each component examination identified by any table of this chapter. Each component examination shall identify any manufacturing defect that the performance tests might not detect. The presence of a defect that could adversely affect the component's performance constitutes a failure.

4.11.2 Visual Examination. A visual examination shall verify that good workmanship was employed during manufacture of a component and that the component is free of any physical defect that could adversely affect performance. A visual examination may include the use of optical magnification, mirrors, or specific lighting, such as ultraviolet illumination. Visual examination shall be performed before and after all non-operating and operating environments.

1. With the unaided eye, inspect all accessible areas of the component.
2. Under 10X minimum magnification, inspect all critical surfaces and interfaces of the component.
3. Connector pins and sockets shall be inspected for corrosion, debris and bent pins.

4.11.3 Dimension Measurement. A dimension measurement of a component shall verify that the component satisfies all its dimensional specifications.

4.11.4 Weight Measurement. A weight measurement of a component shall verify that the component satisfies its weight specification.

4.11.5 Identification Check. An identification check of a component shall verify that the component has one or more identification tags that contain information that allows for configuration control and tracing of the component.

As applicable, check identification tags to verify:

a. Component name.
b. Manufacturer identification.
c. Date of manufacture.
d. Date of explosive loading for components containing explosives.
e. Serial number.
f. Part number.
g. Shelf life.
h. Service life.
i. Manufacturer's lot date code.
j. Manufacturing plant.

4.11.6 X-Ray and N-Ray Examination. An X-ray or N-ray examination of a component shall have a resolution that allows detailed inspection of the internal parts of the component and shall identify any internal anomalous condition. The examination shall include enough photographs, taken from different angles, to allow complete coverage of the component's internal parts. The examination shall use the same set of angles for each sample of a component to allow for comparison. A certified technician shall evaluate X-ray and N-ray photographs.

1. The components shall be X-rayed to quality level 2-2T of MIL-STD-453, Radiographic Inspection, or the equivalent unless otherwise specified in the component specification.
2. N-ray radiographic testing shall conform to the requirements of the American Society for Testing and Materials, ASTM E 748, Standard Practices for Thermal Neutron Radiography of Materials.

4.11.7 Internal Inspection. An internal inspection of a component shall demonstrate that there is no wear or damage, including any internal wear or damage, to the component that could adversely affect its performance after exposure to any test environment. An internal inspection shall satisfy all of the following:

a. All internal components and subassemblies, such as circuit board traces, internal connectors, welds, screws, clamps, electronic piece parts, battery cell plates and separators, and mechanical subassemblies shall undergo examination using an inspection method such as a magnifying lens or radiographic inspection.
b. For a component that cannot be disassembled, such as an antenna, potted component, or welded structure, the component shall undergo special procedures such as de-potting the component, cutting into the component, or radiographic inspection.

Destructive disassembly is not usually required unless there is an anomaly.

4.11.8 Leakage. A leakage test shall demonstrate that a component's seal satisfies all its performance specifications before and after the component is subjected to any test environment. The test shall have the resolution and sample rate to demonstrate that the component's leak rate is no greater than its design limit.

1. Perform leak rate tests in accordance with the requirements of MIL-STD-202, Test Methods for Electronic and Electrical Component Parts, method 112, procedure III or IV, or the equivalent.
2. For an ordnance component, the test shall demonstrate a leak rate of no greater than the equivalent of 5×10^{-6} standard cubic centimeters/seconds of helium.
3. For an electronic component, the test shall demonstrate a leak rate of no greater than the equivalent of 10^{-4} standard cubic centimeters/seconds of helium.

4.12 General Qualification Testing and Analysis Requirements

4.12.1 This section applies to each qualification non-operating and operating test or analysis identified by any table of this chapter. A qualification test or analysis shall demonstrate that a component will satisfy all its performance specifications when subjected to the design environmental levels.

4.12.2 Before a component sample undergoes a qualification environmental test, the component sample shall pass all the required acceptance tests.

4.12.3 A component shall undergo each qualification test in a flight representative configuration, with all flight representative hardware such as connectors, cables, and any cable clamps, and with all attachment hardware, such as dynamic isolators, brackets and bolts, as part of that flight representative configuration.

1. Use of flight-like attaching hardware may be acceptable if the attaching hardware (e.g. cable or ETS) is already qualified from another test and the flight-like hardware reflects the same dynamic environmental characteristics.
2. Testing shall validate the mounting of the unit. This may include using locktite or safety wiring. Where testing using a flight configured mounting scheme is impractical, other means shall be used to demonstrate the ability of the flight configured component to meet performance requirements during qualification environments.
3. Component attaching hardware including bolts, cables and ETS shall not be retightened or adjusted throughout each qualification test unless it is to remove the unit to set up for another test.

4.12.4 A component shall undergo re-qualification tests if there is a change in the design of the component or in the environmental levels to which it will be exposed. A component shall undergo re-qualification if the manufacturer location, parts, materials, or processes have changed since the previous qualification. A change in the name of the manufacturer as a result of a sale does not require re-qualification if the personnel, factory location or the parts, material and processes remain unchanged since the last component qualification. The extent of any re-qualification tests shall be the same as the initial qualification tests.

4.12.5 Any component sample that has been subjected to a qualification test environment is not acceptable for flight.

4.12.6 Qualification by Similarity. A Range User may reduce the testing required to qualify or re-qualify a component's design through qualification by similarity to tests performed on identical or similar hardware. To qualify component "A" based on similarity to component "B" that has already been qualified for use, a Range User shall demonstrate that all of the following conditions are satisfied.

a. "B" shall have been qualified through testing, not by similarity.
b. The environments encountered by "B" during its qualification or flight history shall have been equal to or more severe than qualification environments required for "A."
c. "A" shall be a minor variation of "B." The demonstration that A is a minor variation of B shall account for all of the following:
   (1) Any difference in weight, mechanical configuration, thermal effects, or dynamic response.
   (2) Any change in piece-part quality level.
   (3) Any addition or subtraction of an electronic piece-part, moving part, ceramic or glass part, crystal, magnetic device, or power conversion or distribution equipment.
d. "A" and "B" shall perform the same functions, with "A" having equivalent or better capability.
e. The same manufacturer shall produce "A" and "B" in the same location using identical tools and manufacturing processes.
f. The time elapsed since last production of "A" or "B" shall be no greater than three years.

1. Range Safety Office approval for qualification-by-similarity is required. Components that are to be qualified by similarity will be identified at the beginning of the program. The Range Safety Office will approve or disapprove the similarity analysis at that time. The early identification of potential noncompliant hardware, which is qualified by similarity, will allow the user to take proper contractual action at the beginning of the program. Test data and written rationale that support the request for qualification by similarity in lieu of qualification by actual testing shall be provided. Each environmental requirement shall be addressed and justified. Environments that are not justified will require a "delta" or limited qualification test to satisfy those environments. During the "delta" qualification test, some environmental requirements the item was qualified to by similarity might have to be repeated to ensure the cumulative effect of the environments do not degrade the component.
2. Qualification by similarity means the identical FTS component, made by the same manufacturer, has been previously qualified by testing to environmental and functional performance requirements that meet or exceed the environmental and functional requirements of the new program. It does not mean qualification of similar FTS components (for example, two different model FTRs, that may be made by the same manufacturer) simply because the manufacturer uses the same techniques and quality assurance procedures. It also does not mean qualification of FTS components, made by different manufacturers simply because the manufacturers were working from the same drawings and requirements. Qualification by similarity shall be limited to items from a single source having identical design and manufacturing processes.

4.12.7 For <u>any</u> FTS component used for more than one flight, the component qualification tests shall demonstrate that the component satisfies all its performance specifications when subjected to both of the following:

a. Each qualification test environment.
b. The total number of exposures to each MPE for the total number of flights.

4.13 Qualification Non-Operating Environments

4.13.1 <u>General</u>. This section applies to each qualification non-operating environment test or analysis identified by any table of this chapter. A qualification non-operating test or analysis shall demonstrate that a component satisfies all its performance specifications when subjected to each maximum predicted non-operating environment that the component could experience, including all storage, transportation, and installation environments.

4.13.2 <u>Storage Temperature</u>. A storage temperature test or analysis shall demonstrate that a component will satisfy all its performance specifications when subjected to the maximum predicted high and low temperatures, thermal cycles, and dwell-times at the high and low temperatures that the component could experience under storage conditions plus a margin as follows:

Storage temperature testing is usually not required for components stored in a controlled

environment such that the temperature variation that the component experiences does not exceed a temperature range of 20 °C.

a. A storage temperature test shall subject the component to the range of temperatures from 10 ^{o}C lower than the maximum predicted storage thermal range to 10 oC higher. The rate of change from one thermal extreme to the other shall be no less than the maximum predicted thermal rate of change. All thermal dwell-times and thermal cycles shall be no less than those of the maximum predicted storage environment.

1. The minimum storage temperature range is:
   a. -34°C to +71°C for non-ordnance components.
   b. -54°C to +71°C for ordnance components.
2. The component shall be tested to the high and low temperatures for a minimum of 7 cycles and a 12-hour dwell at each temperature extreme.

b. A thermal analysis may be used in lieu of testing. The analysis shall demonstrate that the qualification operating thermal cycle environment is more severe than the storage thermal environment. The analysis shall include thermal fatigue equivalence calculations that demonstrate that the large change in temperature for a few thermal cycles experienced during flight is a more severe environment than the relatively small change in temperature for many thermal cycles that would be experienced during storage.

4.13.3 High Temperature Storage of Ordnance. A component may undergo a high temperature storage test to extend the service-life of an ordnance component production lot. The test shall impart environmental stress levels that simulate a component's aging effects.

1. A lot will have an initial service life of one year if no high temperature storage is performed.
2. Devices using deflagration to detonation ordnance transfers will have a three year service-life extension if high temperature storage is performed. The test shall demonstrate that each component sample satisfies all its performance specifications after being subjected to +71 ^{o}C and 40 to 60 percent relative humidity for no less than 30 days each.
3. Linear ordnance systems initiated by a high order interface will have a five year service-life extension if high temperature storage is performed. The test shall demonstrate that each component sample satisfies all its performance specifications after being subjected to +71 ^{o}C and 40 to 60 percent relative humidity for no less than 39 days each.
4. Certain linear ordnance systems initiated by a high order detonation interfaces may be allowed to have an initial 10 year service extension using the following criteria:
   a. This 10 year initial service life does not apply to initiators or any device using a deflagration-to-detonation interface.
   b. Candidate devices for consideration of the 10 year initial service life include linear shaped charges, conical shaped charges, bi-directional wafer charges, FCDC, SMDC, and Primacord®.
   c. The 10 year shelf life only applies to the first 10 years of the component's shelf-life. Subsequent shelf-life extensions past 10 years are limited to the 5-year extension required in the applicable test tables.
   d. The component must be subjected to a high temperature test for a period of time that imparts the equivalent degradation of 10 years aging. The time and temperature shall be determined by using the Arrhenious Equation using a 95% confidence. Unless otherwise specified, the test shall be performed at +71 ^{o}C for 60 days. The component shall be subjected to at least 90% relative humidity for this test.
   e. The ordnance composition within the component shall have demonstrated functionality on similar devices over 15 years.
      (1) If more than one ordnance composition is in contact with another, then that interface shall have a demonstrated functionality for over 15 years.
      (2) Any materials in contact with ordnance shall have a demonstrated functionality on similar devices over 15 years.
   f. The component shall be tested to demonstrate that it is hermetically sealed to a leak rate of no greater than the equivalent of 5×10^{-6} standard cubic centimeters/seconds of helium.
   g. All materials that make up the component including the housing, passivation, coatings, lubrication and epoxies shall have a demonstrated functionality on similar devices over 15 years.
   h. Ordnance components shall not have storage temperatures that violate maximum predicted levels.
   i. Ordnance components that use a small ordnance load such as shock tube, may not be permitted to use the 10 year initial shelf-life.

a. The initial service-life of an ordnance component, including any component that contains ordnance or is used to directly initiate ordnance, shall start upon completion of the initial production lot sample acceptance tests and shall include both storage time and time after installation until completion of flight. The test tables of this chapter identify the options for the length of any service-life extension for each type of ordnance component.
b. The tables of this chapter identify the number of ordnance component samples that shall undergo any service-life extension test. Each component sample shall be:
   (1) From the same production lot
   (2) Consist of identical parts and materials
   (3) Manufactured through identical processes
   (4) Stored with the flight ordnance component or in an environment that duplicates the storage conditions of the flight ordnance component.

4.13.4 Transportation Shock. A transportation shock test or analysis shall demonstrate that a component satisfies all its performance specifications after being subjected to the maximum predicted transportation induced shock levels that the component could experience when transported in its transported configuration plus a margin. Any analysis shall demonstrate that the qualification operating shock environment is more severe than the transportation shock environment.

Transportation shock shall be performed at worst-case hot/cold temperature if the component is susceptible to the combined environment.

4.13.5 Bench Handling Shock. A bench handling shock test shall demonstrate that a component satisfies all its performance specifications after being subjected to maximum predicted bench handling induced shock levels plus a margin. The test shall include, for each orientation that could occur during servicing; a drop from the maximum predicted handling height onto a representative surface.

1. Configure and position item as it would be for servicing.
2. Using one edge as a pivot, lift the opposite edge of the chassis until one of the following conditions occurs:
   a. The chassis forms an angle of 45° with the horizontal bench top.
   b. The lifted edge of the chassis has been raised 4 inches above the horizontal bench top.
3. Let the item drop freely to the solid wood bench top.
4. Repeat, using other edges of the same horizontal face as pivot points, for a total of four drops.
5. Repeat above procedure with the test item resting on other faces until it has been dropped for a total of four times on each face on which the test item could be placed practically during servicing.
6. The test item shall not be operating during the drops.

4.13.6 Transportation Vibration. A transportation vibration test or analysis shall demonstrate that a component satisfies all its performance specifications as follows:.

a. A transportation vibration test shall subject the component a maximum predicted transportation-induced vibration level when transported in its transportation configuration plus a margin.

1. Any transportation vibration test shall subject a component to vibration in three mutually perpendicular axes for 60 minutes per axis. The test shall subject each axis to the following vibration profile:
   a. 0.01500 ^{g2}/Hz at 10 Hz to 40 Hz.
   b. 0.01500 ^{g2}/Hz at 40 Hz to 0.00015 ^{g2}/Hz at 500 Hz.
   c. If the component is resonant below 10 Hz, the test vibration profile shall extend to the lowest resonant frequency.
2. Transportation vibration shall be performed at worst-case hot/cold temperature if the component will be exposed to the combined environment.

b. A transportation vibration analysis may be used in lieu of testing. The analysis shall demonstrate that the qualification operating vibration environment is more severe than the transportation vibration environment. The analysis shall include vibration fatigue equivalence calculations that demonstrate that the high vibration levels with short duration experienced during flight creates a more severe environment than the relatively low-vibration levels with long duration that would be experienced during transportation.

4.13.7 Fungus Resistance. A fungus resistance test or analysis shall demonstrate that a component satisfies all its performance specifications after being subjected to a fungal growth environment. Any analysis shall demonstrate that all unsealed and exposed surfaces do not contain nutrient materials for fungus.

Testing shall be performed in accordance with MIL-STD-810, test method 508.5.

4.13.8 Fine Sand. For a component that will be exposed to fine sand or dust, a fine sand test or analysis shall demonstrate that the component satisfies all its performance specifications after being subjected to the effects of dust or fine sand particles that may penetrate into cracks, crevices, bearings and joints. The test or analysis shall demonstrate the ability of all externally exposed surfaces to withstand a fine sand environment plus a margin. The test or analysis shall demonstrate the ability of each internal part of a component to withstand a fine sand environment unless the component is environmentally sealed and acceptance testing verifies that the seal works.

1. Relative humidity shall not exceed 30 percent.
2. Silica sand, at least 95 percent by weight SiO_2, shall be used as the test medium. The sand will be of sub-angular structure with a mean Krumbein number range of 0.5 to 0.7 for both roundness and sphericity and a hardness of 7 Mhos. The particle size distribution by weight will meet the following:
   a. 90+/-5% by weigh small than 600 µm and larger than 149 µm.
   b. at least 5% by weigh 600 µm and larger.
3. Expose each face of the test item to a sand dust having a velocity of 18 to 29 meters per second for a total of 90 minutes per face.
4. If operation of the test item is required, continuously operate the test item for a minimum of 10 minutes during the last period of the test.
5. Visually inspect the component for abrasion, clogging effects, and any evidence of sand penetration.

4.13.9 Tensile Load. A tensile load test shall demonstrate that a component satisfies all its performance specifications after being exposed to the maximum predicted tensile and compression loads during transportation and installation plus a margin or a workmanship level, whichever is greater.

1. At a minimum, testing shall be performed at twice the worst-case expected transportation and installation compression and tensile loads, where applicable.
2. Workmanship levels shall be used to ensure that flight hardware will not be damaged during inadvertent or accidental load conditions.
   a. For an ETS and its associated fittings, a pull of no less than 100, pounds unless the Range User establishes procedural controls or tests that prevent or detect mishandling.
   b. For a destruct charge and its associated fittings, a pull of no less than 50 pounds.
   c. For a flight RF connector, a pull and torque of no less than one-half the manufacturer specified limit.
   d. For an LVI wire, a pull of no less than 18 pounds. LVIs contained in a safe and arm device may undergo additional testing once the LVI is installed in the rotor in lieu of the 18 pound pull requirement. Testing shall ensure the LVIs were not damaged during installation. These tests include X-ray, N-ray, Thermal Time Constant and bridgewire resistance.
   e. For an electrical pin of an initiator that is installed or removed in the field, no less than an 18-pound force in axial and compression modes.
      (1) The component and associated fittings shall be capable of withstanding tensile loads for 1-minute minimum without damage or degradation in performance.
      (2) Optical, RF and electrical cables and connectors, including LID pigtails, shall be able to withstand a tensile pull of 30 pounds. Cables and connectors unable to meet this requirement may require special operational constraints, installation procedures and on-vehicle tests to ensure fragile connectors and cables were not damaged and will function reliably during flight.

4.13.10 Handling Drop of Ordnance. A handling drop test shall demonstrate that an ordnance component satisfies all its performance specifications after experiencing the maximum predicted drop and resulting impact that could occur if dropped by personnel.

A six-foot drop onto a representative surface in any orientation that could occur during storage, transportation, or installation.

a. Drop three times onto a 1/2-inches thick, steel plate from a height of 6 feet.
b. Procedure.
   (1) Drop to cause it to impact on the output end. This is drop 1 of 3.
   (2) Drop to cause it to impact on its side. This is drop 2 of 3.
   (3) Drop to cause it to impact on the connector or input pin end. This is drop 3 of 3.
c. The device shall not fire, dud, or deteriorate in performance as a result of this test.

4.13.11 Abnormal Drop of Ordnance. An abnormal drop test shall demonstrate that an ordnance component does not initiate and allows for safe disposal after experiencing the maximum predicted drop and resulting impact onto a representative surface in any orientation that could occur during storage, transportation, or installation. The component need not function after this drop.

The component shall be dropped from 40 feet onto a steel plate.

4.14 Qualification Operating Environments

4.14.1 General. A qualification operating environment test shall demonstrate that a component satisfies all of its performance specifications when subjected to each qualification operating environment, including the physical environments that the component will experience during acceptance testing, during launch countdown, and flight plus a margin in accordance with paragraph 4.10.7. When applicable to flight environments, combined tests such as thermal/vibration or thermal/shock shall be performed to reflect the environments that will be experienced by the flight component during prelaunch and flight. The detailed requirements for combined tests will be determined during tailoring.

1. When applicable to the flight environments, temperature/humidity/altitude test shall be used in lieu of a humidity test.
2. All performance verification tests required by the component test matrix shall be performed before and after each operating environmental test

4.14.2 Qualification Thermal Cycle. A qualification thermal cycle test shall demonstrate that a component satisfies all its performance specifications when subjected to acceptance, lot acceptance and workmanship thermal cycle environment plus a margin as follows:

For high transition thermal transition rates (thermal shock), thermal cycle testing or analysis shall demonstrate that a component can withstand sudden changes in temperature without degradation in performance. When heating or cooling the component, the temperature shall change at the maximum predicted thermal ramp rate. Unless otherwise specified, the component subjected to thermal shock shall be transitioned from ambient to the required low and high temperature extremes within 5 minutes.

a. Active Electronic Components. FTS electronic components that contains active piece-part circuitry, such as microcircuits, transistors, diodes and relays, a qualification thermal cycle test shall satisfy all of the following:
   (1) The qualification thermal cycle environment shall range from 10 ^{o}C above the acceptance test high temperature to 10 °C below the acceptance test low temperature.
   (2) The test shall subject a component to no less than three times the acceptance-number of thermal cycles or 24 thermal cycles, whichever is greater. For each component, the acceptance-number of thermal cycles shall satisfy the requirements of this document. For each cycle, the dwell-time at each of the high and low temperatures shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour. The test shall begin each dwell-time at each high and low temperature with the component turned off. The component shall remain off until the temperature stabilizes. Once the temperature stabilizes, the component shall be turned on and the test shall complete each dwell-time with the component turned on.

A complete electrical performance test shall be performed at hot, cold and ambient qualification temperatures before and after all operating environments are complete.

   (3) When heating or cooling the component, the temperature shall change at a rate of not less than 3 $^{\circ}$C per minute or the maximum predicted rate, whichever is greater.
   (4) The test shall demonstrate a subset of performance verification tests required by the component test matrix with the component at its low and high operating voltages at the high and low temperatures during the first, middle and last thermal cycles.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

   (5) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

b. Passive Electronic Components. For any passive component that does not contain an active electronic piece-part, such as an RF antenna, RF coupler, or cable; a qualification thermal cycle test shall satisfy all of the following:
   (1) The qualification thermal cycle environment shall range from 10 ^{o}C above the acceptance test high temperature to 10 ^{o}C below the acceptance test low temperature.
   (2) The test shall subject a component to no less than three times the acceptance-number of thermal cycles or 24 thermal cycles, whichever is greater. For each component, the acceptance-number of thermal cycles shall satisfy requirements of this document. For each cycle, the dwell-time at each high and low temperature shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour.
   (3) When heating or cooling the component, the temperature shall change at a rate of not less than 3 ^{o}C per minute or the maximum predicted rate, whichever is greater.
   (4) The test shall demonstrate all performance verification required by the component test matrix at the high and low temperatures during the first, middle and last thermal cycles.
   (5) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

c. Mechanical Devices. These devices include electromechanical S&A device with an internal explosive and mechanical valves. An acceptance thermal cycle test shall satisfy all of the following:
   (1) The qualification thermal cycle shall range from 10 ^{o}C above the acceptance test high temperature to 10 ^{o}C below the acceptance test low temperature.
   (2) The test shall subject the component to no less than three times the acceptance-number of thermal cycles or 24 thermal cycles, whichever is greater. For each component, the acceptance-number of thermal cycles shall satisfy the requirements of this document. For each cycle, the dwell-time at each high and low temperature shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour.
   (3) When heating or cooling the component, the temperature shall change at a rate of not less than 3 ^{o}C per minute or the maximum predicted rate, whichever is greater.
   (4) The test shall demonstrate all performance verification required by the component test matrix at the high and low temperatures during the first, middle and last thermal cycles.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

   (5) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure. The component shall be in an armed state for all cycles and thermal transitions. The monitoring and recording

shall have a resolution and sample rate that will detect any component performance degradation.

d. Ordnance Components. Ordnance components shall satisfy all of the following:
   (1) The qualification thermal cycle shall range from 10 ^{o}C above the predicted highest temperature, or 71 ^{o}C, whichever is higher, to 10 ^{o}C below the predicted lowest temperature, or -54 ^{o}C, whichever is lower.
   (2) The test shall subject each ordnance component to no less than the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles shall meet the requirements of this document. For an ordnance component that is used inside an S&A device, the test shall subject the component to three times the acceptance-number of thermal cycles. For each cycle, the dwell-time at each high and low temperature shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than two hours.
   (3) When heating or cooling the component, the temperature shall change at rate not less than 3 ^{o}C per minute or the maximum predicted rate, whichever is greater.

4.14.3 Qualification Thermal Vacuum. A qualification thermal vacuum test or analysis shall demonstrate that a component will satisfies all its performance specifications, including structural integrity when subjected to the acceptance and workmanship thermal vacuum environment plus a margin as follows:

a. The thermal vacuum pressure gradient shall equal or exceed the maximum predicted rate of altitude change that the component will experience during flight. The pressure gradient shall allow for no less than ten minutes for reduction of chamber pressure from ambient pressure to MPE low pressure.

1. With the component in the thermal chamber, reduce the pressure from atmospheric to a critical pressure (pressure at which a corona or arcing is likely to occur). A performance test shall be performed.
2. The time for reduction of chamber pressure from ambient to 20 Pascals (0.15 Torr) shall be at least 10 minutes to allow sufficient time in the region of critical pressure.
3. Reduce the pressure from critical pressure to a minimum of 0.0133 Pascals (0.0001 Torr) or actual flight altitude, whichever is less.

b. The final vacuum dwell-time shall be sufficient to achieve internal component vacuum equilibrium or the maximum predicted flight vacuum time, whichever is greater, plus a margin.

1. Temperature stability is achieved when the rate of change is no more than 3°C per hour. The component heat transfer to the thermally controlled heat sink and the radiation heat transfer to the environment shall be controlled to the same proportions as calculated for the flight environment.
2. The dwell time shall be the greater of the maximum predicted dwell-time or 12 hours.

c. The thermal vacuum test shall be no less than three times the acceptance number of thermal cycles.

A minimum of 3 temperature cycles shall be used.

d. Each thermal cycle shall range from 10°C above the acceptance thermal vacuum range, to 10°C below the acceptance thermal vacuum range.

The component temperature shall be tested at a minimum temperature range from -34°C to 71°C.

e. The test shall demonstrate a subset of performance verification tests required by the component test matrix with the component at the high and low temperatures during the first, middle and last thermal cycles at final vacuum.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

f. The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during all vacuum and thermal transitions.

Electronic components shall be tested at their high operating voltage.

g. A thermal vacuum analysis may be used in lieu of testing. The analysis shall satisfy all of the following:
   (1) For any low voltage component, the analysis shall demonstrate that the component is not susceptible to corona or arcing.

Low voltages are considered less than 50 volts

   (2) For any high voltage component, the component shall undergo a thermal vacuum test unless the component is environmentally sealed and the analysis demonstrates that any low voltage externally exposed part is not susceptible to corona, arcing, or structural failure. A component with any high voltage externally exposed part shall undergo a thermal vacuum test.

High voltages are considered greater than 250 volts.

(3) The analysis shall demonstrate structural integrity of the component when exposed to a vacuum environment.
(4) The analysis shall demonstrate that any internal component heat producing parts are capable of adequately dissipating heat without the need for air convection.

4.14.4 Qualification Humidity. A qualification humidity test or analysis shall demonstrate that a component satisfies all its performance specifications when subjected to the maximum predicted relative humidity environment that the component could experience when stored, transported, or installed plus a margin as follows:

a. The test or analysis shall demonstrate the ability of all externally exposed surfaces to withstand the maximum predicted relative humidity environment.
b. The test or analysis shall demonstrate the ability of each internal part of a component to withstand the maximum predicted relative humidity environment unless the component is environmentally sealed and an acceptance test demonstrates that the seal works.
c. Each test shall satisfy all of the following:
   (1) The test shall subject the component to no less than ten thermal cycles while the component is exposed to a relative humidity of no less than 95 percent.
   (2) The test shall demonstrate a subset of performance verification tests required by the component test matrix with the component at the high and low temperatures during the first, middle and last thermal cycles.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

(3) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

Cycle 1:
a. Gradually increase the internal chamber temperature to 61°C and the relative humidity to 95 percent + 5 percent over a 2-hour period.
b. Maintain temperature and humidity for 6 hours.
c. Maintain 85 percent or greater humidity and reduce the internal chamber temperature in 8 hours to 30°C and 95 percent + 5-percent humidity.
d. Maintain these conditions for 8 hours.

Cycles 2 through 4: Repeat cycle 1.
Cycle 5: Repeat Cycle 1 and perform a performance verification test.
Cycles 5 through 9: Repeat cycle 1.

Cycle 10:

a. Repeat cycle 1 and perform a performance verification test.
b. Decrease the internal chamber temperature to 23°C and 50-percent relative humidity by blowing air through the chamber for 6 hours. The volume of air that is used per minute shall be equal to one to three times the test chamber volume. A suitable container may be used in place of the test chamber for drying the component.
c. Visually inspect the component for physical damage or deterioration.
d. Perform a performance verification test.

4.14.5 Salt Fog. For a component that is will be exposed to salt fog, a salt fog test or analysis shall demonstrate that the component satisfies all its performance specifications when subjected to the effects of a moist, salt-laden atmosphere plus a margin. Functional performance testing shall be performed on electrical components if the component is required to function while in a salt fog environment.

1 Place the test component in a test chamber and expose the component to 5-percent salt fog at 35°C for a period of 48 hours.
2. If required, electrical functional tests shall be performed immediately after completion of salt-fog testing
3 At the end of the exposure period, inspect the component for corrosion.
4. Store the test component in ambient atmosphere for 48 hours.
5. At the end of the ambient stage period, operate the test component again and compare the results with the data collected before the start of the test.
6. The component performance shall not vary from the data that was collected during the full functional test before the start of the test.
7. An analysis may be used in lieu of a salt-fog testing if:
   a. All externally exposed surfaces can withstand a salt-fog environment .
   b. The component is environmentally or hermetically sealed and acceptance testing verifies that the seal is intact.
   c. Electrical interfaces outside the component are less than 50 volts.

4.14.6. Temperature/Humidity/Altitude. A temperature, humidity and altitude test or analysis shall demonstrate that a component satisfies all its performance specifications when subjected to the temperature, humidity and altitude mission environments plus a margin as follows:

1. A component shall satisfy all its performance specifications, including structural integrity, corona and internal component electrical/optical degradation.
2. To demonstrate the ability of the component to perform in an environment of low temperature/low pressure and high temperature/high humidity that may be obtained by flying equipment between extreme environments.

   a. The test shall demonstrate a subset of performance verification tests required by the component test matrix at the high and low temperatures under altitude and humidity conditions.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

b. The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.
c. The qualification thermal cycle environment shall range from 10°C above the mission high temperature to 10°C below the mission low temperature.
d. The test shall subject a component to no less than four thermal, humidity and altitude cycles.

1. Low Temperature Step. Place the component in a test chamber that is maintained at sea level pressure and reduce the chamber temperature to the minimum expected mission temperature minus 10°C within 2 hours.
2. Altitude Step.
   a. Reduce the chamber pressure at a rate of 1,000 to 1,500 feet/minute to 50,000 feet or the highest altitude obtained, whichever is higher, while maintaining the low temperature.
   b. When the altitude of the component has stabilized, conduct a performance test on the component.
3. Humidity Step.
   a. Within 30 minutes, raise the chamber pressure to ambient pressure, return the chamber to ambient temperature, and then, raise the chamber humidity to 95-percent RH.
   b. Maintain the temperature and humidity conditions for 2 ½ hours.
4. High Temperature Step.
   a. During the next 30 minutes, increase the temperature to the maximum expected mission temperature plus 10°C and maintain the humidity at 95-percent RH.
   b. Maintain the temperature and humidity conditions for 6 hours.
   c. When the chamber and component stabilize, conduct another performance test.
5. Ambient Temperature Step.
   a. During the next 8 hours, reduce the chamber temperature at a uniform rate to standard ambient temperature while maintaining the humidity at 95% RH.
   b. Maintain the standard temperature at 95% RH for 2 hours.
   c. When the chamber and component stabilize, conduct another performance test.
6. Repeat Tests. Repeat the Temperature/Humidity/Altitude test described in steps 1-6 for 3 additional cycles for a total of 4 cycles.

4.14.7 Qualification Acceleration.

a. A qualification acceleration test or analysis of a component shall demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the acceptance acceleration environment plus a margin. The attached items shall include any isolator, grounding strap, bracket, ETS, or cable to the first tie-down. Any cable that interfaces with the component during any test shall be representative of the cable used for flight.

Acceleration shall be performed at worst-case hot/cold temperature if the component will be exposed to the combined environment.

b. A component shall be tested to demonstrate it meets all abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

c. The qualification acceleration test environment shall be twice the maximum predicted acceleration environment and test tolerances.

d. The qualification acceleration duration shall be three times the MPE in each direction for each of the three orthogonal axes.

e. The acceleration analysis may be used in lieu of testing. The acceleration analysis shall demonstrate that the another qualification operating environmental test encompasses the qualification acceleration environment.

When using random vibration as baseline, the analysis shall account for the peak vibration and acceleration levels and durations.

f. Any test shall continuously monitor and record all performance and status-of-health parameters while the component is subjected to the qualification environment. This monitoring shall have a sample rate of once every millisecond or better.

1. The specified accelerations apply to the geometric center of the test component. 2. If a centrifuge is used, the arm measured to the geometric center of the test component shall be at least five times the dimension of the test component measured along the arm. 3. The minimum duration of the test shall be 5 minutes per each axis in each direction.

4.14.8 Qualification Shock.

a. A qualification shock test of a component shall demonstrate that the component and each connection to any item that attaches to the component satisfies all their performance specifications when subjected to the maximum predicted or breakup shock environment plus a margin. The attached items shall include any isolator,

grounding strap, bracket, ETS, or cable to the first tie-down. Any cable that interfaces with the component during the test shall be representative of the cable used for flight.

Shock testing shall be performed at worst-case hot/cold temperature if the component will be exposed to the combined environment.

b. The minimum qualification shock environment shall be 3-dB above MPE plus test tolerances for all frequencies from 100 Hz to 10000 Hz.

For a shock test with a 3-dB lower test tolerance, the qualification test environment shall be 6dB above the MPE.

c. The test shall subject the component simultaneously to a shock transient and all the required frequencies.

d. The test shall subject each component to three shocks in each direction along each of the three orthogonal axes.

1. For single axis and direction shock simulators, a minimum of 18 shocks consisting of three shocks in each direction, positive and negative, for each of three mutually perpendicular axes are required.
2. 3 shocks may only be required for shock simulators that can meet all G-levels with one shock event in all 3 axes in both directions.

e. The shock shall last as long as the maximum predicted shock event.

f. The test shall continuously monitor each component's critical performance parameters for any discontinuity or inadvertent output while the component is subjected to the shock environment.

g. A component shall be tested to demonstrate it meets the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

For multi-stage vehicles, a component shall satisfy all its performance specifications when exposed to a 1300 G minimum shock as described in Table 4.14-1 below.

TABLE 4.14-1. MINIMUM BREAKUP QUALIFICATION SHOCK LEVELS	
Frequency Range (Hz)	**Minimum Acceleration Spectral Density**
100	100 G
2000	1300 G
10000	1300 G
Note. Q (Resonant Amplification Factor) = 10	

4.14.9 Qualification Acoustic.

a. A qualification acoustic vibration test or analysis of a component shall demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the acceptance and workmanship acoustic vibration environment plus a margin. The attached items shall include any isolator, grounding strap, bracket, ETS, or cable to the first tie-down. Any cable that interfaces with the component during any test shall be representative of the cable used for flight.

Acoustic dB-sound pressure levels are referenced to 20 micropascals.

b. A component shall be tested to demonstrate it meets all abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

c. The minimum qualification acoustic vibration environment shall ensure a positive margin between highest acceptance and the lowest qualification test levels This positive margin shall include test tolerances.

1. The minimum qualification test level shall be 144 dB.
2. Acoustic frequency range shall be from 50 Hz to 10000 Hz.

d. For any component that uses one or more shock or vibration isolators during flight, the component shall undergo any qualification acoustic vibration test mounted on its isolator or isolators as a unit. Each isolator shall satisfy the test requirements of this document.

e. Any test shall continuously monitor and record all performance and status-of-health parameters while the component is subjected to the qualification environment. This monitoring shall have a sample rate of once every millisecond or better.

f. An acoustic vibration analysis may be used in lieu of testing. The analysis shall demonstrate that the qualification random vibration test environment of paragraph 4.14.11 encompasses the qualification acoustic vibration environment.

When using random vibration as baseline, the analysis shall account for the peak vibration and acceleration levels and durations.

4.14.10 Qualification Sinusoidal Vibration.

a. A qualification sinusoidal vibration test or analysis of a component shall demonstrate that the component and each connection to any item that attaches to the component satisfy all their performance specifications when subjected to the maximum predicted level, frequency duration and frequency band plus a margin environment. The attached items shall include any vibration or shock isolator, grounding strap, bracket, ETS, or cable to the first tie-down. Any cable that interfaces with the component during any test shall be representative of the cable used for flight.

Sinusoidal vibration shall be performed at worst-case hot/cold temperature if the component will be exposed to the combined environment.

b. A component shall be tested to demonstrate it meets all abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

c. The test shall subject each of three mutually perpendicular axes of the component to the qualification sinusoidal vibration environment, one axis at a time. For each axis, the duration of the vibration shall be no less than three times the maximum predicted sinusoidal vibration duration.

d. The qualification sinusoidal vibration environment shall be no less than 6dB greater than the maximum predicted sinusoidal vibration environment for no less than three times the maximum predicted duration.

e. The sinusoidal frequency shall range from the lowest maximum predicted frequency range to highest than the maximum predicted frequency range plus a margin.

The sinusoidal frequency shall range from 50 percent lower than the maximum predicted frequency range to 50 percent higher than the maximum predicted frequency range.

f. The sinusoidal sweep rate shall be no greater than one-third the maximum predicted sweep rate or three times the maximum predicted dwell for stationary sinusoids, whichever more accurately reflects the flight environment.

g. A sinusoidal vibration analysis may be used in lieu of testing. The analysis shall demonstrate that the qualification random vibration environment encompasses the qualification sinusoidal vibration environment.

4.14.11 Qualification Random Vibration.

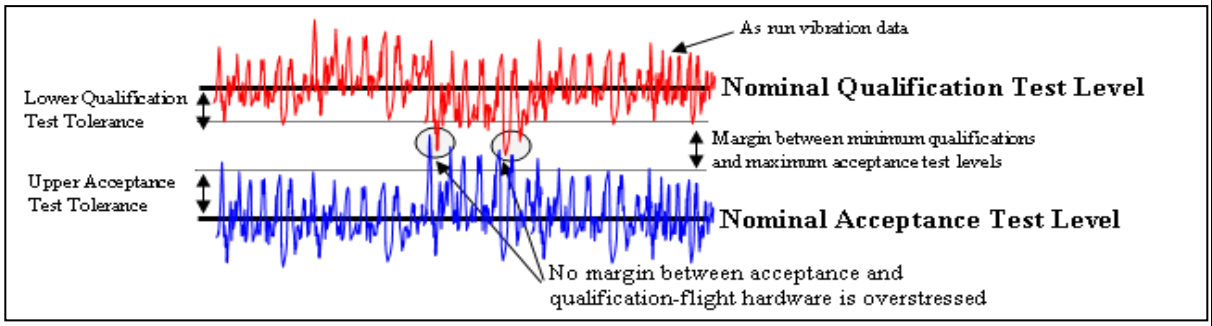
a. A qualification random vibration test shall demonstrate that the component and each connection to the component satisfies all their performance specifications when subjected to the acceptance and workmanship random vibration level, duration and frequency band plus a margin. The attached items shall include any isolator, grounding strap, bracket, ETS, or cable to the first tie-down. Any cable that interfaces with the component during any test shall be representative of the cable used for flight.

Random vibration shall be performed at worst-case hot/cold temperature if the component will be exposed to the combined environment.

b. A component shall be tested to demonstrate it meets all abbreviated performance verification tests in accordance with paragraph 4.10.5 during environmental exposure.

c. The minimum qualification random vibration environment shall meet all the applicable following requirements:
   (1) Maintain a 3-dB minimum margin between the maximum acceptance random vibration test environment and the minimum qualification test levels including isolator and test tolerances for all frequencies from 20 Hz to 2,000 Hz.

1. This paragraph applies to components that are subjected to vibration acceptance testing.
2. The qualification test margin shall be 6 dB above the acceptance test levels for a ± 1.5 dB test tolerance. The minimum and maximum test environments shall account for all the test tolerances to ensure that the test maintains the 3-dB margin.



3. The following criteria shall be met where vibration isolators are used:
   a. Flight isolators shall be 100% screened to ensure that flight vibration levels into the component maintain a 3 dB margin between MPE and minimum qualification test level.
   b. An additional margin shall be added to the hardmount qualification level to prevent using isolators that have lesser performance characteristics than the isolators used for qualification. The maximum isolator variability margin shall be +1.5dB margin. Note: there is no lower bound on the isolator specification since these isolators would attenuate better than the qualification test isolators would. For example, the +1.5 dB isolator pass/fail criteria would drive a 6 dB qualification test level to 7.5 dB. This allows for a +1.5 dB variation in flight isolator performance when compared to the performance of the isolators used for qualification testing. The more margin added to the qualification test level, the less stringent the isolator screening criteria and, therefore, less isolators may have to be discarded.
   c. Isolator variability shall also account for the isolator attenuation and amplification due to the maximum predicted operating random vibration environment, including any thermal effects and acceleration pre-load performance variability.
4. Regardless of test tolerances, the minimum qualification test level shall be a minimum of 4.5 dB above MPE.

(2) Maintain a 4.5-dB minimum margin between the MPE and the minimum qualification test levels including system and test tolerances for all frequencies from 20 Hz to 2,000 Hz.

1. This paragraph applies to components that are not subjected to vibration acceptance testing. These tests are usually reserved for components such as ordnance and silver-zinc batteries.
2. The qualification test margin shall be 6 dB above the acceptance test levels for a ± 1.5 dB test tolerance. Test tolerances shall ensure that the there is a minimum 4.5-dB margin between the minimum qualification test level and MPE or minimum qualification workmanship.

(3) The component shall be subjected to the minimum qualification workmanship levels in Table 4.14-2.

1. Minimum qualification level demonstrates that the minimum workmanship acceptance screening will not damage flight units. Minimum qualification levels shall test both MPE plus margin and the minimum qualification spectrum.
2. One of the following methods shall be used for qualification testing:
   a. A single test that envelopes both MPE plus margin and the minimum qualification level.
   b. Two tests may be performed that separate the MPE plus margin and the minimum qualification level in Table 4.14-2. Acceptance and qualification testing shall be performed using the same methodology.

d. Testing shall be performed to the expected flight vibration spectrum. The minimum spectrum shall be from 20 to 2000 Hz.

e. The duration used for qualification testing shall be the greater of the maximum predicted or acceptance test durations plus a margin.

1. The minimum duration shall be 3 times the MPE or 3 times the acceptance test durations.
2. The minimum qualification random vibration time shall be 3 minutes per axis.
3. For long duration missions such as captive carry missiles, the margin may be reduced to 1.3 times the MPE.
4. One of the following methods shall be used for qualification testing:
   a. A single test that envelopes three times the acceptance test duration.
   b. Two tests may be performed that separate flight and workmanship levels.
      (1) The duration for the first test shall be three times the MPE
      (2) The duration for the second test shall be three times the acceptance test duration. Acceptance and qualification testing shall be performed using the same methodology.
      (3) The total duration of these tests shall add up to a minimum of 3 minutes per axis.

f. Tests shall be performed in all three perpendicular axes.

g. Acceptance and qualification test methodologies shall be identical except for levels and durations.

h. If there is insufficient time to complete all performance tests within the required qualification test time, the qualification vibration environment may be reduced to the acceptance test level at the end of qualification random vibration. The remaining performance tests may be completed at the acceptance test level.

Range Safety will determine which tests will be run at the lower vibration levels.

i. Components mounted on isolators (soft-mount) shall also be tested as follows (see Figure 4.14-1):
   (1) The entire flight configured isolated system shall be demonstrate it meets all its performance requirements when subjected to the qualification test environment.

1. The flight configured isolated system includes the flight isolators, brackets, component under test and attaching hardware (e.g. electrical cables, RF cables and explosive transfer lines) attached to the worst-case length tie-down point.
2. Qualification of the isolator system may be performed with a component mass simulator (non-flight hardware) as long as it includes all attaching hardware in a flight configuration.
3. The flight configured isolator system shall be qualified to ensure:
   a. Isolators can withstand qualification random vibration environments
   b. Identifies isolator-induced displacements and rocking modes that create new vibration modes.
   c. Added displacements can cause failures in attaching hardware and induce new vibration modes into the component.

   (2) The component shall demonstrate that it meets all its performance requirements when subjected to the isolated input qualification test environment. .

The isolated input qualification random vibration level can be tested using the following two methods.
   a. Characterize the component qualification test level input through the isolators and test the flight hardware hardmounted (without isolators)
   b. Test the flight hardware in a flight-configuration using a qualification test input into the vibration isolated system. Note: this test could be combined with the isolator system test in paragraph 4.14.11.i(1).

   (3) The component shall meet all its performance requirements when subjected to the minimum qualification workmanship level in Table 4.14-2.

1. The minimum workmanship screening level input is directly into the component and not through the isolated system.
2. This test is typically performed hardmount since the isolator system often attenuates the test level below the required minimum workmanship levels.

TABLE 4.14-2. MINIMUM QUALIFICATION RANDOM VIBRATION TESTING

Frequency Range (Hz)	Minimum Power Spectral Density
20	0.021 ^{g2}/Hz
20-150	3 dB/octave slope
150-600	0.16 ^{g2}/Hz
600-2000	-6 dB/octave slope
2000	0.014 ^{g2}/Hz
Overall Grms = 12.2	

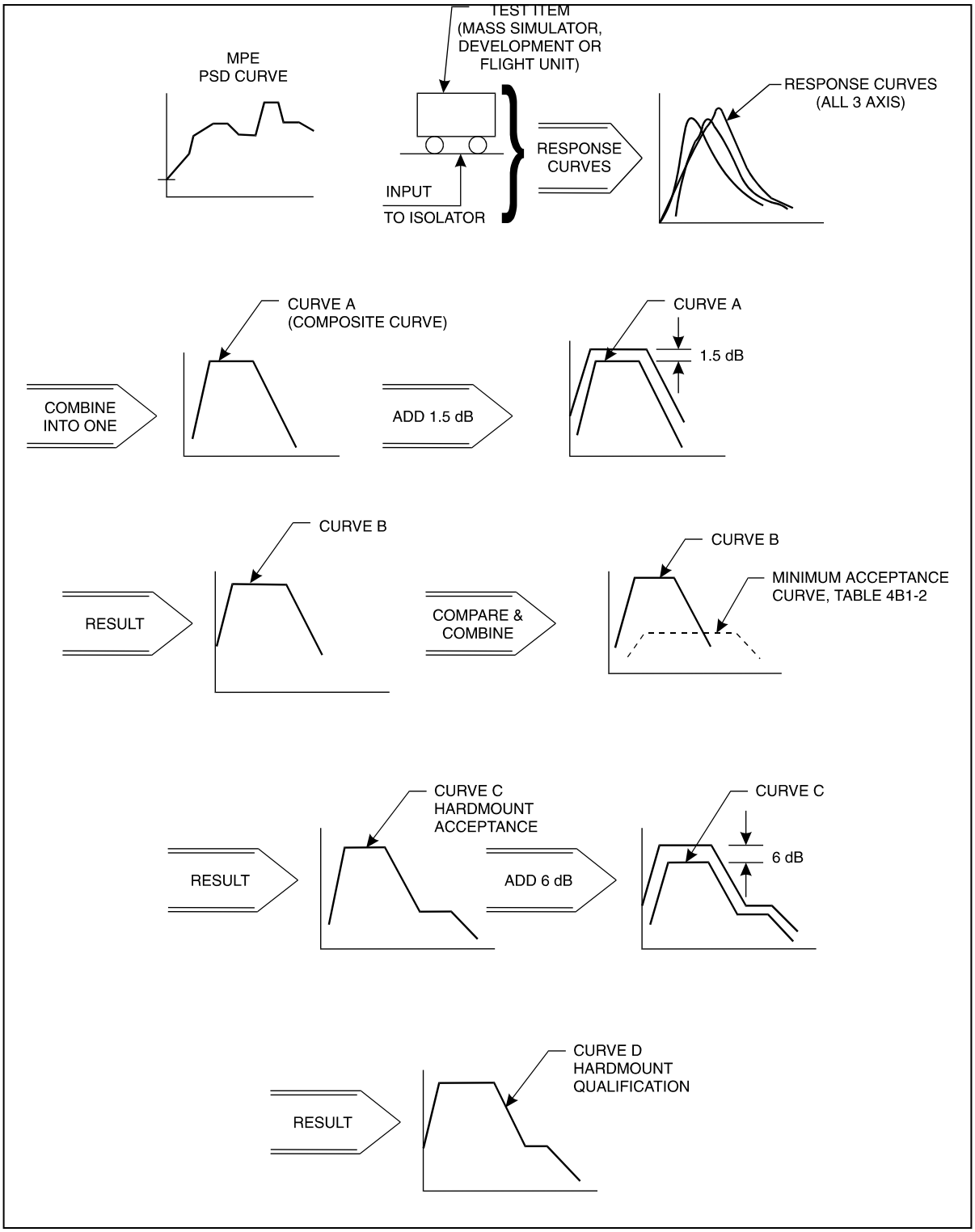


Figure 4.14-1. Procedure for hardmount qualification of components on vibration isolators.

4.14.12 Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC). EMI and EMC tests shall demonstrate that a component satisfies all its performance specifications when subjected to radiated or conducted emissions from all flight vehicle systems and external

ground transmitter sources. In addition, the test shall demonstrate that the component does not radiate or conduct electromagnetic interference that would degrade the performance of any other FTS component.

1. FTS components shall be tested to the requirements of MIL-STD-461, "Requirements for The Control of Electromagnetic Interference Characteristics of Subsystems and Equipment." The following methods are required where applicable: CE102, CE106, CS101, CS103, CS104, CS105, CS114, CS115, CS116, RE102, RE103 and RS103. Other methods may be required for unique vehicle environments.
2. MIL-STD-461 tests, frequencies, limits and levels shall envelope electromagnetic operating environments or the default test environments, whichever is greater.

4.14.13 Explosive Atmosphere. An explosive atmosphere test or analysis shall demonstrate that a component will not ignite an explosive atmosphere as follows:

a. While being laboratory tested, the component shall operate in the presence of the optimum fuel vapor-laden environment that requires the least amount of energy for ignition.
b. The unit shall be tested to the abbreviated performance requirements of the applicable test tables.
c. A test method selected from an appropriate Military Standard or equivalent document is acceptable.
d. The test component shall not ignite the explosive atmosphere and shall be capable of meeting the requirements of the applicable specification(s) without any physical damage or degradation in performance.

An analysis may be used to satisfy this requirement if it can be shown that:

a. The component will never be subjected to an explosive atmosphere
b. The unit cannot produce sufficient heat, arcing or other ignition sources that could ignite an explosive atmosphere.

4.15 Acceptance Testing and Analysis

4.15.1 General. This section applies to each acceptance test or analysis identified by any table of this chapter. An acceptance test or analysis shall demonstrate that a component does not have any material or workmanship defect that could adversely affect the component's performance and that the component satisfies all its performance specifications when subjected to each acceptance environment, including each workmanship and maximum predicted operating environment.

All performance verification tests required by the component test matrix shall be performed before and after each operating environmental test

a. An acceptance test of a component shall subject the component to one or more of the component's MPEs. An acceptance test shall not subject a component to a force or environment that is not tested during qualification testing.

b. Each component sample that is intended for flight shall undergo each acceptance test identified by any table of this chapter. A single-use component, such as ordnance or a battery, shall undergo the production lot sample acceptance tests identified by any tables of this chapter.

c. If a launch vehicle uses a previously flown and recovered FTS component, the component shall undergo one or more reuse acceptance tests before each next flight to demonstrate that the component still satisfies all its performance specifications when subjected to each MPE. Each reuse acceptance test shall be the same as the initial acceptance test for the component's first flight. Each reuse acceptance test shall follow a written component reuse qualification, refurbishment, and acceptance plan and procedures. Each acceptance reuse test shall compare performance parameter measurements taken during the test to all previous acceptance test measurements to ensure that the data show no trends that indicate any degradation in performance that could prevent the component from satisfying all its performance specifications during flight.

d. Each acceptance test of a component shall use test tolerances that are all consistent with the test tolerances used by each qualification test of the component.

4.15.2 Acceptance Thermal Cycle. An acceptance thermal cycle test of a component shall demonstrate that the component satisfies all its performance requirements when exposed to the maximum predicted and minimum workmanship acceptance thermal cycle environment.

For high transition rate thermal transition rates (thermal shock), thermal cycle testing or analysis shall demonstrate that a component can withstand sudden changes in temperature without degradation in performance. When heating or cooling the component, the temperature shall change at the maximum predicted thermal ramp rate. Unless otherwise specified, the component subjected to thermal shock shall be transitioned from ambient to the required low and high temperature extremes within 5 minutes.

a. Acceptance-Number of Thermal Cycles. For each component, the acceptance-number of thermal cycles shall the greater of eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays and recycling. Fractional samples shall be rounded up to the nearest whole number.

b. Active Electronic Components. Electronic components shall satisfy all of the following thermal cycle test requirements:
   (1) The acceptance thermal cycle environment shall range from the higher of the MPE high temperature or 61 ^{o}C workmanship screening level, to the lower of the predicted low temperature or a -24 ^{o}C workmanship screening level.
   (2) The test shall subject a component to no fewer than 10 cycles plus the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles shall satisfy paragraph 4.15.2. For each cycle, the dwell-time at each high and low temperature shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour. The test shall begin each dwell-time at each high and low temperature with the component turned off. The component shall remain off until the temperature stabilizes. Once the temperature stabilizes, the test shall complete each dwell-time with the component turned on.

1. A complete electrical performance test shall be performed at hot, cold and ambient acceptance temperatures after all operating environments are complete.
2. This requirement can be met by performing 10 thermal cycles, dynamic environmental tests and finishing the remaining thermal cycles (usually 8 more cycles) with a final electrical performance test on the last hot, cold and ambient thermal cycle.

   (3) When heating or cooling the component, the temperature shall change at an rate of no less than 3 ^{o}C per minute or the maximum predicted rate, whichever is greater.
   (4) The test shall demonstrate a subset of performance verification tests required by the component test matrix with the component at its low and high operating voltages at the high and low temperatures during the first and last thermal cycles.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

   (5) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

c. Passive Electrical Components. For any passive component that does not contain any active electronic piece-part, such as any RF antenna, coupler, or cable, an acceptance thermal cycle test shall satisfy all of the following:
   (1) Unless otherwise noted, the acceptance thermal cycle environment shall range from the higher of the MPE high temperature or a 61 °C workmanship screening temperature, to the lower of the predicted lowest temperature or a -24 °C workmanship screening temperature.
   (2) The test shall subject a component to no fewer than the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles shall satisfy 4.15.2. For each cycle, the dwell-time at each high and low

temperature shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour.

(3) When heating or cooling the component, the temperature shall change at a rate of no less than 3 °C per minute or the maximum predicted rate, whichever is greater.

(4) The test shall demonstrate all performance verification tests required by the component test matrix at the high and low temperatures during the first and last thermal cycles.

(5) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during all cycles and thermal transitions.

d. Mechanical Devices. These devices include electromechanical S&A device with an internal explosive and mechanical valves. An acceptance thermal cycle test shall satisfy all of the following:

(1) The acceptance thermal cycle environment shall range from the higher of the MPE high temperature or the minimum workmanship screening temperature of 61 °C to the lower of the predicted lowest temperature or the minimum workmanship screening temperature of -24 °C.

(2) The test shall subject a component to no fewer than the acceptance-number of thermal cycles. For each component, the acceptance-number of thermal cycles shall satisfy 4.15.2. For each cycle, the dwell-time at each high and low temperature shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour.

(3) When heating or cooling the component, the temperature shall change at a rate of no less than 3 °C per minute or the maximum predicted rate, whichever is greater.

(4) The test shall demonstrate a subset of performance verification and tests required by the component test matrix with the component at the high and low temperatures during the first and last thermal cycles.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

(5) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure. The component shall be in an armed state for all cycles and thermal transitions at its nominal operating voltage.

4.15.3 Acceptance Thermal Vacuum. An acceptance thermal vacuum test or analysis shall demonstrate that a component satisfies all its performance specifications when exposed to the acceptance thermal vacuum environment as follows:

a. The thermal vacuum pressure gradient shall equal or exceed the maximum predicted rate of altitude change that the component will experience during flight. The pressure gradient shall allow for no less than ten minutes for reduction of chamber pressure from ambient pressure to MPE low pressure.

1. With the component in the thermal chamber, reduce the pressure from atmospheric to a critical pressure (pressure at which a corona or arcing is likely to occur). A function test shall be performed.
2. The time for reduction of chamber pressure from ambient to 20 Pascals (0.15 Torr) shall be at least 10 minutes to allow sufficient time in the region of critical pressure.
3. Reduce the pressure from critical pressure to a minimum of 0.0133 Pascals (0.0001 Torr) or actual flight altitude, whichever is less.

b. The final vacuum dwell-time shall be sufficient to achieve the greater of the internal component vacuum equilibrium or the maximum predicted flight vacuum time.

1. Temperature stability is achieved when the rate of change is no more than 3°C per hour. The component heat transfer to the thermally controlled heat sink and the radiation heat transfer to the environment shall be controlled to the same proportions as calculated for the flight environment.
2. The dwell time shall be the greater of the maximum predicted dwell-time or 12 hours.

c. During the final vacuum dwell-time, the environment shall include no less than the maximum predicted number of thermal cycles
d. Each thermal cycle shall range from the higher of the MPE high temperature or the workmanship screening high temperature of 61°C, to the lower of the predicted low temperature or the workmanship screening low temperature of -24°C.
e. The test shall demonstrate a subset of performance verification and tests required by the component test matrix with the component at the high and low temperatures during the first and last thermal cycles at final vacuum.

All performance verification tests shall be performed at high and low temperature except continuity and isolation resistance.

f. The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during all vacuum and thermal transitions.

Electronic components shall be tested at their high operating voltage.

g. A thermal vacuum analysis may be used in lieu of testing. The analysis shall satisfy all of the following:
   (1) For any low voltage component, the analysis shall demonstrate that the component is not susceptible to corona or arcing.

Low voltages are considered less than 50 volts.

(2) For any high voltage component, the component shall undergo a thermal vacuum test unless the component is environmentally sealed and the analysis demonstrates that any low voltage externally exposed part is not susceptible to corona, arcing, or structural failure. A component with any high voltage externally exposed part shall undergo a thermal vacuum test.

High voltages are considered greater than 250 volts.

(3) The analysis shall demonstrate structural integrity of the component when exposed to a vacuum environment.
(4) The analysis shall demonstrate that any internal component heat producing parts are capable of adequately dissipating heat without the need for air convection.

4.15.4 Acceptance Acoustic Vibration.

a. The vibration level shall equal or exceed the maximum predicted acoustic level in each of three mutually perpendicular axes.

The frequencies range used for testing shall be 50 Hz to 10,000 Hz.

b. For each axis, the vibration shall last the maximum predicted duration or 60 seconds, whichever is greater.

c. A component shall be tested to demonstrate it meets all abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

If the duration of the acceptance acoustic vibration environment leaves insufficient time to complete any required performance verification test while the component is subjected to the full acceptance environment. The test shall continue at no lower than 6dB below the acceptance environment. The test need only continue for the additional time needed to complete the performance verification test.

d. An acoustic vibration analysis may be used in lieu of testing. The analysis shall demonstrate that the acceptance random vibration test environment of 4.15.6 encompasses the acoustic vibration environment.

When using random vibration as baseline, the analysis shall account for the peak vibration and acceleration levels and durations.

4.15.5 Acceptance Sinusoidal Vibration. An acceptance sinusoidal vibration test shall demonstrate that a component satisfies all its performance specifications when exposed to the acceptance sinusoidal vibration environment as follows:

a. The acceptance sinusoidal vibration environment shall equal or exceed the greater of the maximum predicted random vibration level for the expected sinusoidal frequencies in each of three mutually perpendicular axes
b. For each axis, the sinusoidal vibration test duration shall be the maximum expected flight sinusoidal duration or sweep rate.
c. A component shall be tested to demonstrate it meets all abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.
d. For any component that is mounted on one or more vibration or shock isolators during flight, the component shall undergo the acceptance random vibration test in the same isolator-mounted configuration or hard-mounted configuration as the component's qualification random vibration test.
e. A sinusoidal vibration analysis may be used in lieu of testing. The analysis shall demonstrate that the acceptance random vibration environment encompasses the acceptance sinusoidal vibration environment.

4.15.6 Acceptance Random Vibration. An acceptance random vibration test shall demonstrate that a component satisfies all its performance specifications when exposed to the acceptance random vibration environment as follows:

a. The acceptance random vibration environment shall be the greater of the maximum predicted random vibration level or the minimum workmanship acceptance test level from 20 Hz to 2000 Hz in each of three mutually perpendicular axes.
b. For each axis, the vibration shall last the greater of three times the maximum predicted duration or a minimum workmanship screening level of 60 seconds.
c. For a component sample that undergoes qualification testing and shall experience the acceptance environment before it experiences the qualification environment, such as an FTR, the test shall use the same configuration and methods for the acceptance and qualification random vibration environments. An acceptance random vibration test of a flight component sample shall use a configuration and method representative of the component's qualification tests to ensure that the requirements of this section are met.
d. For any component that is mounted on one or more vibration or shock isolators during flight, the component shall undergo the acceptance random vibration test in the same isolator-mounted configuration or hard-mounted configuration as the component's qualification random vibration test as follows:
   (1) Any hard-mounted acceptance random vibration test shall subject the component to an acceptance random vibration environment that:
      - Accounts for the isolator attenuation and amplification due to the maximum predicted operating random vibration environment, including any thermal effects and acceleration pre-load performance variability, and adds a 1.5dB margin to account for any isolator attenuation variability.
      - Is no less than the minimum workmanship screening acceptance random vibration level.

(2) Any isolator-mounted acceptance random vibration test shall:
- Use an isolator or isolators that passed the required tests.
- Have an input to each isolator of no less than the required acceptance random vibration environment.
- Subject the component to no less than the minimum workmanship screening acceptance random vibration level. If the isolator or isolators prevent the component from experiencing the minimum workmanship level, the component shall undergo a hard-mount test that subjects the component to the workmanship level.

e. A component shall be tested to demonstrate it meets all abbreviated performance verification tests required in the component test matrix and paragraph 4.10.5 during environmental exposure.

f. If the duration of the acceptance random vibration environment leaves insufficient time to complete any required performance verification test while the component is subjected to the full acceptance environment, the test shall continue at no lower than 6dB below the acceptance environment. The test need only continue for the additional time needed to complete the performance verification test.

g. The test shall continuously monitor all performance and status-of-health parameters with any electrical component at its nominal operating voltage. This monitoring shall have a sample rate of once every millisecond or better.

TABLE 4.15-1. MINIMUM WORKMANSHIP POWER SPECTRAL DENSITY FOR ACCEPTANCE RANDOM VIBRATION

Frequency Range (Hz)	Minimum Power Spectral Density
20	0.0053 g^2/Hz
20-150	3 dB/Octave Slope
150-600	0.04 g^2/Hz
600-2000	-6 dB/Octave Slope
2000	0.0036 g^2/Hz
Overall Grms = 6.1	

4.15.7 Tensile Loads. An acceptance tensile load test of a component shall demonstrate that the component is not damaged and satisfies all its performance specifications after experiencing twice the maximum predicted pull-force that the component could experience before, during, or after installation.

4.16 RF Receiving System

This section applies to an RF receiving system, that includes each FTS antenna and RF coupler and any RF cable or other passive device used to connect an FTS antenna to a command receiver.

TABLE 4.16-1. RF RECEIVING SYSTEM ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested		
		Cable	Coupler	Antenna
Component Examination	4.11.1			
Visual Examination	4.11.2	100%	100%	100%
Dimension Measurement	4.11.3	100%	100%	100%
Identification Check	4.11.5	100%	100%	100%
Performance Verification	4.10.4	-		
VSWR	4.16.2	100%	100%	100%
Insertion Loss (1), (2)	4.16.3	100%	100%	-
Isolation (1)	4.16.4	-	100%	100%
Abbreviated Antenna Pattern	4.16.7	-	-	100%
Abbreviated Performance Verification	4.10.5			
VSWR(1), (2)	4.16.5	-	-	100%
Operating Environment Tests	4.15.1			
Thermal Cycling	4.15.2	100%	100%	100%
Thermal Vacuum	4.15.3	-	100%	100%
Acoustic	4.15.4	-	100%	100%
Sinusoidal	4.15.5		100%	100%
Random Vibration	4.15.6	-	100%	100%
Tensile Load	4.15.7	100%	-	-

Notes for Table 4.16-1:

(1) These tests shall be performed on the first and last thermal hot and cold dwell cycle for thermal cycle and thermal vacuum testing.

(2) These tests shall be performed during acoustic and random vibration testing.

TABLE 4.16-2. RF RECEIVING SYSTEM QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [5]		
		Cable X=3	Coupler X=3	Antenna X=3
Acceptance Tests	Table 4.16.1	X	X	X
Antenna Pattern	4.16.6	X	X	X
Performance Verification	4.10.4			
VSWR	4.16.2	X	X	X
Insertion Loss [1], [2], [3]	4.16.3	X	X	-
Isolation [1]	4.16.4	-	X	X
Abbreviated Antenna Pattern	4.16.7	-	-	X
Abbreviated Performance Verification	4.10.5			
VSWR[1], [2], [3]	4.16.5	-	-	X
Non-Operating Environment Tests	4.13.1			
Storage Temperature	4.13.2	X	X	X
Transportation Shock	4.13.4	X	X	X
Bench Handling Shock	4.13.5	X	X	X
Transportation Vibration	4.13.6	X	X	X
Fungus Resistance	4.13.7	1	1	1
Fine Sand	4.13.8	1	1	1
Operating Environment Tests[4]	4.14.1			
Thermal Cycling	4.14.2	X	X	X
Thermal Vacuum	4.14.3	X	-	X
Humidity	4.14.4	X	X	X
Salt Fog	4.14.5	X	X	X
Temperature/Humidity/Altitude	4.14.6	X	X	X
Acceleration	4.14.7	X	X	X
Shock	4.14.8	X	X	X
Acoustic	4.14.9	X	X	X
Sinusoidal Vibration	4.14.10	X	X	X
Random Vibration	4.14.11	X	X	X
Tensile Load	4.13.9	X	X-	X-
Internal Inspection	4.11.7	-	X	X

Notes for Table 4.16-2:

(1) This test shall be performed for thermal cycle, humidity, temperature/altitude/humidity, salt fog and thermal vacuum testing.
(2) These tests shall be performed during acceleration, acoustic, sinusoidal vibration, and random vibration testing.
(3) These tests shall be performed during shock.
(4) A component shall undergo this test with flight RF cables attached in the flight representative configuration.
(5) The same three sample components shall undergo each test designated with an X. For a test designated with a quantity of less than three, each sample component tested shall be one of the original three sample components.

4.16.1 General.

The components of an RF receiving system shall satisfy each test or analysis identified by any table of this section to demonstrate that:

a. The system is capable of delivering command control system RF energy to each FTS receiver.
b. The system satisfies all it performance specifications when subjected to each non-operating and operating environment and any performance degradation source. Such sources include any command control system transmitter variation, non-nominal vehicle flight condition, and FTS performance variation.

1. If power splitters, combiners, hybrids, coaxial cables, or other passive devices are used to connect the antenna to the FTR, these shall then be considered as part of the FTS antenna system.
2. If FTS antenna heat shields are used, they shall be considered part of the antenna system and shall be subjected to all the antenna system requirements for design, test, pattern measurements, and approval.

4.16.2 VSWR. A voltage standing wave ratio test shall demonstrate that the component meets performance requirements at the assigned operating frequency and at the high and low frequencies of the operating bandwidth.

1. Antenna VSWR testing shall be performed on a ground plane that allows repeatable performance.
2. Voltage Standing Wave Ratio (VSWR). Unless otherwise specified, FTS antenna system components shall be designed for a nominal 50-ohm impedance, and the antenna system shall have a VSWR of 2:1 or less across the specified bandwidth and over the operating environments.
3. The 3 dB bandwidth of the component shall be greater than ±180 kHz.

4.16.3 Insertion Loss. An RF component or subsystem shall demonstrate that the component or subsystem satisfies its performance specifications when subjected to performance degradation caused by ground transmitter variations and non-nominal vehicle flight. This shall include demonstrating all of the following:

a. The RF coupler insertion loss at the assigned operating frequency and at the high and low frequencies of the operating bandwidth satisfy all their performance specifications.

The 3 dB bandwidth of the coupler shall be greater than ±180 kHz.

b. The cable insertion loss at the assigned operating frequency and at the high and low frequencies of the operating bandwidth satisfies all its performance specifications.

4.16.4 Isolation.

a. An isolation test shall demonstrate that each RF coupler input and output port satisfies its performance specification.

b. For multi-band antennas, an isolation test shall demonstrate that the FTS antenna output port satisfies its performance specification with other antenna ports at the operating frequencies and maximum worst-case power plus a margin.

Vehicle radiating sources shall use a 50 percent power margin

4.16.5 Voltage Standing Wave Ratio. The component's VSWR shall be tested to demonstrate it meets performance requirements while the component is under environmental stress conditions. VSWR shall be continuously monitored to detect any variation in amplitude.

1. The monitoring shall have a sample rate of once every 0.1-millisecond or better. 2. The absolute VSWR measurement value for an antenna is not critical for this test since it will change depending on where the antenna is tested. The parameter being tested is the relative changes in performance such as chatter or fluctuations.

4.16.6 Antenna Pattern. An antenna pattern test shall demonstrate that the radiation gain pattern of the entire RF receiving system, including the antenna(s), RF cables, and RF coupler will satisfy all the system's performance specifications during vehicle flight. This shall include all of the following:

a. The test shall determine the radiation gain pattern around the launch vehicle and demonstrate that the system is capable of providing the required performance specifications.
b. All test conditions shall emulate flight conditions, including ground transmitter polarization, using a simulated flight vehicle and a flight configured RF command destruct system.
c. The test shall measure the radiation gain for 360 degrees around the vehicle in increments that are small enough to identify any deep pattern null. Each antenna pattern measurement gain increment shall not exceed two degrees.
d. The test shall generate an antenna pattern in a data format that is compatible with the format needed to perform the FTS system RF link analysis.

Antenna pattern test requirements and formats can be found in RCC 253, Missile Antenna Pattern Coordinate System and Data Formats.

4.16.7 Abbreviated Antenna Pattern. An abbreviated antenna pattern test shall ensure that flight hardware is representative of the qualification test units and detect any antenna pattern changes that might occur due to damage resulting from exposure to test environments.

a. The test shall use a standard ground plane.

b. The test shall verify that a sampling of antenna gain measurements are repeatable and the flight antennas have the same characteristics of the antenna used for qualification testing.

1. The test shall include gain measurements in the 0° and 90° roll plane vectors and a conical cut at 45°.
2. This test is not intended to duplicate the system antenna pattern data in paragraph 4.16.6.

4.17 Flight Termination Receiver

After the initial adjustment, the FTR shall perform in accordance with the requirements of RCC 313, Test Standards for Flight Termination Receivers; the procurement specification; and of this document, without subsequent adjustment.

TABLE 4.17-1. FTR ACCEPTANCE TESTS REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Inspection	4.11.2	100%
Dimension	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification (4)	4.10.4	100%
Continuity and isolation	4.17.1	100%
Input Current	4.17.2	100%
Command and Control	4.17.3	100%
Output Command Circuits	4.17.4	100%
Output Monitors	4.17.5	100%
Self-Test	4.17.6	100%
Circuit Protection	4.17.7	
Low Voltage	4.17.7b	100%
Dropout	4.17.7c	100%
Watchdog Circuit	4.17.7d	100%
Fail-Safe	4.17.10	100%
Tone-based RF Processing	4.17.11	100%
Inadvertent Command Output	4.17.12	100%
Abbreviated Performance Verification	4.10.5	
Input Current (2)	4.17.2	100%
Output Monitors (2)	4.17.5	100%
Output Command Circuits (2)	4.17.4a	100%
	4.17.4b	
Thermal Performance (1), (3)	4.17.13	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic	4.15.4	100%
Sinusoidal	4.15.5	100%
Random Vibration	4.15.6	100%
In-band Interference	4.17.11m	100%
Leakage	4.11.8	100%

Notes for Table 4.17-1:

(1) These tests shall be performed during thermal vacuum and thermal cycle operating environments.
(2) These tests shall be performed during random, sinusoidal and acoustic operating environments.
(3) A component shall undergo abbreviated thermal performance at the first and last hot and cold thermal dwell cycles. A component shall be continuously monitored for input current, SSTO, monitor tone and inadvertent command output during all thermal cycles and transitions.
(4) These tests shall also be performed as part of the preflight tests in Chapter 5.

TABLE 4.17-2. FTR QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [5] X=3
Acceptance Tests [1]	Table 4.17.1	X
Performance Verification	4.10.4	
Continuity and isolation	4.17.1	X
Input Current	4.17.2	X
Command and Control	4.17.3	X
Output Command Circuits	4.17.4	X
Output Monitors	4.17.5	X
Self-Test	4.17.6	X
Circuit Protection	4.17.7	X
Overvoltage	4.17.7a	X
Low Voltage	4.17.7b	X
Dropout	4.17.7c	X
Watchdog Circuit	4.17.7d	X
Fail-Safe	4.17.10	X
Tone-based RF Processing	4.17.11	X
Inadvertent Command Output	4.17.12	X
Abbreviated Performance Verification	4.10.5	
Input Current [2], [6]	4.17.2	X
Output Monitors[2], [6]	4.17.5	X
Output Command Circuits [2]	4.17.4a	X
	4.17.4b	
Thermal Performance [3][4]	4.17.13	X
Non-Operating Environment Tests	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Handling Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Fungus Resistance	4.13.7	1
Fine Sand	4.13.8	1
Operating Environment Tests	4.14.1	
Thermal Cycling	4.14.2	X
Thermal Vacuum	4.14.3	X
Humidity	4.14.4	X
Salt Fog	4.14.5	X
Temperature/Humidity/Altitude	4.14.6	X
Acceleration	4.14.7	X
Shock	4.14.8	X
Acoustic	4.14.9	X
Sinusoidal Vibration	4.14.10	X
Random Vibration	4.14.11	X
Electromagnetic Interference and Compatibility	4.14.12	2
Explosive Atmosphere	4.14.13	1

Table 4.17-2. FTR Qualification Test Requirements. (Continued)

Test	Paragraph	Quantity Tested (5) X=3
Repetitive Function	4.17.8	1
Circuit Protection	4.17.7	
Overvoltage	4.17.7a	2
Monitor Protection	4.17.7e	2
Leakage	4.11.8	X
Internal Inspection	4.11.7	2
Memory	4.17.9	1

Notes for Table 4.17-2:

(1) Each sample component to undergo qualification testing shall first successfully complete all applicable acceptance tests.
(2) These tests shall be performed during random vibration, acceleration, sinusoidal vibration and acoustic operating environments.
(3) A component shall undergo thermal performance at the first, middle and last hot and cold thermal dwell cycles. A component shall be continuously monitored for input current, SSTO, monitor tone and inadvertent command output during all thermal cycles and transitions.
(4) These tests shall be performed during thermal vacuum, temperature/humidity/altitude , thermal cycle, humidity, salt fog operating environments.
(5) The same three sample components shall undergo each test designated with an X. For a test designated with a quantity of less than three, each sample component tested shall be one of the original three sample components.
(6) The FTRs flight critical functions shall be monitored while the unit is subjected to the operating shock environment. At a minimum, the input current and output monitors shall be monitored during the shock test for variations in performance.

4.17.1 Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances of the FTR to demonstrate that it satisfies all its performance specifications.

Isolation resistance shall be 2 MΩ.

4.17.2 Input Current. Input current of the FTR shall be monitored to demonstrate that it meets all its performance requirements.

The receiver input current shall be monitored at a 0.1 ms resolution during dynamic environmental testing.

4.17.3 Command and Control. An FTR shall be tested to demonstrate that all commands, controls, and inhibits function correctly. At a minimum, the following functions shall be tested.

These requirements address non-RF commands that may exist on some FTRs that have additional functions such as fail-safe, power transfer and disable commands.

a. Input commands and control circuits shall be tested to demonstrate they meet their performance requirements.

b. The command and control signal circuitry shall be tested to demonstrate that it will not accidentally trigger when subjected to the specified no-trigger performance level.

c. The unit shall be tested to demonstrate that it powers up in a safe state.

The unit shall be armed, powered down for 3 seconds and then powered up. The unit shall power-up in the safe state.

4.17.4 Output Command Circuits. An FTR shall be tested to demonstrate that the output meets specified requirements.

a. All FTR command outputs shall be functioned to demonstrate that all required logic sequences are validated.

b. The FTR output shall be tested to demonstrate that the unit delivers the required output at the unit's specified worst-case high and low operating voltages.

1. All receiver outputs shall be functioned to demonstrate that all required output performance specifications are met.
2. Output functional testing shall include drawing the expected current at the receiver's low, nominal and high input specified voltages using output impedances that simulate the flight-configured load.
3. The test shall demonstrate that a command receiver is capable of simultaneously outputting arm and terminate.
4. Output functional tests shall be performed at 10 times the expected pulse duration used for prelaunch checkout and flight.

c. The FTR shall be tested to demonstrate that its output leakage current meets performance requirements during transient start-up and steady state operation.

1. The FTR shall not produce any command outputs (MONITOR, OPTIONAL, ARM, or TERMINATE) greater than 1 volt in amplitude for more than 200 microseconds into a 10k-ohm load during the voltage transient and shall meet its performance requirements after the application of the voltage transient.
2. Leakage Current. The leakage current from the TERMINATE output with no TERMINATE command applied shall be 50 microamperes maximum unless otherwise agreed to by the ranges through the LRSO.

d. Demonstrate that an FTR satisfies all of its performance specifications for response time, from receipt of command sequence to initiation of command output.

The average response time of each function shall be between 4 and 25 milliseconds from the time the command is received by the FTR.

4.17.5 Output Monitors. Output monitor circuits shall be tested to verify that all the required monitor signals meet their specified performance requirements.

1. All monitors shall receive the required stimulus necessary to demonstrate they meet their performance requirements.
2. During environmental testing, monitors shall be continuously sampled.
3. Output monitors include SSTO, fail-safe indicators and tone monitor.

4.17.6 Self Test. The FTR shall demonstrate it can perform self-tests, detect errors, and output the results.

4.17.7 Circuit Protection. A circuit protection test shall demonstrate that the FTR satisfies all its performance specifications when subjected to abnormal conditions. The demonstration shall include all of the following:

a. Overvoltage. The FTR shall demonstrate that it meets all of its performance requirements after being subjected to the forward and reverse polarity of the unit's specified maximum input voltage.

The FTR shall function nominally after being subjected to the application of up to ±45 Vdc or the OCV of the power source, whichever is greater, to the power input port for a period not less than 5 minutes.

b. Low Voltage. The FTR shall not be damaged or produce an inadvertent output command when subjected to voltages below the specified level.

The FTR shall be tested from 0 volts to the minimum specified voltage back to 0 volts without damage or producing a spurious output regardless of the rate of transition between the voltage present. The FTR shall function nominally after this test.

c. Dropout. The FTR shall be tested to verify that it will meet its performance requirements after being subjected to the specified input power dropout.

The FTR shall be fully functional and meet all performance requirements after a 50 millisecond dropout.

d. Watchdog Circuit. All watchdog circuits shall be tested to verify they meet their performance specifications.

e. Monitor Protection. Demonstrate that failures in output monitors will not degrade the performance of the critical circuits within the FTR. Each output monitor shall be subjected to a short circuit and the specified highest positive or negative voltages.

1. During qualification testing the monitor outputs shall be subjected to the following tests in both the unpowered and powered state. a. Monitor outputs shorted b. Monitor outputs connected to the worst-case OCV or ±45 Vdc, whichever is greater. 2. Voltage shall be applied for a duration of no less than five minutes. 3. Monitor outputs may be damaged during this test but the critical circuits required for issuing a termination command shall not be degraded.

4.17.8 Repetitive Function. This test shall demonstrate that the FTR satisfies all its performance specifications when subjected to the required number of output commands, plus a margin, into a flight load.

1. The FTR shall be tested for five times the number of command outputs into a representative flight load without degradation, including acceptance, prelaunch and potential rework and re-acceptance test.
2. Typical number of command outputs into a representative flight load is 200.

4.17.9 Memory. An FTR shall demonstrate that data stored in memory is not degraded and it is able to meet all performance requirements after remaining in the powered-off condition for the maximum specified time.

Data loaded into an FTR shall remain in memory for no less than 180 days without primary direct current (dc) power being applied.

4.17.10 Fail-Safe. Fail-safe circuits within the FTR shall be tested to demonstrate that the failsafe circuits function within their performance requirements as indicated below.

a. The fail-safe system shall demonstrate it will meet all input and output failsafe combinations when it experiences either loss-of-command-link, low voltage or combination resulting in loss of the redundant system.

1. Both redundant FTS sides shall be capable of being cross strapped together such that the Arm and Terminate outputs for the programmed fail-safe condition occurs only if both paths are fail-safe enabled and both paths experience a fail-safe condition.
2. When both redundant paths are cross strapped together, if only one of the redundant paths receives a fail-safe enable signal the path that received the fail-safe enable will ignore the input from the other path and output an ARM and TERMINATE if it experiences a fail-safe condition.
3. Testing shall be performed with all combinations of each receiver enabled and disabled. For testing purposes, the additional receiver input may be simulated.

b. The FTR failsafe inputs and outputs shall be tested to demonstrate that they meet their threshold levels.
   (1) Trigger and no-trigger inputs for enable and disable
   (2) Inputs from other cross-strapped FTRs
   (3) Outputs to other cross-strapped FTRs

c. All FTR failsafe timing circuits shall be tested to demonstrate they meet their performance requirements.
   (1) Low voltage threshold level and timing
   (2) RF carrier dropout/loss of tone
   (3) Reset capability for RF carrier/Loss of tone dropout prior to timeout
   (4) Verify that command output remains latched

4.17.11 Tone-Based RF Processing. An FTR shall demonstrate that it can receive a range command under worst-case ground transmitter tolerances, flight hardware performance variations and RF signal degradation plus a margin. Each tone-based FTR shall satisfy all of the following for all preflight and flight environments:

1. The FTR threshold level is the minimum level where commands can be processed.
2. Flight signal degradation causes includes locally induced RF noise sources, vehicle plume, multi-path, noise-floor and abnormal launch vehicle flight.
3. For most applications, meeting the solutions within the text boxes of this section will meet the requirements for ground command transmitter compatibility, flight hardware performance variations and RF signal degradation.

a. Decoder Channel Deviation. The FTR shall satisfy all its performance specifications when subjected to the required minimum and maximum RF deviation specifications plus a margin.

1. Current range command transmitter performance supports a tone deviation of plus and minus 30 KHz per tone
2. The RF deviation threshold for each channel.
   a. The FTR shall meet all specifications when the input RF carrier is deviated over the range of plus and minus 27 to plus and minus 33 kHz per tone.
   b. Tone decoder operating threshold region shall be tested between 9 and 18 kHz.

b. Operational Bandwidth. The FTR shall be tested to demonstrate that it meets its performance requirements when subjected to the required operational bandwidth plus a margin.

1. The minimum operational bandwidth shall be +/- 45 KHz.
2. Threshold sensitivity shall not vary by more than 3dB across the bandwidth.

c. RF Dynamic Range. The FTR shall be tested to demonstrate it satisfies all performance specifications when subjected to the variations of the RF input signal level that will occur during checkout and flight. The FTR shall output all commands with input from the RF threshold level up to the maximum RF level that it will experience from the range command transmitter during checkout and flight plus a 3-dB margin.

1. An RF level of +13 dBm will meet the maximum RF level requirement for most vehicle applications.
2. A minimum of five uniformly distributed RF input levels, to include the measured RF threshold and maximum RF level, shall be used for this test.

d. Capture Ratio. The FTR shall be tested to demonstrate that it processes all commands when an interfering signal of less than 80 percent of the intended signal level is present.

The capture ratio test shall be performed by continuously sending a command while sending an interfering CW signal and a modulated command signal at a lower power level. The intended command shall not drop out. The specific requirement for an interfering modulated signal will be determined on a case by case basis.

e. Signal Strength Telemetry Output (SSTO) Monitor. The FTRs SSTO monitoring circuit shall be tested to demonstrate the following:
   (1) The FTRs SSTO monitoring circuit shall be tested to demonstrate it accurately monitors and outputs the strength of the RF input signal during flight.
   (2) The SSTO output of the monitor circuit shall be directly related and proportional to the strength of the RF input signal from the receiver threshold SSTO to SSTO saturation.
   (3) The SSTO quiescent threshold level shall equate to a receiver with no RF input.
   (4) The dynamic range of the RF input from threshold to saturation shall be no less than 50 dB. The monitor circuit output amplitude from threshold to saturation shall have sufficient resolution to allow accurate determination of RF level.
   (5) The SSTO monitor output signal level shall be tested to verify it meets its response time requirement.

The response time of the SSTO circuitry shall be 4 milliseconds or less.

   (6) The slope of the monitor circuit output shall not change polarity.

1. Signal Strength Telemetry Output (SSTO) Monitor. The receiver's SSTO voltage, while operating into a 10,000-ohm and flight representative TM load, shall be in accordance with the following requirements:
   a. The quiescent (no RF signal) condition shall be 0.5 ±0.25 Vdc.
   b. The measured command threshold sensitivity input condition shall be 0.1 Vdc minimum above the quiescent value.
   c. The SSTO output level shall reach 4.5 Vdc with no less than -60 dBm or no more than -50 dBm of RF input.
   d. The shape of the transfer function shall not exceed approximately 1 Vdc change in voltage for each 13-dB change in RF input signal over the range between threshold and saturation.
   e. The maximum SSTO voltage shall not exceed 5 Vdc under all conditions.
   f. The slope of the SSTO voltage shall not change polarity from measured threshold to a +13 dBm level. The slope shall be monotonic with no more than 50 millivolts of drop after saturation has been reached.
2. The SSTO voltage shall not be used as a command output monitor.

f. RF Input Characteristics.

(1) Threshold Sensitivity. The FTRs shall be tested to demonstrate that the threshold sensitivity is repeatable and in-family.

1. The measured RF threshold sensitivity of the receiver shall be greater than -116 dBm across a 50-ohm impedance.
2. An FTRs threshold sensitivity shall be tested to demonstrate it is repeatable within a tolerance of plus and minus 3 dB.

(2) Guaranteed Sensitivity. The FTR shall be tested to demonstrate it meets all performance requirements at the RF guaranteed sensitivity.

The guaranteed sensitivity of the receiver shall be between -107 dBm to -116 dBm across a 50-ohm impedance.

g. Voltage Standing Wave Ratio. The FTR VSWR shall be tested to demonstrate it meets its performance requirements.

The FTR shall be tested for a VSWR of 2:1 or less into a 50-ohm impedance.

h. Decoder Channel Bandwidth. A FTR shall be tested to demonstrate it meets its performance requirements when subjected to the specified combined variations in tone frequency and FM deviation variations.

1. Test methodology.
   a. Tests are performed by deviating the FM signal above the threshold deviation level (determined in paragraph 4.17.11a) and determining the detection bandwidth for each tone frequency.
   b. The bandwidth is determined by first starting outside the bandwidth of the tone decoder and sweeping the frequency of the tone generator until the tone is detected.
   c. To detect individual tones at the component level, commands are often used where one tone is varied and the other is held at specification while detecting for an output command.
2. Standard RCC Tone.
   a. The decoder channel bandwidth shall be ±1 percent or greater of the assigned tone frequency at 2-dB above the threshold deviation.
   b. The decoder channel bandwidth shall be ±4 percent or less of the assigned tone frequency at 14-dB above the threshold deviation.
   c. The decoder channel bandwidth shall be ±4 percent or less of the assigned tone frequency at 20-dB above the threshold deviation. This test shall be performed at the decoder board level.
   d. Channel Filters. The channel filters shall be centered about the RCC tone center frequency within ±0.5 percent.
3. High Alphabet Decoder Channel Bandwidth. The decoder channel bandwidth shall be ±40 Hz minimum at 2 dB and ±600 Hz maximum at 20 dB.

i. Tone Balance. The FTR shall be tested to demonstrate it meets its performance requirements when subjected to the specified imbalance between two tones within the same command sequence or message.

j. Message Timing. An FTR shall be tested to verify that it meets its performance requirements when subjected to the specified command timing sequences.

k. Check Channel. The FTR shall be tested to demonstrate it will decode the check channel or pilot tone and provide a telemetry output. The test shall also demonstrate that the presence or absence of this tone signal shall have no effect on a FTR command processing and output capability.

l. Dynamic Stability. The FTR shall be tested to demonstrate it meets its performance requirements after being subjected to an RF input short-circuit, open-circuit, or changes in input voltage standing wave ratio.

m. In-band Interference. Where there are in-band interfering sources during prelaunch and flight, the FTR shall be tested to characterize any degradation that occurs because of the interfering signal.

1. Testing shall be performed to simulate the worst-case interfering signal characteristic.
2. Note: This data is used to determine whether interfering sources must be deconflicted or a different FTS frequency is required.

n. Out of Band Rejection. The FTR shall be tested to demonstrate that it meets its performance requirements when subjected to the specified out-of-band RF sources.

(1) The FTR shall be tested to demonstrate it can reliably process all tones and commands when subjected to out of band interfering frequencies that the FTR could experience during prelaunch and launch operations plus a margin.

1. Testing shall be performed in 10 KHz increments.
2. The FTR shall be tested to demonstrate it can reliably process commands when subjected to any interfering frequency from 10 MHz to 1000 MHz at a power level 60 dB above the guaranteed sensitivity signal level.
3. This requirement can be met by using SSTO as an indicator of out of band interference.

(2) The specified interfering frequencies used for testing shall include all transmitting sources using the maximum bandwidth of each transmitter, receiver image frequency and harmonics of the assigned center frequency plus a margin.

1. Continuous-Wave (CW) Bandwidth. The receiver shall have an intermediate frequency (IF) bandwidth of 180 kHz minimum at the 3-dB point and 360 kHz maximum at the 60-dB point, centered within 0.005 percent of the assigned RF center frequency.
2. Spurious-Response Rejection. The receiver shall provide at least 60 dB of rejection from 10 to 1000 MHz, excluding the frequency band within the 60-dB bandwidth at the assigned center frequency referenced to response at center frequency.
3. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.
4. Noise Immunity. The FTR shall be capable of processing all command outputs when the FTR is subjected to an RF input signal of -95 dBm that is FM modulated with white noise with a minimum bandwidth of 600 kHz and at an amplitude of 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.
5. Ranges typically have transmitting sources in the C-band, S-band, L-band and X-band frequencies. FTRs shall be tested for all intended and unintended Range transmitting sources.

o. Adjacent Tone Decoder Channel Rejection. The FTR shall be tested to demonstrate that it meets all performance requirements when subjected to the specified over-modulation of adjacent tones.

The decoder shall not cause a keyed channel to drop out in the presence of adjacent-channel interference resulting from any combination of simultaneous tones with carrier FM deviation set at plus and minus 50 kHz per tone.

4.17.12 Inadvertent Command Output. An FTR shall satisfy all of the following to ensure that it does not provide an output other than when it receives a valid command.

a. Dynamic Stability. The FTR shall be tested to demonstrate it will not produce an inadvertent output when subjected to an RF input short-circuit, open-circuit, or changes in input voltage standing wave ratio.

Only RF input short-circuit and open-circuit testing need to be tested for acceptance.

b. RF Rejection. The FTR shall be tested to demonstrate it will not respond to any specified in-band and out-of-band RF transmitter source.
   (1) The FTR shall be tested to demonstrate it provides sufficient rejection for any out of band interfering frequency that it could experience during prelaunch and flight. For these tests, the interfering signal shall be a command or tones that can be processed by FTR.

1. The FTR shall be tested to demonstrate it provides 60 dB of rejection for any out of band interfering frequency from 10 MHz to 1000 MHz.
2. Special attention should be given to other command termination frequencies used on a Range.

(2) The interfering frequencies use for testing shall include all specified interfering transmitting sources using the maximum bandwidth, receiver image frequency and harmonics of the assigned center frequency.

1. Continuous-Wave (CW) Bandwidth. The receiver shall have an intermediate frequency (IF) bandwidth of 180 kHz minimum at the 3-dB point and 360 kHz maximum at the 60-dB point, centered within 0.005 percent of the assigned RF center frequency.
2. Spurious-Response Rejection. The receiver shall provide at least 60 dB of rejection from 10 to 1000 MHz, excluding the frequency band within the 60-dB bandwidth at the assigned center frequency referenced to response at center frequency.
3. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.
4. Noise Immunity. The FTR shall be subjected to an RF input signal of -95 dBm that is FM modulated with white noise with a minimum bandwidth of 600 kHz and at an amplitude of 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.
5. Ranges typically have transmitting sources in the C-band, S-band, L-band and X-band frequencies. FTRs shall be tested for all intended and unintended transmitting sources.

(3) In-band Interference. Where there are in-band interfering sources during prelaunch and flight, the FTR shall be tested to characterize any inadvertent output that occurs because of the interfering signal.

Testing shall be performed to simulate the worst-case interfering signal characteristic.
Note: This data is used to determine whether interfering sources must be deconflicted or a different FTS frequency is required.

c. Decoder Channel Bandwidth Rejection. The FTR shall be tested at the specified FM deviation noise to demonstrate it will not trigger any tone channel outputs.

The decoder shall not provide any output at deviation levels of less than plus and minus 9 kHz per tone.

d. Adjacent Tone Decoder Channel Rejection. The FTR shall be tested to demonstrate that it will not inadvertently issue any tones or commands when subjected to the specified over-modulation of adjacent tones.

The decoder shall not produce an output on un-keyed channels in the presence of adjacent-channel interference resulting from any combination of simultaneous tones with carrier FM deviation set at plus and minus 50 kHz per tone.

e. AM Rejection. The FTR shall be tested to demonstrate that it does not output a tone or command when subjected to the specified amplitude modulated signals and noise that can be generated by the range command transmitter or other sources.

1. Acceptance testing shall be performed at 50 percent AM. Qualification testing shall be performed at 100 percent AM.
2. AM Rejection 50 Percent and 100 Percent. Verify that the FTR can reject an AM modulated signal, and the FTR shall not produce an output from any decoder channel under the following conditions:
   a. An RF input signal at the assigned center frequency of -90.1 dBm (7 microvolts) with 50-percent AM modulation by the assigned Range Commanders Council (RCC) tone frequencies.
   b. An RF input signal at the assigned frequency of -85.4-dBm (12 microvolts) signal with 50-percent AM modulation at any modulation frequency.
   c. An RF input signal at the assigned RF center frequency of -67 dBm (100 microvolts) with 100-percent peak AM modulation at low pass filter (LPF) 3-dB frequencies of 3.5 kHz or 7.0 kHz.

Note: This requirement addresses an AM signal modulated on the range transmitted FM signal.

f. Power Cycling. The FTR shall be tested to demonstrate it will not produce an inadvertent output of a tone or command when the receiver is repeatedly powered up or powered down

The power shall be cycled a minimum of 30 times with less than 2 seconds between power cycles.

g. Receiver Abnormal Logic.
   (1) The FTR shall be tested to demonstrate it will not respond to any combination of tones or tone pairs other than the correct command sequence(s).
   (2) The FTR shall be tested to demonstrate it will not output a command when one tone in the sequence is dropped or missing.
   (3) The FTR shall be tested to demonstrate it provides a terminate command only if preceded by an Arm command.

h. Noise Immunity. The FTR shall be tested to demonstrate that it rejects the specified RF FM white noise.

1. The FTR shall not respond to a frequency modulated white noise RF input that has a minimum frequency modulated deviation of 12 dB above the measured threshold deviation.
2. The FTR shall not produce command outputs when the FTR is subjected to an RF input signal of -95 dBm that is FM modulated with white noise with a minimum bandwidth of 600 kHz and at an amplitude of 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.

4.17.13 Thermal Performance. A thermal performance test shall demonstrate that an FTR satisfies its performance specifications when subjected to operating and workmanship thermal environments. A FTR shall undergo a thermal performance test during thermal cycle and thermal vacuum testing. The FTR shall be subjected to the performance testing at low and high operating voltage while the FTR is at the high and low temperatures. Performance tests at high and low temperatures shall include the following tests.

#	Test	Para	#	Test	Para
1.	Input Current	4.17.2	8.	Operational Bandwidth	4.17.11b
2.	Command and Control	4.17.3	9.	RF Dynamic Range	4.17.11c
3.	Output Command Circuits	4.17.4	10.	SSTO	4.17.11e
4.	Output Monitors	4.17.5	11.	RF Threshold Sensitivity	4.17.11.f1
5.	Self-Test	4.17.6	12.	Decoder Channel Bandwidth	4.17.11h
6.	Fail-Safe	4.17.10	13.	Check Channel	4.17.11k
7.	Decoder Channel Deviation	4.17.11a			

4.18 Autonomous Flight Termination Unit (AFTU)

The AFTU processes the tracking data, makes a determination of whether to initiate termination and outputs a command. Individual tracking component requirements are addressed in RCC Document 324, "Global Positioning and Inertial Measurements Range Safety Tracking Systems' Commonality Standard."

TABLE 4.18-1. AFTU ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Inspection	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification (3)	4.10.4	
Continuity and Isolation	4.18.8	100%
Input Current (1)	4.18.7	100%
Terminate Decision Criteria	4.18.2	100%
Abbreviated Terminate Criteria (1)	4.18.9	100%
Output Firing Circuit (1)	4.18.3	100%
Command and Control (1)	4.18.4	100%
Output Monitors(1)	4.18.5	100%
Circuit Protection		
Low Voltage	4.18.10b	100%
Dropout	4.18.10c	100%
Watchdog Circuit	4.18.10d	100%
Self Test (1)	4.18.6	100%
Abbreviated Performance Verification (2)	4.10.5	
Output Monitors	4.18.5	100%
Input Current	4.18.7	100%
Abbreviated Terminate Criteria	4.18.9	100%
Operating Environment Tests	4.15.1	
Thermal Cycling (1)	4.15.2	100%
Thermal Vacuum (1)	4.15.3	100%
Acoustic (2)	4.15.4	100%
Sinusoidal Vibration (2)	4.15.5	100%
Random Vibration (2)	4.15.6	100%
Leakage	4.11.8	100%

Notes for Table 4.18-1:

(1) A component shall undergo these tests at the first and last of the hot and cold thermal dwell cycles for thermal cycle and thermal vacuum tests. Input current and command output shall be continuously monitored during all other thermal cycles and transitions.
(2) Abbreviated performance verification tests shall be performed during dynamic operating environments.
(3) These tests shall also be performed as part of the preflight tests in Chapter 5.

TABLE 4.18-2. AFTU QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested X=3
Acceptance Tests (1)	Table 4.18.1	X
Performance Verification (2)	4.10.4	
Continuity and Isolation	4.18.8	X
Input Current (4)	4.18.7	X
Terminate Decision Criteria	4.18.2	X
Abbreviated Terminate Criteria(4)	4.18.9	X
Output Firing Circuit (4)	4.18.3	X
Command and Control (4)	4.18.4	X
Output Monitors (4)	4.18.5	X
Circuit Protection		
Low Voltage	4.18.10b	X
Dropout	4.18.10c	X
Watchdog Circuit	4.18.10d	X
Self Test (4)	4.18.6	X
Abbreviated Performance Verification (3)	4.10.5	
Output Monitors	4.18.5	X
Input Current	4.18.7	X
Abbreviated Terminate Criteria	4.18.9	X
Non-Operating Environment Tests	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Handling Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Fungus Resistance	4.13.7	1
Fine Sand	4.13.8	1
Operating Environment Tests	4.14.1	
Thermal Cycling (4)	4.14.2	X
Thermal Vacuum (4)	4.14.3	X
Humidity (4)	4.14.4	X
Salt Fog	4.14.5	2
Temperature/Humidity/Altitude (4)	4.14.6	X
Acceleration (3)	4.14.7	X
Shock(5)	4.14.8	X
Acoustic (3)	4.14.9	X
Sinusoidal Vibration (3)	4.14.10	X
Random Vibration (3)	4.14.11	X
Electromagnetic Interference and Compatibility	4.14.12	2
Explosive Atmosphere	4.14.13	2

Table 4.18-2. AFTU Qualification Test Requirements (Continued)

Test	Paragraph	Quantity Tested X=3
Memory	4.18.12	
Repetitive Functioning	4.18.11	X
Circuit Protection	4.18.10	1
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

Notes for Table 4.18-2:

(1) Each qualification test component shall successfully complete all acceptance tests before undergoing qualification testing.
(2) This test shall include all components of the system in a flight configuration. Special tests that validate this requirement shall be approved by Range Safety.
(3) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
(4) A component shall undergo these tests for thermal cycle, humidity temperature/humidity/altitude and thermal vacuum tests. Input current and command output shall be continuously monitored during all other thermal cycles and transitions.
(5) The AFTU flight-critical functions shall be monitored while the unit is subjected to the operating shock environment. At a minimum, the input current, output monitors, and output commands shall be monitored during the shock test for variations in performance.

(2) is not referenced.

4.18.1 General. AFTU shall be electrically tested using tracking inputs to demonstrate that it satisfies its performance specifications when subjected to non-operating and operating environments. This testing shall be conducted in accordance with the acceptance and qualification test matrices and accompanying requirements of this section.

a. Input into the AFTU shall use tracking source inputs that duplicates the flight interface including processing delays, sample rate, measurement data and message structure.
b. All tracking sources inputs used for testing shall be capable of independently simulating nominal and errant vehicle trajectories.

4.18.2 Terminate Decision Criteria. The AFTU's processing shall be tested to demonstrate that the unit will initiate a terminate output when any mission rule is violated and will not initiate a terminate output under other conditions. These tests shall be performed using simulated signals to the AFTU to perform a series of trajectory scenarios. The component shall demonstrate compliance to all of the following performance test requirements:

1. A standard set of test conditions shall be developed that simulates the dynamics of a typical flight trajectory.
2. The same software shall be used for all qualification and acceptance tests of all flight units.
3. Performance variations shall be evaluated using the standard software package to screen for potential design or software modifications or manufacturing defects.

a. The AFTU shall initiate a termination command in the specified time when all tracking sources are lost. Testing shall be performed at different points along the trajectory.

When tracking source data is lost, the terminate logic shall assume the vehicle has taken a worst-case stable turn towards a termination boundary. The AFTU shall calculate the time (minimum time to endanger) it takes to reach this boundary and terminate flight prior to reaching the boundary.

b. Termination Scenario.
   (1) The AFTU shall initiate a terminate output when all adequate tracking sources violate terminate criteria.

Non-nominal vehicle trajectories include:
a. Ground launched/non-programming (straight up)
b. Rapid turn towards impact limit line
c. Slow turn towards impact limit line
d. For space launch, inability to make orbit

(2) The AFTU shall initiate a terminate output when one adequate source is on the nominal trajectory and the other adequate source violates terminate criteria.

c. Loss of one tracking source. The AFTU shall initiate a terminate output when one tracking source fails (no data) with an inadequate second tracking source. The AFTU shall NOT initiate a terminate output and process data normally when one tracking source fails (no data) with a second adequate tracking source.

1. Examples of inadequate source test conditions for GPS are as follows:
   a. Loss of all data
   b. DOP exceeds specification
   c. GPS is in a "coast' mode
   d Filter residuals that indicate errors exceed specification.
   e. Other indicators will be included on a case-by-case basis that indicate GPS may not be producing the required specification state vector output.
2. Examples of inadequate source test conditions for INS are as follows:
   a. Loss of all data
   b. INS has not been validated by another source after each vehicle shock event.
   c. Any discrepancies such as unrealistically large jumps in state vector or diverging data with GPS.
   d. Where two INS tracking sources are used to validate one another, there shall be no common-cause failures that could cause both sources to produce false position data (e.g. alignment).
   e. Other indicators will be included on a case-by-case basis that indicate INS may not be producing the required specification state vector output.

d. Diverging tracking source. The AFTU shall NOT initiate a terminate output and process data normally when all adequate tracking sources diverge but do not violate terminate criteria. The AFTU shall initiate a terminate output when one adequate tracking source violates a terminate criteria and the other does not.

e. Nominal Trajectory. The AFTU shall NOT initiate a terminate output and process data normally during a nominal flight trajectory including any allowable deviation due to nominal vehicle performance variability.

f. The AFTU shall initiate a termination command if the vehicle trajectory is sufficiently off course to prevent accomplishment of the mission.

AFTU shall terminate a space vehicle if it is unable to achieve orbit due to a flight anomaly.

g. The AFTU shall initiate a termination command if the vehicle is performing erratically such that it may degrade FTS component reliability.

1. Testing shall include tumbling and 90 degree trajectory turns.
2. A GPS based tracking source can detect tumbling by showing that the instantaneous impact point has stopped moving.

h. The AFTU shall initiate a termination command when its processor and the other AFTU processor cease functioning. The AFTU shall initiate a terminate command in a timeframe that meets performance requirements.

1. The AFTU shall output a terminate command when all the following conditions are met and not output a command when only one of these conditions are met:
   a. The AFTU's processor under test is stopped.
   b. A simulated input from another AFTU's processor is stopped, including loss of connectivity between the units.
2. This test verifies the "heartbeat" monitor circuit.
3. Tests shall be performed at different times in the flight trajectory.

i. For qualification testing, the AFTU shall meet its performance requirements when subjected to a random series of trajectories and tracking data input scenarios.

4.18.3 Output Firing Circuit. An AFTU shall be tested to demonstrate the firing output specification requirements.

a. The AFTU output shall be tested to demonstrate that the AFTU delivers the required energy at the unit's specified worst-case high and low operating voltages.

b. The AFTU shall be tested to demonstrate that its output leakage current meets performance requirements during transient start-up and steady state operation.

The AFTU shall not produce any command outputs (MONITOR, OPTIONAL, ARM, or TERMINATE) greater than 1 volt in amplitude for more than 200 microseconds into a 10k-ohm load during the voltage transient and shall meet its performance requirements after the application of the voltage transient.

4.18.4 Command and Control. An AFTU shall be tested to show all commands, controls, and inhibits are functioning correctly. As a minimum, the following functions shall be tested.

a. The Arm and Disable commands shall be tested to demonstrate they meet their performance requirements.

1. The two AFTU logic Arm and Master Arm inputs shall be tested to validate that they trigger at the required voltage levels:
   a. The Logic Arm input shall be tested to demonstrate it only enables the AFTU logic and processors.
   b. The Master Arm command shall be tested to demonstrate it enables the power used for the terminate output. The AFTU shall be tested to ensure that a terminate output cannot occur if Master Arm is not enabled.
2. The AFTU disable commands shall demonstrate that the Master Arm and Logic Arm can be removed with the required voltage signal level.
3. The AFTU shall power-up in the safe condition after power has been removed for greater than 1 second.

b. The AFTU's command circuitry shall be tested to demonstrate that it will not trigger inadvertently when subjected to the guaranteed no-fire trigger performance levels. The maximum guaranteed no-fire trigger threshold shall be at least 20 dB above the worst-case noise or current leakage environment.

The AFTU's Arm and disable command circuits shall not trigger when a 5 volt signal is applied for 5 minutes.

c. Input Arming commands shall be tested to demonstrate that they latch and not require a continuous command to remain latched.
d. The unit shall be tested to demonstrate that it powers up in a safe state.

The unit shall be armed, powered down for 30 seconds and powered up. The unit shall power-up in the safe state.

4.18.5 Output Monitors. Output monitor circuits shall be tested to verify that all the required monitor signals meet their specified performance requirements.

4.18.6 Self Test. The AFTU shall demonstrate it can perform self-tests, detect errors, and output the results.

4.18.7 Input Current. Input current of the AFTU shall be monitored to demonstrate that it meets all its performance requirements.

Input current to the AFTU's input power and arm power shall be monitored at a 0.1 ms resolution during dynamic environmental testing.

4.18.8 Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances of the AFTU to demonstrate that it satisfies all its performance specifications.

Isolation resistance shall be 2 MΩ.

4.18.9 Abbreviated Terminate Criteria. An abbreviated functional test shall exercise a AFTU's flight critical functions while the unit is subjected to each required operating environment. This shall include subjecting the AFTU to termination scenarios during each environment while monitoring command outputs and function time to demonstrate that it satisfies all its performance specifications.

The AFTU shall use an abbreviated test routine that exercises terminate and non-terminate scenarios in paragraph 4.18.2. This same routine shall be used for qualification and acceptance testing.

4.18.10 Circuit Protection. A circuit protection test shall demonstrate that any circuit protection allows a AFTU to satisfy all its performance specifications, when subjected to any improper launch processing, abnormal flight condition, or any failure of another launch vehicle component. The demonstration shall include all of the following:

a. Overvoltage. The AFTU shall demonstrate that it meets all of its performance specifications after being subjected to the forward and reverse polarity at the maximum input voltage of the unit's ground or airborne power source.

The AFTU will not be damaged when it is subjected to the application of up to ±45 Vdc or the OCV of the power source, whichever is greater, to the power input port for a period not less than 5 minutes.

b. Low Voltage. The AFTU shall not degrade in performance or produce an inadvertent output command when subjected to voltages below the specified level.

1. The AFTU shall be tested from 0 volts to the maximum specified voltage back to 0 volts without damage or producing a spurious output regardless of the rate of transition between the voltage present.
2. The AFTU shall meet all performance requirements after power is removed for greater than 1 second. Specifically, the unit shall return to full functionality after power is reapplied without having to reload flight parameters or software.

c. Dropout. The AFTU shall be tested to verify that it will meet its performance requirements after a specified input power dropout.

The AFTU shall be fully functional and meet all performance requirements after a 50 millisecond dropout.

d. Watchdog Circuit. All watchdog circuits shall be tested to verify they meet their performance specifications.
e. Monitor Protection. Demonstrate that failures in output monitors will not degrade the performance of the critical circuits within the AFTU. Each output monitor shall be subjected to a short circuit or the highest positive or negative voltage capable of being supplied by the monitor batteries or other power supplies.

1. During qualification testing the monitor outputs shall be shorted and connected to ±45 Vdc in both the unpowered and powered state.
2. Voltage shall be applied for a duration of no less than five minutes.
3. Monitor outputs may be damaged during this test but the critical circuits required for issuing a termination command shall not be degraded.

4.18.11 Repetitive Function. This test shall demonstrate that the AFTU satisfies all its performance specifications when subjected to repetitive functioning for five times the worst-case number of operational outputs required for acceptance, checkout and operations, including any retest due to schedule delays.

1. The worst-case total operating time shall include an additional 30-minute wait period for solid rocket motors.
2. The AFTU shall be tested for 1000 operational outputs without degradation.
3. This test may be combined with the Monte Carlo simulation tests.

4.18.12 Memory. An AFTU shall demonstrate that data stored in memory is not degraded and it is able to meet all performance requirements after remaining in the powered-off condition for the maximum specified time.

Data loaded into an AFTU shall remain in memory for no less than 180 days without primary direct current (dc) power being applied.

4.19 Valves for Thrust Cutoff Systems

TABLE 4.19-1. ELECTROMECHANICAL VALVE ACCEPTANCE[1]

Test	Paragraph	Quantity Tested
Component Examination:	4.11	100%
Visual Examination [6]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check [6]	4.11.5	100%
Performance Verification [6]	4.10.4	
Continuity and Isolation	4.19.2	100%
Actuation Resistance (Solenoid coil)	4.19.3	100%
Insulation Resistance (Solenoid coil to case)	4.19.4	100%
Actuation Test	4.19.7	100%
Operating Environment Tests:	4.15.1	
Thermal Cycle [5]	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic [3], [4]	4.15.4	100%
Sinusoidal Vibration [3], [4]	4.15.5	100%
Random Vibration [3], [4]	4.15.6	100%
External Leak/Proof Test	4.19.5	100%
Performance Verification:	4.10.4	
Valve Actuation Test	4.19.7	100%
Continuity and Isolation	4.19.2	100%
Actuation Resistance (Solenoid coil)	4.19.3	100%
Insulation Resistance (Solenoid coil to case)	4.19.4	100%
Component Examination:	4.11	
Visual Examination	4.11.2	100%
X-ray	4.11.6	100%

Notes for Table 4-19-1:

(1) The tests required by this table apply to all valve subassembly including the actuation assembly.
(2) Reserved.
(3) Perform Valve Actuation Test in accordance with paragraph 4.19.7 for the hot and cold dwells of the first and last thermal cycle.
(4) Valve testing during vibration shall verify valve functionality in its intended FTS configuration:
   a. The valve shall not leak beyond specification in the closed condition for first half the vibration test.
   b. Open the valve and verify pressure on valve output port.
   c. Second half of vibration test verify no transfer of valve back to the closed position and verify no out of specification loss of pressure.
   d. Perform Valve Actuation Test in accordance with paragraph 4.19.7 prior to end of vibration test for each axis.
(5) System-level engine firing may be used in lieu of component vibration tests provided that the valves are subjected to the required acceptance test vibration levels and durations.
(6) Perform Valve Cycle Test in accordance with paragraph 4.19.12 for cycles 4-7 of the hot dwell thermal cycles.
(7) These tests shall also be performed as part of preflight testing at the launch site.

TABLE 4.19-2. ELECTROMECHANICAL VALVE QUALIFICATION[1]

Test	Section	Quantity Tested = 3		
		X=1	X=1	X=1
Acceptance Testing	Table 4.19-1	X	X	X
Non-Operating Environments:	4.13.1			
Storage Temperature	4.13.2	X	X	X
Transportation Shock	4.13.4	X	X	X
Bench Handling	4.13.5	X	X	X
Transportation Vibration	4.13.6	X	X	X
Fungus Resistance	4.13.7	X	X	X
Fine Sand	4.13.8	X	X	X
Operating Environment Tests	4.14.1			
Thermal Cycling [4]	4.14.2	X	X	X
Thermal Vacuum [4]	4.14.3	X	X	X
Humidity [4], [6]	4.14.4	X	X	X
Salt Fog [7]	4.14.5	X	X	X
Temperature/Humidity/Altitude [4]	4.14.6	X	X	X
Acceleration [3]	4.14.7	X	X	X
Shock [5]	4.14.8	X	X	X
Acoustic [3]	4.14.9	X	X	X
Sinusoidal Vibration [3]	4.14.10	X	X	X
Random Vibration [3]	4.14.11	X	X	X
Electromagnetic Interference and Compatibility	4.14.12	X	X	X
Explosive Atmosphere	4.14.13	X	X	
Cycle Life	4.19.13	X	X	X
External Leak Test	4.19.5	X	X	X
Pressure Cycle Life	4.19.11	X	X	X
Performance Verification:	4.10.4			
Valve Actuation Test	4.19.7	X	X	X
Component Examination:	4.11	X	X	X
Visual Examination	4.11.2	X	X	X
System Tests [8]	4.19.9		X	X
System Functional Margin [8]	4.19.6	X	X	X
Extended Stall	4.19.10	X		
Burst Test	4.19.14	X	X	

Notes for Table 4.19-2:

(1) The tests required by this table apply to fully assembled valves including the actuation assembly, electrical wiring, flight brackets, connectors and plumbing.
(2) Reserved.
(3) Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

1. The valve shall not leak beyond specification in the closed condition for first half the vibration test.
2. Open the valve and verify pressure on valve output port.
3. Second half of vibration test verify no transfer of valve back to the closed position and verify no out of specification loss of pressure.
4. Perform Valve Actuation Test in accordance with paragraph 4.19.7 prior to end of vibration test for each axis.

(4) Perform Valve Actuation test in accordance with paragraph 4.19.7.
(5) Two-thirds of all shock tests on each component shall be performed in a closed position with MEOP pressure applied to inlet. Unit shall meet leak rate performance requirements after shock. One-third of all shock tests on each component shall be performed in an open position to verify the valve does not move after the shock. Valve position movement may be verified by visual inspection. Perform Valve Actuation test in accordance with paragraph 4.19.7 after shock testing is completed.
(6) Test may be performed at system level during engine firings if the minimum humidity level required for operational use is enveloped during testing.
(7) Perform Valve Actuation Test in accordance with paragraph 4.19.7.
(8) Only one of these tests will be required. Range Safety shall determine which one of these tests shall be performed on a case-by-case basis. These tests may be performed as part of system-level engine testing if valves demonstrate margin over acceptance testing.

TABLE 4.19-3. PNEUMATICALLY ACTUATED VALVE ACCEPTANCE[1]

Test	Section	Quantity Tested
Component Examination:	4.11	100%
Visual Examination [6]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check [6]	4.11.5	100%
Performance Verification: [6]	4.10.4	
Valve Actuation Test	4.19.7	100%
Operating Environment Tests:	4.15.1	100%
Thermal Cycle [2], [4]	4.15.2	100%
Thermal Vacuum [2]	4.15.3	100%
Acoustic [3], [5]	4.15.4	100%
Sinusoidal Vibration [3], [5]	4.15.5	100%
Random Vibration [3], [5]	4.15.6	100%
External Leak/Proof Test	4.19.5	100%
Performance Verification:	4.10.4	
Valve Actuation Test	4.19.7	100%
Component Examination:	4.11	
Visual Examination	4.11.2	100%
X-ray	4.11.6	100%

Notes for Table 4.19-3:

(1) The tests required by this table apply to all valve subassembly including the actuation assembly.
(2) Perform Valve Actuation Test in accordance with paragraph 4.19.7 for the hot and cold dwells of the first and last thermal cycle.
(3) Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

1. The valve shall not leak beyond specification in the closed condition for first half the vibration test.
2. Open the valve and verify pressure on valve output port.
3. Second half of vibration test verify no transfer of valve back to the closed position and verify no out of specification loss of pressure.
4. Perform Valve Actuation Test in accordance with paragraph 4.19.7 prior to end of vibration test for each axis.

(4) Perform Valve Cycle Test in accordance with paragraph 4.19.12 for cycles 4-7 of the hot dwell thermal cycles.
(5) System-level engine firing may be used in lieu of component vibration tests provided that the valves are subjected to the required acceptance test vibration levels and durations.
(6) These tests shall also be performed as part of preflight testing at the launch site.

TABLE 4.19-4. PNEUMATICALLY ACTUATED VALVE QUALIFICATION[1]

Test	Section	Quantity Tested = 3		
		X=1	X=1	X=1
Acceptance Testing	Table 4.19-3	X	X	X
Non-Operating Environments:	4.13.1			
Storage Temperature	4.13.2	X	X	X
Transportation Shock	4.13.4	X	X	X
Bench Handling	4.13.5	X	X	X
Transportation Vibration	4.13.6	X	X	X
Fungus Resistance	4.13.7	X	X	X
Fine Sand	4.13.8	X	X	X
Operating Environment Tests	4.14.1			
Thermal Cycling [4]	4.14.2	X	X	X
Thermal Vacuum [4]	4.14.3	X	X	X
Humidity [4], [6]	4.14.4	X	X	X
Salt Fog [7]	4.14.5	X	X	X
Temperature/Humidity/Altitude [4]	4.14.6	X	X	X
Acceleration [3]	4.14.7	X	X	X
Shock [5]	4.14.8	X	X	X
Acoustic [3]	4.14.9	X	X	X
Sinusoidal Vibration [3]	4.14.10	X	X	X
Random Vibration [3]	4.14.11	X	X	X
Electromagnetic Interference and Compatibility	4.14.12	X	X	
Explosive Atmosphere	4.14.13	X	X	
Cycle Life	4.19.13	X	X	X
External Leak Test	4.19.5	X	X	X
Pressure Cycle Life	4.19.11	X	X	X
Performance Verification:	4.10.4			
Valve Actuation Test	4.19.7	X	X	X
Component Examination:	4.11	X	X	X
Visual Examination	4.11.2	X	X	X
System Tests [8]	4.19.9		X	X
System Functional Margin [8]	4.19.6	X	X	X
Burst Test	4.19.14	X	X	

Notes for Table 4.19-4:

(1) The tests required by this table apply to fully assembled valves including the actuation assembly, pilot valves, flight brackets, connectors and plumbing.
(2) Reserved.
(3) Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

1. The valve shall not leak beyond specification in the closed condition for first half the vibration test.
2. Open the valve and verify pressure on valve output port.
3. Second half of vibration test verify no transfer of valve back to the closed position and verify no out of specification loss of pressure.
4. Perform Valve Actuation Test in accordance with paragraph 4.19.7 prior to end of vibration test for each axis.

(4) Perform Valve Actuation test in accordance with paragraph 4.19.7.
(5) Two-thirds of all shock tests on each component shall be performed in a closed position with MEOP pressure applied to inlet. Unit shall meet leak rate performance requirements after shock. One-third of all shock tests on each component shall be performed in an open position to verify the valve does not move after the shock. Valve position movement may be verified by visual inspection. Perform Valve Actuation test in accordance with paragraph 4.19.7 after shock testing is completed.
(6) Test may be performed at system level during engine firings if the minimum humidity level required for operational use is enveloped during testing.
(7) Perform Valve Actuation Test in accordance with paragraph 4.19.7.
(8) Only one of these tests will be required. Range Safety shall determine which one of these tests shall be performed on a case-by-case basis. These tests may be performed as part of system-level engine testing if valves demonstrate margin over acceptance testing.

TABLE 4.19-5. ELECTRO-PNEUMATIC VALVE ACCEPTANCE (PILOT VALVES)(1)

Test	Section	Quantity Tested
Component Examination:	4.11	100%
Visual Examination (5)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check (5)	4.11.5	100%
Performance Verification (5)	4.10.4	
Continuity and Isolation	4.19.2	100%
Actuation Resistance	4.19.3	100%
Insulation Resistance	4.19.4	100%
Electro-Pneumatic Functional Test	4.19.8	100%
Operating Environment Tests:	4.15.1	
Thermal Cycle (2), (4)	4.15.2	100%
Thermal Vacuum (2)	4.15.3	100%
Acoustic (3)	4.15.4	100%
Sinusoidal Vibration (3)	4.15.5	100%
Random Vibration (3)	4.15.6	100%
Performance Verification:	4.10.4	
Electro-Pneumatic Functional Test	4.19.8	100%
Continuity and Isolation	4.19.2	100%
Actuation Resistance	4.19.3	100%
Insulation Resistance	4.19.4	100%
Component Examination:	4.11	
Visual Examination	4.11.2	100%
X-ray	4.11.6	100%

Notes for Table 4.19-5:

(1) The tests required by this table apply to all valve subassemblies including the actuation assembly.
(2) Perform Electro-Pneumatic Functional Test in accordance with paragraph 4.19.8 for the hot and cold dwells of the first and last thermal cycle.
(3) Perform Valve Actuation Test in accordance with paragraph 4.19.8 prior to end of vibration test for each axis. Valve testing during vibration shall verify valve functionality in its intended FTS configuration.
(4) Perform Valve Cycle Test in accordance with paragraph 4.19.12 for cycles 4-7 of the hot dwell thermal cycles.
(5) These tests shall also be performed as part of preflight testing at the launch site.

TABLE 4.19-6. ELECTRO-PNEUMATIC VALVE QUALIFICATION (PILOT VALVES)[1]

Test	Section	Quantity Tested = 3		
		X=1	X=1	X=1
Acceptance Testing	Table 4.19-5	X	X	X
Non-Operating Environments:	4.13.1			
Storage Temperature	4.13.2	X	X	X
Transportation Shock	4.13.4	X	X	X
Bench Handling	4.13.5	X	X	X
Transportation Vibration	4.13.6	X	X	X
Fungus Resistance	4.13.7	X	X	X
Fine Sand	4.13.8	X	X	X
Operating Environment Tests	4.14.1			
Thermal Cycling [2]	4.14.2	X	X	X
Thermal Vacuum [2]	4.14.3	X	X	X
Humidity [2]	4.14.4	X	X	X
Salt Fog [2]	4.14.5	X	X	X
Temperature/Humidity/Altitude [2]	4.14.6	X	X	X
Acceleration [3]	4.14.7	X	X	X
Shock [4]	4.14.8	X	X	X
Acoustic [3]	4.14.9	X	X	X
Sinusoidal Vibration [3]	4.14.10	X	X	X
Random Vibration [3]	4.14.11	X	X	X
Electromagnetic Interference and Compatibility	4.14.12	X	X	
Explosive Atmosphere	4.14.13			
Electro-Pneumatic Cycle Life	4.19.15	X	X	X
Performance Verification:	4.10.4			
Electro-Pneumatic Functional Test	4.19.8	X	X	X
Component Examination:	4.11	X	X	X
Visual Examination	4.11.2	X	X	X
Extended Stall	4.19.10		X	X
System Tests [5]	4.19.9		X	X
System Functional Margin [5]	4.19.6	X	X	X

Notes for Table 4.19-6:

(1) The tests required by this table apply to fully assembled valves including the actuation assembly, electrical wiring, flight brackets, connectors and plumbing. This includes pneumatic valves.
(2) Perform Electro-Pneumatic Functional Test in accordance with paragraph 4.19.8.
(3) Perform Valve Actuation Test in accordance with paragraph 4.19.8 prior to end of vibration test for each axis. Valve testing during vibration shall verify valve functionality in its intended FTS configuration.
(4) Test shall demonstrate that the component will maintain a pressure output during shock testing. Verify unit meets performance requirements after shock testing. Perform Pneumatic Functional Test in accordance with paragraph 4.19.8 immediately after the test.
(5) Only one of these tests will be required. Range Safety shall determine which one of these tests shall be performed on a case-by-case basis.

4.19.1 General. This section applies to any shutdown valves and associated hardware that is part of the primary means of providing flight termination system, including the mechanism for actuation, whether it is electromechanical, hydraulic, pneumatic, pyrotechnic, or any combination thereof.

a. Any valve must satisfy each test or analysis identified by any table of this section. This is to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

1. The types of valves described in this section are as follows:
   a. Electromechanical valves. These valves are actuated by an electrical input resulting in direct interruption or venting of fluids.
   b. Pneumatically actuated valves. These valves are actuated by a pressure input resulting in direct interruption or venting of fluids.
   c. Electro-pneumatic valves. These valves are actuated by an electrical input and output a corresponding change in pneumatic pressure. These valves are typically used to actuate pneumatically actuated valves (pilot valves).
2. Supplemental valves, used for mission assurance, that provide an additional system level of redundancy that exceeds RCC 319 requirements may allow reduction in testing for the primary FTS valves. Tailoring shall include these non-primary valves, but only to document Range User planned tests and not levy RCC 319 requirements.

b. If critical to FTS functionality, supporting hardware such as fluid transfer lines must be tested to demonstrate they meet their performance requirements.

1. Pressure lines shall not leak at 1.5 times Maximum Expected Operating Pressure (MEOP)
2. Pressure lines shall not burst at 4 times Maximum Expected Operating Pressure (MEOP)

4.19.2 Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances to demonstrate that they satisfy all their performance specifications.

Isolation resistance shall be 2 MΩ.

4.19.3 Actuation Resistance. The test shall demonstrate that the motor or solenoid drive motor circuit meets performance specification.

4.19.4 Insulation Resistance. An insulation resistance test shall measure mutually insulated pin-to-pin and pin-to-case points using maximum operating voltage plus a margin. The test shall demonstrate that the internal wiring, connectors and other insulation material are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 500 VDC between the mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application. The voltage used for this test shall not damage or degrade the valve or solenoid.
2. The measurement error at the required insulation resistance value shall not exceed 10 percent.
3. The insulation resistance between all insulated parts shall be greater than 2 MΩ.

4.19.5 External Leak/Proof Test. A valve shall be tested to demonstrate that it meets leak rate requirements when exposed to Maximum Expected Operating Pressure (MEOP) plus a margin. The external leak shall also be used to demonstrate valve structural integrity.

1. The maximum leak rate shall meet performance requirements at 1.25 times the MEOP. Maximum allowable leakage rate shall conform to Class II of ANSI/FCI 70-2-1976, in which no greater than 0.5% of full flow may leak at 1.25 times the MEOP.
2. External leakage shall be sufficient to prevent explosive atmosphere, hazards to personnel or potential FTS failure conditions such as propellant compatibility with FTS components or freezing the valve closed.
3. Test shall be performed while cycling the valve at least 5 times.
4. This test also serves as a proof pressure test.
5. This test may be run with Helium or other inert gas.

4.19.6 System Functional Margin. A valve or valve subsystem shall be tested to demonstrate it can functionally open, close and throttle (if applicable) at high and low input operating voltage or pressure with a representative liquid propellant present using a flight flow rate and pressure plus a margin.

a. A valve shall be tested to demonstrate that it meets the required leak rate in the closed position when exposed to Maximum Expected Operating Pressure (MEOP) plus a margin.

b. A valve shall be tested to demonstrate it can be opened and closed while being subjected to maximum expected flow rate plus a margin at MEOP.

1. The minimum leak rate for a closed valve shall be in specification and family at 1.25 times the MEOP. The leak rate specification for a closed valve shall ensure that no propellant comes in contact with downstream propulsion systems that could result in performance degradation or personnel safety hazards. Closed valve leak rate shall also ensure there is no residual thrust on a flight vehicle.
2. If the valve flow control mechanism is visible, throughput in the open position may be performed with a visual inspection that can demonstrate the valve is in the fully open before and after testing is complete.
3. Where applicable, these tests shall include pilot valves.

4.19.7 Valve Actuation. A valve shall be tested to demonstrate it can functionally open, close and throttle (if applicable) at high and low input operating voltage or pressure. The valve shall demonstrate the required leak rate when closed. The valve shall meet all performance requirements including response time and valve input current, where applicable.

Leak testing shall be performed with a gaseous medium at MEOP in a no flow configuration.

4.19.8 Electro-Pneumatic Functional Test. A valve shall be tested to demonstrate it can produce a pneumatic output that meets its required performance requirements at high and low input operating voltages. The valve shall meet all performance requirements including pressure rise/decay and valve input current.

1. Test equipment shall use flight-like downstream hardware including pneumatic lines and valves. 2. Pressure monitoring equipment shall provide data at a resolution to generate pressure versus time plots that can be used for performance evaluation.

4.19.9 System Tests. Valves shall be tested in a flight configuration, including actuation assembly, electrical wiring, flight brackets, connectors and plumbing.

This test is intended to be performed during a system engine test firing.

a. The test shall be performed to the expected flight duration plus a margin.

The total duration used for system-level qualification testing shall be a minimum of three times the valve component acceptance test requirement.

b. The test shall demonstrate that the valves can be cycled for the maximum expected number of shutdown cycles for ground checkout and flight.

1. This test also serves as a “water hammer” test. 2. Valve performance parameters shall be taken during this test including cycle time and input current.

c. The actual vehicle propellants shall be used for this test.

d. The system test shall be conducted at a humidity level that represents worst-case prelaunch and launch environments at the planned launch Range.

4.19.10 Extended Stall. An electromechanical or pneumatic valve shall be tested to demonstrate it will not degrade in performance nor result in a hazardous condition when continuous current is applied in both the open and closed positions.

1. An extended stall test shall be performed at worst-case system high current for 5 minutes without degradation in performance.
2. For valves in contact with propellant with personnel present, the valve shall be tested to demonstrate it does not produce enough heat that would initiate the propellant after being exposed to worst-case actuation current for 1 hour.
3. For electro-pneumatic valves, only the 5 minute extended stall test is required.

4.19.11 Pressure Cycle Life. A valve shall be tested to demonstrate that it will function within all its performance parameters without degradation after being exposed to the worst-case pressure cycles at its fluid inlet that it would experience for prelaunch and launch plus a margin. Valve shall undergo valve actuation test in accordance with paragraph 4.19.7 after the test.

1. Testing shall be performed to demonstrate that the valve meets all performance requirements after being exposed to five times the worst-case checkout and operational pressure cycles.
2. Pressure cycles shall be performed from ambient pressure to 1.25 MEOP at a pressure rate of change that envelopes flight pressure application.

4.19.12 Cycle Test. A valve shall be tested to demonstrate that it has undergone infant-mortality testing and has been screened for workmanship and production defects. Testing shall demonstrate that the valve functions in accordance with its performance requirements after being subjected to an elevated workmanship temperature while repeatedly cycling the valve.

The valve shall be open/close cycled a minimum of 25 times for each of the four required hot thermal cycles.

4.19.13 Cycle Life. A valve shall be cycle life tested the maximum expected number of shutdown cycles for acceptance, ground checkout and flight plus a margin. Valve actuation test shall be performed in accordance with paragraph 4.19.7 after the cycle life test.

1. This test may be performed unpressurized.
2. Valves shall be cycle life tested for five times the maximum expected number of shutdown cycles or a minimum of 500 cycles, whichever is greater.
3. Hold actuation pressure at MEOP during last cycle for 1 hour minimum to satisfy performance requirement.

4.19.14 Burst Test. The valve shall be tested to demonstrate they will not create fratricide that could disable the FTS or create a hazardous condition to ground personnel when exposed to any MEOP or acceptance test pressure plus a margin.

1. Hydraulic valves shall be tested to demonstrate they will not burst when subjected to pressure of 1.5 x MEOP.
2. Pneumatic valves shall be tested to demonstrate they will not burst when subjected to pressure of 1.25 x MEOP.

4.19.15 Electro-Pneumatic Cycle Life. A valve shall be cycle life tested the maximum expected number of shutdown cycles for acceptance, ground checkout and flight plus a margin. Electro-Pneumatic Functional test shall be performed in accordance with paragraph 4.19.8 after the cycle life test.

1. This test shall be performed with input pressure ports at MEOP.
2. Valves shall be cycle life tested for five times the maximum expected number of shutdown cycles or a minimum of 500 cycles, whichever is greater.
3. Hold actuation pressure at MEOP during last cycle for 1 hour minimum to satisfy performance requirement.

4.20 Miscellaneous Components

This section applies to any component that is critical to the reliability of an FTS and is not otherwise identified by this chapter. This includes any new technology or any component that may be unique to the design of a vehicle, such as any auto-destruct box, current limiter, or timer. A miscellaneous component shall satisfy each test or analysis identified by any table of this section to demonstrate that the component satisfies all its performance specifications when subjected to each non-operating and operating environment. For any new or unique component, the Range User shall identify any additional test requirements necessary to ensure its reliability.

TABLE 4.20-1. MISCELLANEOUS COMPONENT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification (1), (3)	4.10.4	100%
Abbreviated Performance Verification (2)	4.10.5	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic	4.15.4	100%
Sinusoidal Vibration	4.15.5	100%
Random Vibration	4.15.6	100%
Leakage	4.11.8	100%

Notes for Table 4.20-1:

(1) The detailed performance verification test requirements need to be determined during the design and tailoring process.
(2) The detailed abbreviated performance verification test requirements need to be determined during the design and tailoring process.
(3) These tests shall also be performed as part of the preflight tests in Chapter 5.

TABLE 4.20-2. MISCELLANEOUS COMPONENT QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested (3)
		X=3
Acceptance Tests	Table 4.20.1	X
Performance Verification (1)	4.10.4	X
Non-Operating Environment Tests	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Handling Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Fungus Resistance	4.13.7	1
Fine Sand	4.13.8	1
Abbreviated Performance Verification (2)	4.10.5	X
Operating Environment Tests	4.14.1	
Thermal Cycling	4.14.2	X
Thermal Vacuum	4.14.3	X
Humidity	4.14.4	X
Salt Fog	4.14.5	X
Temperature/Humidity/Altitude	4.14.6	X
Acceleration	4.14.7	X
Shock	4.14.8	X
Acoustic	4.14.9	X
Sinusoidal Vibration	4.14.10	X
Random Vibration	4.14.11	X
Electromagnetic Interference and Compatibility	4.14.12	X
Explosive Atmosphere	4.14.13	1
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

Notes for Table 4.20-2:

(1) The detailed performance verification test requirements need to be determined during the design and tailoring process.
(2) The detailed abbreviated performance verification test requirements need to be determined during the design and tailoring process.
(3) The same three sample components shall undergo each test designated with an X. a test designated with a quantity of less than three, each component tested shall be one of the original three sample components.

4.21 Electrical Connectors and Harnesses

This section applies to any electrical connector or harness that is critical to the functioning of an FTS during flight, but is not otherwise part of an FTS component

TABLE 4.21-1. ELECTRICAL CONNECTOR AND HARNESS TEST REQUIREMENTS

Test	Paragraph	Qualification Quantity Tested	Acceptance Quantity Tested
		X=3	
Component Examination	4.11		
Visual Examination	4.11.2	-	100%
Dimensional Measurement	4.11.3	-	100%
Tensile Load	4.13.9	-	100%
Performance Verification Tests	4.10.4	-	100%
Dielectric Strength	4.21.2	-	100%
Insulation Resistance	4.21.4	-	100%
Continuity & Isolation Resistance	4.21.3	-	100%
Operating Environment	4.14.1		
Humidity (1)	4.14.4	X	-
Salt Fog (1)	4.14.5	X	-
Temperature/Humidity/Altitude (1)	4.14.6	X	-
Acceleration (2)	4.14.7	X	-
Shock (2)	4.14.8	X	-
Sinusoidal Vibration (2)	4.14.10	X	-
Random Vibration (2)	4.14.11	X	-
Tensile Load	4.13.9	X	-
Performance Verification Tests	4.10.4	X	-
Dielectric Strength	4.21.2	X	-
Insulation Resistance	4.21.4	X	-
Continuity & Isolation Resistance	4.21.3	X	-

Notes for Table 4.21-1:

(1) This test shall measure each connector and cable pin to pin and pin-to-case resistance immediately after the connector or harness is subjected to the test environment.

(2) This test shall continuously monitor connector and cable continuity using a sample rate of no less than once every millisecond.

4.21.1 General. Any electrical connector or harness shall satisfy each test or analysis identified by the table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

4.21.2 Dielectric Strength. The test shall measure the dielectric withstanding voltage between mutually insulated portions of the harness or connector to demonstrate that the harness or connector satisfies all its performance specifications at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomena.

1. Dielectric Strength testing shall be taken at a minimum of 500 VDC or 150 percent of the operating voltage, whichever is greater. Measurements shall be taken between mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application.
2. The voltage used for this test shall not damage or degrade the component.
3. The measurement error at the required insulation resistance value shall not exceed 10 percent.

4.21.3 Continuity and Isolation. The test shall measure all pin-to-pin, pin-to-case and pin-to-shield resistances and demonstrate that each satisfies all its performance specifications.

Isolation resistance shall be 2 MΩ and continuity less than 0.05 ohms.

4.21.4 Insulation Resistance. The test shall demonstrate the ability of the insulation resistance between each wire shield and harness or conductor and the insulation between each harness or connector pin to every other pin to withstand the maximum expected flight voltage plus a margin.

1. Insulation resistance measurements shall be taken at a minimum of 500 VDC or 150 percent of the operating voltage, whichever is greater. Measurements shall be taken between mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application.
2. The voltage used for this test shall not damage or degrade the component.
3. The measurement error at the required insulation resistance value shall not exceed 10 percent.
4. The insulation resistance between all insulated parts shall be greater than 2 MΩ.

4.22 Silver-Zinc Batteries

TABLE 4.22-1. MANUALLY ACTIVATED SILVER-ZINC BATTERY ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	COUPON CELL[3] X=1 cell per battery	Quantity Tested X= 100% of Batteries
Cell Capacity	4.22.2	X	-
Insulation Resistance	4.22.3	-	X
Cell Proof Pressure	4.22.19a	X	X
Electrolyte	4.22.20	-	X
Battery Mounting and Case Integrity [1]	4.22.21	-	X
Component Examination	4.11.1		
Visual Examination [2], [4]	4.11.2	X	X
Internal Inspection	4.11.7	-	X
Dimension Measurement [2]	4.11.3	X	X
Weight Measurement [2]	4.11.4	X[5]	X
Identification Check [2]	4.11.5	X	X
Pre-Activation [2]	4.22.7	-	X
Continuity and Isolation [2]	4.22.4	-	X
Performance Verification	4.10.4		
Monitoring Capability [2]	4.22.8	-	X
Heater Circuit Verification [2]	4.22.9	-	X
Coupon Cell Acceptance [2]	4.22.18	X	
Activation [2]	4.22.10	X	[2]
No-load Voltage [2]	4.22.5	X	[2]
Pin-to-Case Isolation [2]	4.22.6	-	X
Electrical Performance [2]	4.22.11	X	[2]
Battery Case Proof Pressure [2]	4.22.19b	-	X

Notes for Table 4.22-1:

(1) This test applies only to any battery with a mounting or case that contains a weld.
(2) A battery shall undergo this test at the launch site just before installation.
(3) For each battery, no less than one cell that is representative of the cells that make up the battery shall undergo this test. This test shall be performed at the same location where the flight battery is activated.
(4) Visual inspection shall include subassembly verification of internal wiring and cable harnessing.
(5) Coupon cell weight measurements shall include pre and post activation weights to validate the required electrolyte has been used for activation.

TABLE 4.22-2. MANUALLY ACTIVATED SILVER-ZINC BATTERY QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [4]	
		Batteries X=3	Cells X=12
Battery and Coupon Acceptance Test	Table 4.22.1	X [7]	-
Insulation Resistance	4.22.3	X	-
Cell Proof Pressure	4.22.19a	X	X
Electrolyte	4.22.20	X	X
Battery Mounting and Case Integrity [1]	4.22.21	X	-
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Internal Inspection	4.11.7	X	
Dimension Measurement	4.11.3	X	X
Weight Measurement [9]	4.11.4	X	X
Identification Check	4.11.5	X	X
Pre-Activation	4.22.7	X	X
Continuity and Isolation	4.22.4	X	-
Non-Operating Environment Tests	4.13.1		
Storage Temperature	4.13.2	X	X
Transportation Shock	4.13.4	X	-
Bench Handling Shock	4.13.5	X	-
Transportation Vibration	4.13.6	X	-
Fungus Resistance	4.13.7	X	-
Fine Sand	4.13.8	X	-
Performance Verification	4.10.4		
Monitoring Capability	4.22.8	X	-
Heater Circuit Verification	4.22.9	X	-
Activation	4.22.10	X	X
No-load Voltage	4.22.5	X	X
Pin-to-Case Isolation	4.22.6	X	-
Electrical Performance	4.22.11	X	X
Battery Case Proof Pressure	4.22.19b	X	-
Activated Stand Time	4.22.12	X	X
Overcharge [6]	4.22.13	X	-
Charge-Discharge Cycles [6]	4.22.14	X	X
Operating Environment Tests	4.14.1		
Thermal Cycle [2], [5], [10]	4.22.15	X	X
Thermal Vacuum [2], [3], [5], [10]	4.14.3	X	-
Humidity [5]	4.14.4	X	-
Salt Fog	4.14.5	X	-
Temperature, Altitude and Humidity[8], [10]	4.14.6	X	X
Acceleration [2], [3], [5], [10]	4.14.7	X	-
Shock [3], [5], [10]	4.14.8	X	-

Table 4.22-2 Manually Activated Silver-Zinc Battery Qualification Test Requirements. (Continued)

Test	Paragraph	Quantity Tested (4)	
		Batteries X=3	Cells X=12
Operating Environment Tests (Continued)		-	
Acoustic (2), (3), (5), (10)	4.14.9	X	-
Sinusoidal Vibration (2), (3), (5), (10)	4.14.10	X	-
Random Vibration (2), (3), (5),(10)	4.14.11	X	-
Electromagnetic Interference and Compatibility (5)	4.14.12	1	-
Explosive Atmosphere (5)	4.14.13	1	-
Performance Verification	4.10.4		
Monitoring Capability	4.22.8	X	X
Heater Circuit Verification	4.22.9	X	-
Discharge and Pulse Capacity (5)	4.22.16	X	X
Pin-to-case Isolation	4.22.6	X	X
Battery Case Proof Pressure (5)	4.22.19b	X	-
Internal Inspection (5)	4.22.17	X	X

Notes for Table 4.22-2:

(1) This test applies only to any battery that has a mounting or case that contains a weld.
(2) A battery or cell shall undergo the electrical performance test of 4.22.11 section while the battery is under ambient conditions before the battery undergoes this operating environment test and again while the battery is subjected to the operating environment.
(3) This test shall include continuous monitoring of the battery to verify that the required voltage regulation is maintained while supplying the required operating steady-state current. The monitoring shall have a sample rate of once every 0.1milsecond or better. Any dropout constitutes a test failure.
(4) The same three sample batteries shall undergo each test designated with an X in that column and the same 12 sample cells shall undergo each test designated with an X in that column. For tests designated with a quantity of less than three, each battery tested shall be one of the original three sample batteries.
(5) Each battery or cell sample shall undergo this test at the end of the wet stand time after the last operating charge.
(6) This test only applies if normal operation of the battery includes charging.
(7) For each of the three battery samples, no less than one cell that is representative of the cells that make up the battery shall undergo this test. These cells, no less than three, are in addition to the 12 cells of the far right column.
(8) If this test is performed in its entirety, the humidity test and 3 cycles of the thermal cycling test required in the Manually-Activated Silver-Zinc Battery Qualification Test Requirements will not have to be performed.
(9) Weight measurements shall include pre and post activation weights to validate the required electrolyte has been used for activation.
(10) A pin to case isolation test (paragraph 4.22.6) is required before and after these specific operational environmental tests.

TABLE 4.22-3. SILVER-ZINC BATTERY STORAGE LIFE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested X=2 Cells Per Year (1)
Cell Proof Pressure	4.22.19b	X
Electrolyte	4.22.20	X
Component Examination	4.11	
Visual Examination	4.11.2	X
Dimension Measurement	4.11.3	X
Identification Check	4.11.5	X
Weight Measurement	4.11.4	X
Performance Verification	4.10.4	
Monitoring Capability	4.22.8	X
Activation	4.22.10	X
No-Load Voltage	4.22.5	X
Electrical Performance	4.22.11	X
Operating Environment Tests	4.14.1	X
Activated Stand Time	4.22.12	X
Charge-Discharge Cycles (2)	4.22.14	X
Thermal Cycling (3) (4)	4.22.15	X
Discharge and Pulse Capacity (4)	4.22.16	X
Cell Proof Pressure (4)	4.22.19b	X
Internal Inspection (4)	4.22.17	X

Notes for Table 4.22-3:

(1) Two silver-zinc cells from the production lot used for qualification testing shall undergo each test designated with an X, each year of the manufacturer specified storage life, to demonstrate that they still satisfy their performance specifications.
(2) This test only applies if normal operation of the battery includes charging.
(3) Each cell shall undergo the electrical performance test of 4.22.11 under ambient conditions before the cell undergoes this operating environment test and again while the cell is subjected to the operating environment.
(4) Each cell sample shall undergo this test at the end of the wet stand time after the last operating charge.

4.22.1 General. Any silver-zinc battery shall satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all its performance specifications when subjected to each non-operating and operating environment.

4.22.2 Cell Capacity.

a. Single Electrical Cycle. For a sample silver-zinc cell from a battery that has only one charge-discharge cycle, a capacity test shall satisfy all of the following:
   (1) The cell shall undergo activation that satisfies 4.22.10.
   (2) At the end of the manufacturer-specified wet stand time, the cell shall undergo a discharge of the nameplate capacity.
   (3) The test shall then subject the cell to the electrical performance test of 4.22.11 using the qualification electrical load profile described in 4.22.11g2.
   (4) The cell shall then undergo a final discharge to determine the positive and negative plate capacity.
   (5) The test shall demonstrate that each capacity satisfies the manufacturer specification and is in-family.

b. Multiple Electrical Cycles. For a silver-zinc cell from a battery that has more than one charge-discharge cycle, a capacity test shall satisfy all of the following:
   (1) The cell shall undergo activation that satisfies 4.22.10.
   (2) The test shall subject the cell to the maximum predicted number of charge-discharge cycles that the battery will experience during normal operations.
   (3) At the end of each cycle life after each charge, the test shall:
      - Undergo a discharge of the manufacturer nameplate capacity.
      - Then undergo the electrical performance test of 4.22.11 using the qualification electrical load profile described in 4.22.11g2.
   (4) At the end of the last charge/discharge cycle, the cell shall then undergo a final discharge to determine the positive and negative plate capacity.
   (5) The test shall demonstrate that each capacity for each cycle satisfies the manufacturer specification and is in-family.

4.22.3 Insulation Resistance. An insulation resistance test shall measure mutually insulated pin-to-pin and pin-to-case points using maximum operating voltage plus a margin. The test shall demonstrate that the internal wiring, connectors and other insulation material are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 500 VDC between the mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application. The voltage used for this test shall not damage or degrade the component.
2. Measurement error at the required insulation resistance value shall not exceed 10 percent.
3. The insulation resistance between all insulated parts shall be greater than 2 MΩ.
4. Testing shall be performed prior to connecting any battery harness to the cells.
5. This measurement should not be considered the equivalent of dielectric withstanding voltage tests.

4.22.4 Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications.

1. Isolation resistance shall be 2 MΩ and continuity measurement is less than 0.05 ohms.
2. The test shall measure the continuity of the battery harness after completion of all wiring, but before battery activation to demonstrate that the continuity resistances satisfy their performance specifications.

4.22.5 No-Load Voltage. The test shall demonstrate that each battery cell satisfies its performance specification for voltage without any load applied. A battery shall undergo this test just after introduction of electrolyte to each cell, after electrical conditioning of the battery, before and after each electrical performance test and, for a flight battery, just before installation into the launch vehicle.

4.22.6 Pin-to-case Isolation. The test shall measure voltage isolation between each pin and the battery case to demonstrate that no current leakage path exists as a result of electrolyte leakage. This measurement shall use a voltmeter with a high input impedance and has a resolution that detects any leakage current of 0.1 milliamps or greater.

1. This measurement shall use a voltmeter with an internal resistance of no less than 2 MΩ.
2. The test shall measure voltage across a circuit using a 150K ohm resistor from pin to case.

4.22.7 Pre-activation. A pre-activation test shall demonstrate that a battery or cell will not experience a loss of structural integrity or create a hazardous condition when subjected to predicted operating conditions and all required margins. This shall include all of the following:

a. The test shall demonstrate that any battery or cell pressure relief device satisfies all its performance specifications.
b. The test shall exercise 100 percent of all pressure relief devices that can function repeatedly without degradation.
c. The test shall demonstrate that each pressure relief device opens within ± 10 percent of its performance specification.

4.22.8 Monitoring Capability. A monitoring capability test shall demonstrate that each device that monitors a silver-zinc battery's voltage, current, or temperature satisfies all its performance specifications.

4.22.9 Heater Circuit Verification. A heater circuit verification test shall demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications.

4.22.10 Activation. The key points of the activation procedure are:

a. The activation of a battery or cell shall follow a procedure that is approved by the manufacturer and includes the manufacturer activation steps.
b. The activation procedure and equipment for acceptance testing shall be equivalent to those used for qualification and storage life testing.
c. The activation procedure shall include verification that the electrolyte satisfies the manufacturer specification for percentage of potassium hydroxide.
d. The quantity of electrolyte for activation of the batteries and cells for any qualification test shall satisfy all of the following:
   (1) One of the three required qualification battery samples and six of the 12 required individual qualification cell samples shall undergo activation with no less than the manufacturer specified maximum amount of electrolyte.
   (2) One of the three required qualification battery samples and six of the 12 required individual qualification cell samples shall undergo activation with no greater than the manufacturer specified minimum amount of electrolyte.

4.22.11 Electrical Performance. An electrical performance test shall demonstrate that a battery or cell satisfies all its performance specifications and is in-family while the battery is subjected to the electrical load profile described in 4.22.11g and include all of the following:

a. The test shall demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specifications and is in family with previous test results.
b. The test shall monitor each of the battery or cell's critical electrical performance parameters; including voltage, current, and temperature, with a resolution and sample rate that detects any failure to satisfy a performance specification. For a battery, the test shall monitor the battery's performance parameters and the voltage of each cell within the battery. During the current pulse portion of the load profile, the voltage monitoring shall have a sample rate of once every 0.1 millisecond or better.
c. The test shall measure a battery or cell's no-load voltage before and after the application of any load to the battery or cell.
d. A silver-zinc battery or cell shall undergo this test after the battery or cell is activated and after the manufacturer specified soak period.
e. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage of each electronic component that the battery powers while the battery or cell is subjected to the steady state portion of the load profile.
f. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the battery or cell is subjected to the pulse portion of the load profile.
g. The test load profile shall satisfy one of the following:
   (1) For acceptance testing, the load profile shall begin with a steady-state flight load that lasts for no less than 180 seconds followed without interruption by a current pulse. The pulse width shall be no less than 1.5 times the ordnance initiator

qualification pulse width or a minimum workmanship screening pulse width of 100 milliseconds, whichever is greater. The pulse amplitude shall be no less than 1.5 times the worst-case operational high current pulse. After the pulse, the acceptance load profile shall end with the application of a steady-state flight load that lasts for no less than 15 seconds; or

(2) For qualification testing or any storage life testing, the load profile shall begin with a steady-state flight load that lasts for no less than 180 seconds followed by a current pulse. The pulse width shall be no less than three times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds, whichever is greater. The pulse amplitude shall be no less than 1.5 times the worst-case operational high current pulse. After the pulse, the qualification load profile shall end with a steady-state flight load that lasts for no less than 15 seconds.

4.22.12 Activated Stand Time. An activated stand time test shall demonstrate that a silver-zinc battery or cell satisfies all its performance specifications after it is activated and subjected to the environments that the battery or cell will experience from the time it is activated until flight. This shall include all of the following requirements.

a. The test environment shall simulate the preflight battery or cell conditioning environments, including the vehicle installation environment.
b. The test environment shall simulate the worst case temperature exposure and any thermal cycling, such as due to any freezer storage, and any diurnal cycling on the launch vehicle.
c. The test shall measure the battery or cell's open-circuit voltage at the beginning and again at the end of the activated stand time to demonstrate that it satisfies its performance specifications.
d. The test shall apply an electrical load to the battery or cell at the end of the activated stand time to demonstrate whether the battery or cell is in a peroxide or monoxide chemical state that satisfies its performance specifications before undergoing any other operating environment test.

4.22.13 Overcharge. An overcharge test only applies to a battery or cell that undergoes charging during normal operations. The test shall demonstrate that the battery or cell satisfies all its performance specifications when subjected to an overcharge of no less than the manufacturer specified overcharge limit using the nominal charging rate.

4.22.14 Charge-Discharge Cycles. This test only applies to a battery or cell that undergoes charging during normal operations. The test shall satisfy all of the following:

a. The test shall subject the battery or cell sample to the maximum predicted number of charge-discharge cycles that the battery or cell will experience during normal operations.
b. After activation, each battery or cell sample shall undergo three thermal cycles at the end of the first cycle life and three thermal cycles at the end of each cycle life after each intermediate charge before the final charge.

c. During each set of three thermal cycles for each charge-discharge cycle, the test shall satisfy the thermal cycle test requirements of paragraph 4.22.15b through paragraph 4.22.15e.
d. For a battery, after the three thermal cycles for each charge-discharge cycle, the battery shall undergo a pin-to-case isolation test that satisfies 4.22.3.4.
e. Each battery or cell shall undergo a discharge of its nameplate capacity before each charge.
f. The battery or cell shall undergo any further operating environment tests only after the final charge.

4.22.15 Thermal Cycle. A thermal cycle test shall demonstrate that a silver-zinc battery or cell satisfies all its performance specifications when subjected to preflight thermal cycle environments, including acceptance testing, and flight thermal cycle environments. This shall include all of the following:

a. The test shall subject the battery or cell to no less than the acceptance-number of thermal cycles that satisfies 4.15.2a.
b. The thermal cycle environment shall satisfy all of the following:
   (1) Each thermal cycle shall range from 10 °C above the maximum predicted temperature range to 5.5 °C below. If the vehicle's telemetry system does not provide the battery's temperature before and during flight as described in 3.8.2.9, each thermal cycle shall range from 10 °C above the maximum predicted temperature range to 10 °C below.
   (2) For each cycle, the dwell-time at each high and low temperature shall last long enough for the battery or cell to achieve internal thermal equilibrium and shall last no less than one hour.
   (3) When heating and cooling the battery or cell, the temperature change at a rate that averages 1 °C per minute or the maximum predicted rate, whichever is greater.
c. Each battery or cell shall undergo the electrical performance test of 4.22.11 when the battery or cell is at ambient temperature before beginning the first thermal cycle and after completing the last cycle.
d. Each battery or cell shall undergo the electrical performance test of 4.22.11, at the high and low temperatures during the first, middle and last thermal cycles.
e. The test shall continuously monitor and record all critical performance parameters, including the battery or cell's OCV, during all thermal cycle dwell times and transitions with a resolution and sample rate that will detect any performance degradation.

4.22.16 Discharge and Pulse Capacity. A discharge and pulse capacity test shall demonstrate that a silver zinc battery or cell satisfies all its electrical performance specifications at the end of its specified capacity limit for the last operating charge and discharge cycle. The test shall include all of the following:

a. The battery or cell shall undergo discharge at flight loads until the total capacity consumed during this discharge and during all previous qualification tests reaches the manufacturer specified capacity.

b. The test shall demonstrate that the total amount of capacity consumed during the discharge test and all previous qualification tests satisfies the battery or cell's minimum performance specification.
c. After satisfying 4.22.16a and 4.22.16b above, the test shall measure the battery or cell's no-load voltage and then apply a qualification load profile that satisfies all of the following:
   (1) The load profile shall begin with a steady state flight load for no less than 180 seconds followed by a current pulse.
   (2) The pulse width shall be no less than three times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds; whichever is greater.
   (3) The pulse amplitude shall be no less than 1.5 times the worst-case operational high current pulse.
   (4) After the pulse, the qualification load profile shall end with a steady state flight load that lasts for no less than 15 seconds.
d. The test shall monitor each of the battery or cell's critical electrical performance parameters; including voltage, current, and temperature, with a resolution and sample rate that detects any failure to satisfy a performance specification. For a battery, the test shall monitor the battery's performance parameters and the voltage of each cell within the battery. During the current pulse portion of the load profile, the voltage monitoring shall have sample rate of once every 0.1 millisecond or better.
e. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage of each electronic component that the battery powers while the battery or cell is subjected to the steady state portion of the load profile.
f. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the battery or cell is subjected to the pulse portion of the load profile.
g. After satisfying 4.22.16a through 4.22.16f above, the battery or cell shall undergo a complete discharge and the test shall demonstrate that the total silver plate capacity is in-family.

1. Discharge each battery using a C/2 discharge rate to the cutoff voltage.
2. The cutoff depends on the lowest specified voltage of the electronic components or the manufacturer cutoff voltage, whichever is greater. For example, receivers are tested to a minimum of 24-volt direct current (Vdc).
3. Monitor the battery and/or cell voltage and current.
4. At a minimum, the capacity demonstrated during this test and the amp-hour drawn during the operational environmental tests shall be the manufacturer-warranted rating and be equal to, or greater than, 150 percent of the capacity that is required for actual use.

4.22.17 Internal Inspection. An internal inspection of a battery must identify any excessive wear or damage to the battery, including any of its cells, after the battery is exposed to all the qualification test environments.

a. An internal inspection shall satisfy 4.11.7.

1. An internal examination to verify that there was no movement of any component within the battery that stresses that component beyond its design limit
2. An examination to verify the integrity of all cell and wiring interconnects
3. An examination to verify the integrity of all potting and shimming materials
4. The cells shall be removed and examined for any physical damage
5. Test each cell for leaks.
6. One cell from each corner and two cells from the middle of the Qualification battery shall undergo Destructive Physical Analysis (DPA). The destructive physical analysis must verify the integrity of all connections between all plate tabs and cell terminals, and the integrity of each plate and separator. X-ray may be used as an alternate method
7. The inspection shall verify the integrity of each plate tab, identify any anomaly in each plate, including its color or shape, and identify any anomaly in each separator, including its condition, silver migration, and any oxalate crystals.

b. For storage life testing, one of the two cells required to undergo all the storage life tests shall undergo destructive physical analysis.

c. A test that demonstrates that the zinc plate capacity of the cells satisfies the manufacturer specification. For each battery sample required to undergo all the qualification tests, the test shall determine the zinc plate capacity for three cells from the battery, other than the cells used for DPA. For storage life testing, the test shall determine the zinc plate capacity for one cell that is required to undergo all the storage life tests, other than the cells used for DPA.

4.22.18 Coupon Cell Acceptance. A coupon cell acceptance test shall demonstrate that the silver-zinc cells that makeup a flight battery were manufactured the same as the qualification battery cells and satisfy all their performance specifications after being subjected to the environments that the battery experiences from the time of manufacture until activation and installation. This shall include all of the following:

a. One test cell that is from the same production lot as the flight battery, ant that has the same lot date code as the cells in the flight battery, shall undergo the test.
b. The test cell shall have been attached to the battery from the time of the manufacturer acceptance test and have experienced the same non-operating environments as the battery.
c. The test shall occur immediately before activation of the flight battery.
d. The test cell shall undergo activation that satisfies paragraph 4.22.10.
e. The test cell shall undergo discharge at a moderate rate, using the manufacturer specification, undergo two qualification load profiles of 4.22.11.g2 at the nameplate capacity, and then undergo further discharge until the minimum manufacturer

specified voltage is achieved. The test shall demonstrate that the cell's amp-hour capacity and voltage characteristics satisfy all their performance specifications and are in-family.

f. For a silver-zinc battery that will undergo charging during normal operations, the test cell shall undergo the requirements of 4.22.18e for each qualification charge-discharge cycle. The test shall demonstrate that the cell capacity and electrical characteristics satisfy all their performance specifications and are in family for each charge-discharge cycle.

1. Initial procurement of flight production batteries shall include two additional cells per year for the manufacturer stated shelf life.
2. These cells shall be of the same lot when they are procured and electrically conditioned the same way as the other batteries and/or cells.

4.22.19 Proof Pressure.

a. Cells. Each individual cell or each cell within a battery shall undergo pressurization to 1.5 times the worst case operating differential pressure or highest setting of the cell vent valve for no less than 15 seconds. The test shall demonstrate that the leak rate satisfies its performance specification. After pressurization, each cell shall remain sealed until activation. For a battery, the test shall demonstrate the integrity of each cell seal when in the battery configuration.

b. Battery Cases. Each battery case shall undergo pressurization to 1.5 times the worst case operating differential pressure for no less than 15 minutes. The test shall demonstrate no loss of structural integrity and no hazardous condition. For a sealed battery, the test shall demonstrate that the leak rate satisfies its performance specification.

4.22.20 Electrolyte. A test of each electrolyte lot for battery activation shall demonstrate that the electrolyte satisfies the manufacturer specifications, including volume and concentration.

4.22.21 Battery Mounting and Case Integrity. A battery mounting and case integrity test shall demonstrate that any welds in the battery's mounting hardware or case are free of workmanship defects using X-ray examination.

4.23 Remotely-Activated Silver-Zinc Batteries

TABLE 4.23-1. REMOTELY-ACTIVATED SILVER-ZINC BATTERY LOT ACCEPTANCE TEST REQUIREMENTS

Test (7)	**Paragraph**	**Battery Lot Acceptance Sample** (1), (3)
Low Voltage Initiator Lot Acceptance Test (12)	Table 4.28.3	-
Component Examination (2)	4.11.1	-
Visual Inspection (13)	4.11.2	100%
Dimensions Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check (13)	4.11.5	100%
X-ray	4.11.6	100%
Battery Mounting (9)	4.23.10	100%
Performance Verification (2)		
Continuity and Isolation (13)	4.23.5	100%
Dielectric Strength	4.23.4	100%
Monitoring Capability (13)	4.23.7	100%
Heater Circuit Verification (13)	4.23.11	100%
Activation Circuit (LVI) Resistance (13)	4.23.12	100%
Pin to Case Voltage Isolation	4.23.6	100%
Static Discharge	4.28.10	Lot Sample
Battery Venting	4.23.3	Lot Sample or 100%
Non-Operating Environment Tests (2)	4.13.1	
Thermal Cycle (10)	4.14.2d	Lot Sample
Performance Verification (8)	4.10.4	
Heater Circuit Verification	4.23.11	Lot Sample
Monitoring Capability	4.23.7	Lot Sample
Thermal/Electrical Performance	4.23.8	Lot Sample
Pin to Case Voltage Isolation	4.23.6	Lot Sample
Operating Environment Tests (11),(4),(5),(3)	4.14.1	
Acceleration	4.14.7	Lot Sample
Shock	4.14.8	Lot Sample
Sinusoidal Vibration	4.14.10	Lot Sample
Random Vibration	4.14.11	Lot Sample
Battery Case Integrity	4.23.2	Lot Sample
X-ray (5)	4.11.6	Lot Sample
Battery Mounting (9)	4.23.10	Lot Sample
Discharge and Pulse Capacity	4.23.9	Lot Sample

Notes for Table 4.23-1:

(1) Failure of a single battery to meet lot sample test requirement shall result in rejection of the production lot. High failure rates for 100 percent screening tests may result in rejection of the lot.
(2) These tests shall be performed prior to activation.
(3) Lot sample consists of 10 percent of the lot, 2 units or one activated unit for each operating environmental axis and thermal extreme, whichever is greater.
   a. All required operating environmental tests shall be performed on an activated unit to obtain cumulative environmental stress.
   b. Where there is insufficient time to perform all environments while the unit is activated, other operating environments shall be performed unactivated prior to the environment requiring activation. This process shall be repeated until all operating environments have been tested on the required number of activated batteries.
   c. Batteries shall be activated during each applicable operating environment if the mission profile requires activation under that operating environment such as vibration and thermal extremes.

1. For extremely short-life batteries, the worst-case number of units for testing shall be a minimum of 18 units. This includes activating batteries at hot and cold temperature and testing for 3 individual axes of vibration, shock, and acceleration.
2. Two batteries may be tested if batteries have sufficient life to perform ALL operating tests in the activated state.

(4) Thermal and operating tests shall be performed concurrently with the battery at MPE+100C and MPE-100C for each activated battery operating test. Combining thermal and operating environments for unactivated batteries shall be required if it reflects the operational flight environment. Electrical Performance tests in accordance with paragraph 4.23.8.
(5) Tests shall be performed prior to and after all operating tests in an activated state.
(6) Test required for battery brackets using welds.
(7) Batteries shall have an initial shelf-life of three to five years dependent on supporting data. Age surveillance extensions will require a tailored retest of the lot acceptance table.
(8) These tests shall be performed during all operating tests for an activated battery
(9) This test required for battery brackets using welds.
(10) Thermal cycle shall be performed using the ordnance thermal cycle requirements.
(11) The order in which each axis is tested for an activated battery shall be changed for each component to ensure that every axis is performed last on different units.
(12) Operating environments during lot acceptance testing are only required for LVIs that will be exposed to operating environments prior to functioning.
(13) These tests shall also be performed at the launch site just before installation.

TABLE 4.23-2. REMOTELY-ACTIVATED SILVER-ZINC BATTERY QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Units Tested X = 3
Component Examination [2]	4.11.1	
Visual Inspection	4.11.2	X
Dimensions Measurement	4.11.3	X
Weight Measurement	4.11.4	X
Identification Check	4.11.5	X
Battery Mounting [8]	4.23.10	X
Performance Verification [2]	4.10.4	
Continuity and Isolation	4.23.5	X
Dielectric Strength	4.23.4	X
Monitoring Capability	4.23.7	X
Heater Circuit Verification	4.23.11	X
Activation Circuit (LVI) Resistance	4.23.12	X
Pin to Case Voltage Isolation	4.23.6	X
LVI No-Fire Verification	4.28.17	X
Static Discharge	4.28.10	X
Battery Venting	4.23.3	Lot Sample or 100%
Non-Operating Environment Tests [2]	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Thermal Cycle [9]	4.14.2d	X
Thermal Vacuum [9]	4.14.3	X
Fungus Resistance	4.13.7	1
Performance Verification [6]	4.10.4	
Heater Circuit Verification	4.23.11	X
Monitoring Capability	4.23.7	X
Thermal/Electrical Performance [9], [4]	4.23.8	X
Pin to Case Voltage Isolation	4.23.6	X
Operating Environment Tests [5], [3]	4.14.1	
Salt Fog	4.14.5	X
Temperature, Altitude, Humidity	4.14.6	X
Acceleration [7],[10]	4.14.7	X
Shock [7],[10]	4.14.8	X
Acoustic [7], [10]	4.14.9	X
Sinusoidal Vibration [7], [10]	4.14.10	X
Random Vibration [7], [10]	4.14.11	X
Explosive Atmosphere	4.14.13	X
Electromagnetic Interference and Compatibility [1]	4.14.12	X
Battery Case Integrity	4.23.2	X
Battery Mounting [8]	4.23.10	X
Discharge and Pulse Capacity	4.23.9	X

Notes for Table 4.23-2:

(1) This test only required if battery contains EMI producing devices such as hall-effect current monitoring circuits and battery heaters/thermostats.
(2) These tests shall be performed prior to activation.
(3) Thermal and operating tests shall be performed concurrently with the battery at MPE+100C and MPE-100C for each activated battery operating test. Combining thermal and operating environments for unactivated batteries shall be required if it reflects the operational flight environment. Electrical Performance tests shall be performed in accordance with paragraph 4.23.8 at each thermal extreme.
(4) Tests shall be performed prior to and after all operating tests in an activated state.
(5) Qualification consists of a minimum of three activated units for each operating environmental axis and thermal extreme.
   a. All required operating environmental tests shall be performed on an activated unit to obtain cumulative environmental stress.
   b. Where there is insufficient time to perform all environments while the unit is activated, other operating environments shall be performed unactivated prior to the environment requiring activation. This process shall be repeated until all operating environments have been tested on the required number of activated batteries.
   c. Batteries shall be activated during each applicable operating environment if the mission profile requires activation under that operating environment such as vibration and thermal extremes.

1. For extremely short-life batteries, the worst-case number of units for testing shall be a minimum of 27 units. This includes activating three batteries for 3 individual axes of vibration, shock, and acceleration. Activation at hot and cold temperature may be required if batteries will be activated at extreme temperatures.
2. Six batteries may be tested if batteries have sufficient life to perform ALL operating environments with the battery activated at hot and cold temperature.
3. Three batteries may be tested if they have sufficient life to perform ALL operating environments in an activated state and the batteries are operationally activated at only ONE temperature. This test scenario would only require activation at the mission qualification temperature.

(6) These tests shall be performed after battery activation.
(7) Apply expected steady state current load for the duration of the test and monitor at 0.1 sec resolution for dropouts.
(8) This test required for battery brackets using welds.
(9) Thermal cycle shall be performed using the ordnance thermal cycle requirements.
(10) The order in which each axis is testing shall be changed for each component to ensure that every axis is performed last on different units.

4.23.1 General.

a. After qualifying a battery design for use by an FTS, acceptance tests are performed on production batteries that will be used in the FTS.

b. Because it is not possible to accurately determine the ability of these reserve batteries to perform acceptably without destructive testing, sample sizes are shown in the test tables and can also be adjusted to accommodate vehicle-dependent variation in the operating environments, as agreed upon by the range representative during tailoring of the FTS battery requirement specification.

c. The ability to activate batteries is primarily a mission assurance concern, in that, if the battery does not meet its required performance, the launch will not be allowed to continue. However, to ensure adequate mission assurance, LVI component and system testing shall be performed in accordance with the LVI requirements.

d. For short-life batteries that do not have the lifetime to be subjected to all environments while activated, multiple batteries shall be added to ensure that the required lot sample is exposed to each required environment.

e. For short-life batteries that do not have the lifetime to be subjected to all environments while activated, multiple batteries will be added to ensure that the required lot sample is exposed to each required environment.

Short-Life Batteries:

a. All required operating and non-operating environments shall be performed on each battery to obtain cumulative effects. These environments may be performed with the battery in the unactivated state.
b. After the unactivated battery has been exposed to all non-operating and operating tests not part of the activated battery testing, the battery shall be activated and complete all the remaining operating tests.
c. These tests shall be repeated until each required operating environment has been tested with three batteries in an activated state.
d. This methodology significantly increases the samples and amount of testing.

f. For an activated battery, these tests shall include continuous monitoring to verify that the required voltage regulation is maintained while supplying the required operating steady-state current. The monitoring shall have a sample rate of once every 0.1 milliseconds or better. Any dropout constitutes a test failure.

g. For vehicles that experience thermal limits during flight, concurrent environmental testing is required. The specified tests shall be performed with the unit under test at MPE±100C.

4.23.2 Battery Case Integrity. A battery case integrity test of a sealed battery shall demonstrate that the battery will not lose structural integrity or create a hazardous condition after being activated and subjected to all predicted operating conditions. The battery leak rate shall satisfy all its performance specifications required in paragraph 4.11.8.

4.23.3 Battery Venting Devices. A test of a battery venting device shall demonstrate that the battery will not experience a loss of structural integrity or create a hazardous condition when subjected to any electrical discharge, charging, or short-circuit condition and satisfy the following requirements:

a. Reusable Venting Devices. For a venting device that is capable of functioning repeatedly without degradation, such as a vent valve, the test shall exercise the device and demonstrate that it satisfies all its performance specifications.
b. Non-Reusable Venting Devices. For a venting device that does not function repeatedly without degradation, such as a burst disc, the test shall exercise a lot sample to demonstrate that the venting device satisfies all its performance specifications. The test shall demonstrate that each device sample vents within ± 10 percent of the manufacturer specified average vent pressure.

4.23.4 Dielectric Strength. The test shall measure the dielectric withstanding voltage between mutually insulated portions of the connector to demonstrate that the internal wiring meets all its performance specifications at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomena.

1. Dielectric Strength testing shall be taken at a minimum of 500 VDC or 150 percent of the operating voltage, whichever is greater. Measurements shall be taken between mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application.
2. The voltage used for this test shall not damage or degrade the component.

4.23.5 Continuity and Isolation. The test shall demonstrate that all battery wiring and connectors are installed according to the manufacturer specifications. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications and are in-family.

Isolation shall be a minimum of 2 MΩ at 500 volts DC.

4.23.6 Pin-to-case Isolation. The test shall measure voltage isolation between each pin and the battery case to demonstrate that no current leakage path exists as a result of electrolyte leakage. This measurement shall use a voltmeter with a high input impedance and has a resolution that detects any leakage current of 0.1 milliamps or greater.

1. This measurement shall use a voltmeter with an internal resistance of no less than 2 MΩ.
2. The test shall measure voltage across a circuit using a 150K ohm resistor from pin to case.

4.23.7 Monitoring Capability. A monitoring capability test shall demonstrate that any internal battery monitoring capability used to measure battery's voltage, current, and temperature satisfies all its performance specifications.

4.23.8 Electrical Performance. An electrical performance test shall demonstrate that a battery satisfies all its performance specifications while the battery is subjected to the electrical load profile described in 4.23.8d below and include all of the following:

a. The test shall demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the performance specifications and is in family with previous test results.
b. The test shall monitor each of the battery critical electrical performance parameters; including voltage, current, and temperature, with a resolution and sample rate that detects any failure to satisfy a performance specification. During the load profile, the monitoring shall have a sample rate of once every 0.1 millisecond or better.
c. The battery shall undergo this test after the battery is activated and after the manufacturer specified wet-life.
d. Load Testing.
   (1) The test shall measure a battery no-load voltage before and after the application of any load to the battery.
   (2) Apply steady state current load for the duration of the test.
   (3) Perform design pulse load and pulse width at the beginning and end of each operating test and verify battery meets all performance requirements.
   (4) After the pulse, the qualification load profile shall end with a steady-state flight load that lasts for no less than 15 seconds.

4.23.9 Discharge and Pulse Capacity. A discharge and pulse capacity test shall demonstrate that a sliver zinc battery or cell satisfies all its electrical performance specifications at the end of its specified capacity limit for the last operating charge and discharge cycle. The test shall include all of the following:

a. The battery shall undergo discharge at flight loads until the capacity consumed during this discharge and during all previous tests reaches the manufacturer specified capacity. A minimum of one battery shall be discharged at MPE + 100C and one battery at MPE- 100C.
b. Perform testing in accordance with 4.23.8 above.
c. The battery shall undergo a complete discharge and the test shall demonstrate that the total capacity meets performance requirements.

1. Discharge each battery using a C/2 discharge rate to the cutoff voltage.
2. The cutoff depends on the lowest specified voltage of the electronic components or the manufacturer cutoff voltage, whichever is greater. For example, receivers are tested to a minimum of 24-volt direct current (Vdc).
3. Monitor the battery and/or cell voltage and current.
4. At a minimum, the capacity demonstrated during this test and the amp-hour drawn during the operational environmental tests shall be the manufacturer-warranted rating and be equal to, or greater than, 150 percent of the capacity that is required for actual use.

4.23.10 Battery Mounting. A battery mounting and case integrity test shall demonstrate that any welds in the battery's mounting hardware or case are free of workmanship defects using X-ray examination or pull testing. X-ray shall meet the requirements of paragraph 4.11.6.

4.23.11 Heater Circuit Verification. A heater circuit verification test shall demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications. At a minimum, heater circuit resistance shall be measured.

4.23.12 Activation Circuit Low Voltage Initiator (LVI) Resistance. An ordnance initiated battery activation circuit shall be tested to ensure it meets its required performance specifications.

4.24 Thermal Batteries

TABLE 4.24-1. THERMAL BATTERY LOT ACCEPTANCE TEST REQUIREMENTS

Test (7)	**Paragraph**	**Battery Lot Acceptance Sample** (1), (3)
Low voltage Initiator Lot Acceptance Test (12)	Table 4.28.3	-
Component Examination (2)	4.11.1	
Visual Inspection (6), (13)	4.11.2	100%
Dimensions Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check (13)	4.11.5	100%
X-ray Inspection	4.11.6	100%
Battery Mounting (9)	4.24.7	100%
Performance Verification (2)		
Continuity and Isolation (13)	4.24.4	100%
Dielectric Strength	4.24.3	100%
Cell Stack Polarity	4.24.9	100%
Monitoring Capability (13)	4.24.5	100%
Activation Circuit (LVI) Resistance (13)	4.24.8	100%
Pin to Case Voltage Isolation	4.24.11	X
Static Discharge	4.28.10	Lot Sample
Non-Operating Environment Tests (2)	4.13.1	
Thermal Cycle (10)	4.14.2d	Lot Sample
Performance Verification (6)	4.10.4	
Thermal/Electrical Performance (10)	4.24.6	Lot Sample
Operating Environment Tests (11), (4), (3)	4.14.1	
Acceleration	4.14.7	Lot Sample
Shock	4.14.8	Lot Sample
Sinusoidal Vibration	4.14.10	Lot Sample
Random Vibration	4.14.11	Lot Sample
Battery Case Integrity	4.24.2	Lot Sample
X-ray (5)	4.11.6	Lot Sample
Battery Mounting(9)	4.24.7	Lot Sample

Notes for Table 4.24-1:

(1) Failure of a single battery to meet lot sample test requirement shall result in rejection of the production lot. High failure rates for 100 percent screening tests may result in rejection of the lot.

(2) These tests shall be performed prior to activation.

(3) Lot sample consists of 10 percent of the lot, 6 units or one activated unit for each operating environmental axis and thermal extreme, whichever is greater.

a. All required operating environmental tests shall be performed on an activated unit to obtain cumulative environmental stress.

b. Where there is insufficient time to perform all environments while the unit is activated, other operating environments shall be performed unactivated prior to the environment requiring activation. This process shall be repeated until all operating environments have been tested on the required number of activated batteries.

c. Batteries shall be activated during each applicable operating environment if the mission profile requires activation under that operating environment such as vibration and thermal extremes.

1. For extremely short-life batteries, the worst-case number of units for testing shall be a minimum of 18 units. This includes activating batteries at hot and cold temperature and testing for 3 individual axes of vibration, shock, and acceleration.
2. Six batteries may be tested if batteries have sufficient life to perform ALL operating tests in the activated state.

(4) Thermal and operating tests shall be performed concurrently with the battery at MPE+100C and MPE-100C for each activated battery operating test. Combining thermal and operating environments for unactivated batteries shall be required if it reflects the operational flight environment. Electrical Performance tests shall be performed in accordance with paragraph 4.24.6 at each thermal extreme.

(5) Reserved.

(6) Visual inspection includes verifying that the “Activation Indicator” indicates that the battery is in the proper state.

(7) Batteries shall have an initial shelf-life of three to five years dependent on supporting data. Age surveillance extensions will require a tailored retest of the lot acceptance table.

(8) Reserved.

(9) This test required for battery brackets using welds.

(10) Thermal cycle shall be performed using the ordnance thermal cycle requirements.

(11) The order in which each axis is tested for an activated battery shall be changed for each component to ensure that every axis is performed last on different units.

(12) Operating environments during lot acceptance testing are only required for LVIs that will be exposed to operating environments prior to functioning.

(13) These tests shall also be performed at the launch site just before installation.

TABLE 4.24-2. THERMAL BATTERY QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Units Tested [5]
Component Examination [2]	4.11.1	
Visual Inspection	4.11.2	X
Dimensions Measurement	4.11.3	X
Weight Measurement	4.11.4	X
Identification Check	4.11.5	X
Battery Mounting [8]	4.24.7	X
Performance Verification [2]	4.10.4	
Continuity and Isolation	4.24.4	X
Dielectric Strength	4.24.3	X
Monitoring Capability	4.24.5	
Cell Stack Polarity	4.24.9	X
Activation Circuit (LVI) Resistance	4.24.8	X
Pin to Case Voltage Isolation	4.24.11	X
LVI NO-FIRE	4.28.17	X
Static Discharge	4.28.10	X
Battery Venting	4.23.3	Lot Sample or 100%
Non-Operating Environment Tests [2]	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Thermal Cycle [9]	4.14.2d	X
Thermal Vacuum [9]	4.14.3	X
Fine Sand	4.13.8	1
Fungus Resistance	4.13.7	1
Performance Verification [6]	4.10.4	
Thermal/Electrical Performance [9], [4]	4.24.6	X
Pin to Case Voltage Isolation	4.24.11	X
Operating Environment Tests [5], [3]	4.14.1	
Salt Fog	4.14.5	X
Temperature, Altitude, Humidity	4.14.6	X
Acceleration [7] [10]	4.14.7	X
Shock [7] [10]	4.14.8	X
Acoustic [7] [10]	4.14.9	X
Sinusoidal Vibration [7] [10]	4.14.10	X
Random Vibration [7] [10]	4.14.11	X
Explosive Atmosphere	4.14.13	X
Electromagnetic Interference and Compatibility [1]	4.14.12	X
Battery Case Integrity	4.24.2	X
Battery Mounting [8]	4.24.7	X
Discharge and Pulse Capacity	4.24.10	X

Notes for Table 4.24-2:

(1) This test only required if battery contains EMI producing devices such as hall-effect current monitoring circuits and battery heaters/thermostats.
(2) These tests shall be performed prior to activation.
(3) Thermal and operating tests shall be performed concurrently with the battery at MPE+100C and MPE-100C for each activated battery operating test. Combining thermal and operating environments for unactivated batteries shall be required if it reflects the operational flight environment. Electrical Performance tests shall be performed in accordance with paragraph 4.24.6 at each thermal extreme.
(4) Tests shall be performed prior to and after all operating tests in an activated state.
(5) Qualification consists of six units or one activated unit for each operating environmental axis and thermal extreme, whichever is greater.
   a. All required operating environmental tests shall be performed on an activated unit to obtain cumulative environmental stress.
   b. Where there is insufficient time to perform all environments while the unit is activated, other operating environments shall be performed unactivated prior to the environment requiring activation. This process shall be repeated until all operating environments have been tested on the required number of activated batteries.
   c. Batteries shall be activated during each applicable operating environment if the mission profile requires activation under that operating environment such as vibration and thermal extremes.

1. For extremely short-life batteries, the worst-case number of units for testing shall be a minimum of 18 units. This includes activating batteries at hot and cold temperature and testing for 3 individual axes of vibration, shock, and acceleration.
2. Six batteries may be tested if batteries have sufficient life to perform ALL operating tests in the activated state.

(6) These tests performed after the battery is activated
(7) Apply expected steady state current load for the duration of the test and monitor at 0.1 sec resolution for dropouts
(8) This test required for battery brackets using welds.
(9) Thermal cycle and thermal vacuum shall be performed using the ordnance thermal cycle requirements.
(10) The order in which each axis is testing shall be changed for each component to ensure that every axis is performed last on different units.

4.24.1 General.

a. After qualifying a battery design for use by an FTS, acceptance tests are performed on production batteries that will be used in the FTS.

b. Because it is not possible to accurately determine the ability of these reserve batteries to perform acceptably without destructive testing, sample sizes are shown in the test tables and can also be adjusted to accommodate vehicle-dependent variation in the operating environments, as agreed upon by the range representative during tailoring of the FTS battery requirement specification.

c. The ability to activate batteries is primarily a mission assurance concern, in that, if the battery does not meet its required performance, the launch will not be allowed to continue. However, to ensure adequate mission assurance, LVI component and system testing shall be performed in accordance with the LVI requirements.

d. For short-life batteries that do not have the lifetime to be subjected to all environments while activated, multiple batteries shall be added to ensure that the required lot sample is exposed to each required environment.

e. For short-life batteries that do not have the lifetime to be subjected to all environments while activated, multiple batteries will be added to ensure that the required lot sample is exposed to each required environment.

Short-Life Batteries.

a. All required operating and non-operating environments shall be performed on each battery to obtain cumulative effects. These environments may be performed with the battery in the unactivated state.
b. After the unactivated battery has been exposed to all non-operating and operating tests not part of the activated battery testing, the battery shall be activated and complete all the remaining operating tests.
c. These tests shall be repeated until each required operating environment has been tested with three batteries in an activated state.
d. This methodology significantly increases the samples and amount of testing.

f. For an activated battery, these tests shall include continuous monitoring to verify that the required voltage regulation is maintained while supplying the required operating steady-state current. The monitoring shall have a sample rate of once every 0.1 milliseconds or better. Any dropout constitutes a test failure.

g. For vehicles that experience thermal limits during flight, concurrent environmental testing is required. The specified tests shall be performed with the unit under test at MPE±100C.

4.24.2 Battery Case Integrity. A battery case integrity test of a sealed battery shall demonstrate that the battery will not lose structural integrity or create a hazardous condition after being

activated and subjected to all predicted operating conditions. The battery leak rate shall satisfy all its performance specifications required in paragraph 4.11.8.

4.24.3 Dielectric Strength. The test shall measure the dielectric withstanding voltage between mutually insulated portions of the connector to demonstrate that the internal wiring meets all its performance specifications at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomena.

1. Dielectric Strength testing shall be taken at a minimum of 500 VDC or 150 percent of the operating voltage, whichever is greater. Measurements shall be taken between mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application.
2. The voltage used for this test shall not damage or degrade the component.

4.24.4 Continuity and Isolation. The test shall demonstrate that all battery wiring and connectors are installed according to the manufacturer specifications. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications and are in-family.

Isolation shall be a minimum of 2 MΩ at 500 volts DC.

4.24.5 Monitoring Capability. A monitoring capability test shall demonstrate that any internal battery monitoring capability used to measure battery's voltage, current, and temperature satisfies all its performance specifications.

4.24.6 Electrical Performance. An electrical performance test shall demonstrate that a battery satisfies all its performance specifications while the battery is subjected to the electrical load profile described in 4.24.6c below and include all of the following:

a. The test shall demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the performance specifications and is in family with previous test results.
b. The test shall monitor each of the battery critical electrical performance parameters; including voltage, current, and temperature, with a resolution and sample rate that detects any failure to satisfy a performance specification. The load profile monitoring shall have a sample rate of once every 0.1 millisecond or better.
c. Load Testing.
   (1) Apply design steady state and pulse load profile for the duration of the test.
   (2) The test shall end with a design steady-state flight load until cutoff voltage is achieved.

4.24.7 Battery Mounting. A battery mounting and case integrity test shall demonstrate that any welds in the battery's mounting hardware or case are free of workmanship defects using X-ray examination or pull testing. X-ray shall meet the requirements of paragraph 4.11.6.

4.24.8 Activation Circuit Low Voltage Initiator (LVI) Resistance. An ordnance initiated battery activation circuit shall be tested to ensure it meets its required performance specifications.

4.24.9 Cell Stack Polarity. The polarity of an unactivated thermal battery cell stack in each of the tapped sections shall be measured. The test shall determine that the battery cell stacks have been properly connected to the terminal pins or connector.

1. The polarity test shall be performed at ambient temperature on the unactivated batteries.
2. Using a high input impedance voltmeter (electrometer), measure the voltage produced on each battery section and any cell stack taps present. If a measurable voltage is not produced by the battery at room temperature, place the battery in a warmer temperature chamber (but not higher than the maximum non-operating temperature specified for the battery) for at least one hour, and repeat the test.
3. The correct polarity of each voltage output in the battery shall be verified.
4. This test shall not be performed on an activated battery.

4.24.10 Discharge and Pulse Capacity. A discharge and pulse capacity test shall demonstrate that a sliver zinc battery or cell satisfies all its electrical performance specifications at the end of its specified capacity limit for the last operating charge and discharge cycle. The test shall include all of the following:

a. The battery shall undergo discharge at flight loads until the capacity consumed during this discharge and during all previous tests reaches the manufacturer specified capacity. A minimum of one battery shall be discharged at MPE + 100C and one battery at MPE- 100C.
b. Perform testing in accordance with 4.24.9 above.
c. The battery shall undergo a complete discharge and the test shall demonstrate that the total capacity meets performance requirements.

1. Discharge each battery using a C/2 discharge rate to the cutoff voltage.
2. The cutoff depends on the lowest specified voltage of the electronic components or the manufacturer cutoff voltage, whichever is greater. For example, receivers are tested to a minimum of 24-volt direct current (Vdc).
3. Monitor the battery and/or cell voltage and current.
4. At a minimum, the capacity demonstrated during this test and the amp-hour drawn during the operational environmental tests shall be the manufacturer-warranted rating and equal to, or greater than, 150 percent of the capacity that is required for actual use.

4.24.11 Pin-to-case Voltage Isolation. The test shall measure voltage isolation between each pin and the battery case to demonstrate that no current leakage path exists as a result of electrolyte leakage. A voltmeter with a high input impedance and a resolution that detects any leakage current of 0.1 milliamps or greater shall be used.

1. This measurement shall use a voltmeter with internal resistance of no less than 2 MΩ.
2. The test shall measure voltage across a circuit using a 150K ohm resistor from pin to case.

4.25 Commercial Nickel-Cadmium Batteries

TABLE 4.25-1. NICKEL CADMIUM CELL LOT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination (2)	4.11	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Cell Inspection and Preparation	4.25.3	100%
Cell Screening (1), (2)		
Cell Reusable Venting Devices	4.25.2a	100%
Cell Conditioning	4.25.4	100%
Cell Characterization	4.25.5	100%
Charge Retention	4.25.6	100%
Performance At Low Temperature	4.25.7	100%
Cell leakage	4.25.19	100%
Cell Selection	4.25.20	
Final Cell Screening	4.25.20a	100%
Final Cell Matching (5)	4.25.20b	100%
X-ray Inspection (6)	4.11.6	100%
Lot Sample Tests (3)		
Non-Reusable Venting Devices	4.25.2b	Lot Sample (4)
Post Acceptance Storage (5)	4.25.8	100%

Notes for Table 4.25-1:

(1) Cell screening shall begin only after all sub-assembly operations have been completed on the cells such as tab welding, ink/paint application, adhesive tape application, coatings, individual cell sleeving. Screening of each lot of cells shall be completed prior to being assembled into batteries.
(2) Unless otherwise annotated, if any cell fails any of these tests, the individual cell is disqualified for use.
(3) If any cell sample fails to pass these tests, the entire lot is disqualified for use.
(4) Lot sample shall 10 percent of the lot with a minimum of five units to a maximum of 15 samples.
(5) After final cell matching, cells shall be assembled into batteries or stored as matched groups.
(6) X-ray inspection shall demonstrate tab integrity at 0 degrees and 90 degrees axes. These cells shall be used in the cell lot and/or battery qualification test units and reinspected after testing by X-ray.

TABLE 4.25-2. NICKEL CADMIUM BATTERY ACCEPTANCE TEST REQUIREMENTS

Test (1)	**Paragraph**	**Quantity Tested**
Cell Lot Acceptance (2)	Table 4.25.1	100% of Cells
Component Examination (7)	4.11.1	
Identification Check (8)	4.11.5	100%
Visual Examination (8)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Performance Verification (7)	4.10.4	
Continuity and Isolation (8)	4.25.10	100%
Charge Retention (8)	4.25.6	100%
Monitoring Capability (8)	4.25.12	100%
Heater Circuit Verification (8)	4.25.13	100%
Non-Reusable Venting Devices (Battery Only)	4.25.2b	Lot Sample (6)
Operating Environment Tests (5) (7)	4.15.1	
Acceptance Thermal Cycle	4.25.15	100%
Acoustic (4)	4.15.4	100%
Sinusoidal (4)	4.15.5	100%
Random Vibration (4)	4.15.6	100%
Performance Verification (7)	4.10.4	
Charge Retention	4.25.6	100%
Electrical Performance (8)	4.25.14	100%
Continuity, Isolation and Insulation Resistance	4.25.10	100%
Component Examination (7)	4.11	
Visual Examination	4.11.2	100%
Reusable Venting Devices (3) (Battery Only)	4.25.2a	100%
Battery Case Integrity (3)	4.25.11	100%
Post Acceptance Storage	4.25.8	100%

Notes for Table 4.25-2:

(1) Each test that requires a battery to undergo a charge or discharge shall satisfy paragraph 4.25.1b. Unless otherwise specified, each test shall begin with the battery fully charged.
(2) All cells used in each qualification or flight battery shall pass all the cell lot acceptance tests of Table 4.25.1.
(3) This test is required only for a sealed battery.
(4) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load during the operating environment An Electrical Performance Test IAW paragraph 4.25.14 shall be performed during the operating environment. The monitoring must have a sample rate of once every 0.1-millisecond or more, and demonstrate that the voltage does not experience any dropouts.
(5) If any cell failure occurs during environmental acceptance testing, the battery and all cells within the battery shall be rejected. The battery case may be recycled, populated with all new cells and restart a new acceptance test. Cells that fail prior to environmental testing may be replaced with a new cell from the same matched group.
(6) Lot sample shall be 10 percent of the lot with a minimum of three units to a maximum of nine samples.
(7) Initial service life of the battery shall be established based on data that demonstrates the battery will survive operating environments at the end of its initial service life. Recertification after the initial service life shall be conducted by re-performing these acceptance tests from this Table. The timetable for recertification shall demonstrate that the battery will survive operating environments at the end of its extended service life.

1. Initial service life of the battery is 4 years from date of cell manufacturing.
2. Service life extension beyond 4 years can be performed using one of the following methods:
   a. Acceptance testing may be re-performed to extend the life of the flight battery an additional 1 year after the initial service life has expired. Reacceptance testing may only be repeated two times on the same battery.
   b. Service Life Extension testing IAW Table 4.25.4

(8) These tests shall also be performed at the launch site just before installation.

TABLE 4.25-3. NICKEL CADMIUM CELL LOT AND BATTERY QUALIFICATION TEST REQUIREMENTS

Test [1], [12]	Paragraph	Qualification [10] Quantity Tested X = 3 Batteries	Cell Lot Qualification [1], [2] Quantity Tested X = 3 Batteries
Battery Acceptance Tests [3]	Table 4.25.2	X	X
Non-Operating Environment Tests	4.13.1		
Storage Temperature	4.13.2	X	X
Transportation Shock	4.13.4	X	X
Bench Shock	4.13.5	X	X
Transportation Vibration	4.13.6	X	X
Fungus Resistance	4.13.7	1	1
Fine Sand	4.13.8	1	1
Performance Verification	4.10.4		
Cycle Life and Pulse Margin	4.25.9	X	X
Operating Environment Tests	4.14.1		
Thermal Cycling	4.25.16	X	X
Thermal Vacuum [4]	4.14.3	X	X
Humidity [6]	4.14.4	X	1
Salt Fog [13]	4.14.5	X	X
Temperature/Humidity/Altitude [7]	4.14.6	X	1
Acceleration [5], [7]	4.14.7	X	X
Shock [5]	4.14.8	X	X
Acoustic [5], [7]	4.14.9	X	X
Sinusoidal Vibration [5], [7]	4.14.10	X	X
Random Vibration [5], [7]	4.14.11	X	X
EMI/EMC	4.14.12	1	1
Performance Verification	4.10.4		
Continuity, Isolation and Insulation Resistance	4.25.10	X	X
Electrical Performance	4.25.14	X	X
Charge Retention	4.25.6	X	X
Operational Stand Time	4.25.17	X	X
Flight Self-Discharge	4.25.21	X	X
Battery Case Integrity [8]	4.25.11	X	X
Explosive Atmosphere	4.14.13	1	1
Internal Inspection	4.25.18	1	1

Notes for Table 4.25-3:

(1) Each new lot of cells shall satisfy all the tests required by this table to demonstrate that any variation in parts, material, or processes between each lot does not affect cell performance. For each new cell lot, three battery assemblies that are made up of cells from the lot shall undergo each test required by this table to demonstrate that each battery and each cell satisfy all their performance specifications when in their packaged flight configuration.

(2) Cell lot qualification testing may not be required if the parts materials and processes for cell manufacturing are placed under configuration control including chemical sources and manufacturing equipment. . A configuration audit shall be performed to demonstrate that each new lot of cells uses the same parts, materials, chemical sources, manufacturing equipment and processes as the lot of cells used for the original qualification.

(3) Each qualification test battery shall pass all the acceptance tests of Table 4.25.2.

(4) Electrical testing shall be performed IAW paragraph 4.25.16e.

(5) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a 0.1 ms rate.

(6) Cycle 5 performance test shall be a capacity discharge test to determine charge retention IAW paragraph 4.26.4 followed by an electrical test IAW paragraph 4.25.14.

(7) Electrical performance testing shall be performed IAW paragraph 4.25.14.

(8) This test is only required for a sealed battery.

(9) Reserved.

(10) Qualification testing is a one time test as long as parts, materials and processes are maintained on the battery.

(11) Reserved.

(12) Each test that requires a battery to undergo a charge or discharge shall satisfy paragraph 4.25.1b. Unless otherwise specified, each test shall begin with the battery fully charged.

(13) Batteries shall begin fully charged. Upon completing exposure to the operating environment , determine charge retention at ambient conditions followed by a continuity and isolation test.

TABLE 4.25-4. NICKEL CADMIUM BATTERY AND CELL SERVICE LIFE REQUIREMENTS		
Test (1)	**Paragraph**	**Quantity X = 1**
Acceptance Testing (2),(6)	Table 4.25.2	X
Cycle Life and Pulse Margin (2)	4.25.9	X
Service Life Extension (5)		
Thermal Cycle	4.25.16	X
Shock (3)	4.14.8	X
Sinusoidal Vibration (4), (3)	4.14.10	X
Random Vibration (4), (3)	4.14.11	X
Continuity, Isolation and Insulation Resistance	4.25.10	X
Electrical Performance	4.25.14	X
Charge Retention	4.25.6	X
Operational Stand Time	4.25.17	X
Flight Self-Discharge	4.25.21	X
Internal Inspection	4.25.18	X

Notes for Table 4.25-4:

(1) The Age Surveillance batteries shall be stored in similar conditions or along with the flight batteries according to the Post Acceptance Storage requirements.
(2) Not required for existing qualification test assets.
(3) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a 0.1 ms rate.
(4) Electrical performance test shall be IAW paragraph 4.25.14.
(5) Service life of the cell lot may be extended by re-qualifying one battery representing that cell lot. Failure of service life testing invalidates all the batteries from that cell lot.

1. Service life extension of the batteries is 3 years from the completion date of life extension testing.
2. Battery used for service life extension may be from newly assembled batteries or existing qualification test assets.

(6) Reacceptance testing is not required for service life extension testing.

4.25.1 General.

a. Compliance. Any commercial nickel-cadmium battery shall satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all its performance specifications when subjected to each non-operating and operating environment.

b. Charging and Discharging of Batteries and Cells. Each test required by any table of this section that requires a battery or cell to undergo a charge or discharge shall include all of the following:

(1) The rate of each charge or discharge shall prevent any damage to the battery or cell and provide for the battery or cell's electrical characteristics to remain consistent. Unless otherwise specified, the battery shall be charged and recharged during acceptance and qualification testing using the same procedure, equipment, and parameters as used during prelaunch. The specification for battery charging shall be provided to Range Safety prior to approval of any test procedures.

1. A discharge of a cell shall subject the cell to the discharge rate until the cell voltage is less than 1.0 volt.
2. A discharge of a battery, shall subject the battery to the discharge rate until the battery voltage is less than 1.0 volt times the number of cells in the battery.
3. Each discharge shall include monitoring of voltage, current, and time with sufficient resolution and sample rate to determine capacity and demonstrate that the battery or cell is in-family.
4. The discharge rate shall be slow enough to prevent cell damage due to cell reversal.

(2) A charge of a battery or cell shall satisfy the manufacturer charging specifications and procedures. When a battery or cell is required to be fully charged, charging shall ensure that the battery capacity will meet the specification. A battery or cell shall not be overcharged such that it will damage the cell or create a hazardous condition.

1. The charging input to the battery or cell shall be no less than 160 percent of the manufacturer specified capacity. The charge rate shall not exceed C/10 unless the Range User demonstrates that a higher charge rate does not damage the battery or cell and results in repeatable battery or cell performance.
2. To avoid creating a hydrogen gas explosion hazard:
   a. The cell voltage shall not exceed 1.55 volts during charging.
   b. The battery voltage shall not exceed 1.55 volts times the number of cells in the battery during charging.

(3) The battery or cell's critical electrical performance parameters shall be monitored with a resolution, precision, accuracy and sample rate to detect any failure to satisfy a performance specification.

1. During the current pulse portion of the load profile, the monitoring must have a sample rate of once every 0.1 millisecond or better.
2. Voltage monitoring during vibration must have a minimum resolution of 10 mV.

(4) The number of charge/discharge cycles shall be recorded.

4.25.2 Venting Devices. A test of a battery or cell venting device shall demonstrate that the battery or cell will not experience a loss of structural integrity or create a hazardous condition when subjected to any electrical discharge, charging, or short-circuit condition. The vent shall protect the cell or battery from a catastrophic rupture that could injure personnel or disable adjacent FTS components.

a. Reusable Venting Devices. For a venting device that is capable of functioning repeatedly without degradation, such as a vent valve, the test shall exercise the device and demonstrate that it satisfies all its performance specifications.

This test may be performed on vents at the subassembly level.

b. Non-Reusable Venting Devices. For a venting device that does not function repeatedly without degradation, such as a burst disc, the test shall exercise a lot sample to demonstrate that the venting device satisfies all its performance specifications.

The test shall demonstrate that each device sample vents within ± 10 percent of the manufacturer specified vent pressure.

4.25.3 Cell inspection and preparation. A cell removed from storage shall undergo inspection and preparation prior to undergoing any testing.

a. Record lot date code, part number and verify cells were manufactured consecutively as part of a single lot.

b. Demonstrate that the cell is clean and free of manufacturing defects

Inspect for missing or loose parts by shaking each cell by hand and listening for a rattling noise

c. Demonstrate that the cell has no leak.

1. Phenolphthalein is an appropriate indicator for determining leakage of hydroxides.
2. Phenolphthalein shall be applied by cotton swab to the vent and crimp areas of the cell. After inspecting for color change, clean off the chemical indicator with purified water or isopropyl alcohol and dry.
3. If color change is noted, thoroughly clean the entire cell with purified water or isopropyl alcohol and dry. Wait at least 24 hours and re-check for leaks. If leakage is indicated a second time, remove the cell from screening.
4. The electrolyte in NiCd cells has a very low surface tension and easily wicks. Thus, one leaky cell can easily contaminate all cells in same storage or shipping container. Only the leaky cell shall be discarded, all others shall be cleaned and screened.

d. As part of the receiving inspection, verify each cell was delivered in its expected discharged state (depth of discharge).

1. NiCd cells shall be stored and shipped in a partially charged state in accordance with manufacturer's specification.
2. If delivered cells have an OCV greater than 0.9, then they should be discharged at a rate that will not cause damage to the cells (usually less than C/20) to manufacturer's specified end of discharge voltage.
3. If any delivered cell has an OCV less than 0.3, then it should be discarded. This indicates a short circuit within the cell.

e. Weigh each cell to verify that it meets its manufacturer's specification.

Weigh and record each cell to within ±0.5 percent of the expected nominal.

f. Cells shall be discharged for storage and transportation to minimize performance degradation over time and personnel hazards due to accidental short-circuit during handling.

Discharge each cell to no greater than 1.0 volt using a discharge rate that will not cause damage to the cell.

g. Cells shall be serialized with indelible markings that will not damage the structural or electrical integrity of the cells. The serialization shall be a unique number for each cell and include or be traceable to the lot date code of the cell manufacturer.

4.25.4 Cell Conditioning. Conditioning of a cell shall stabilize the cell and ensure repeatable electrical performance throughout the cell's service-life. Conditioning of a cell shall include the following:

a. Cells shall be prepared to allow for consistent and repeatable electrical performance.

1. Before any testing, each cell shall age for no less than 11 months after the manufacturer lot date code.
2. Testing shall begin only after all sub-assembly operations have been completed on the cells, e.g., tab welding, ink/paint application, adhesive tape application, coatings, sleeve application, etc.
3. Newly manufactured NiCd cells are not chemically stable. Electrical performance measurements of newly manufactured (fresh) cells are transient and initial results are difficult to repeat over time.
4. If individual cell monitoring is performed as part of prelaunch testing, concern for this requirement is mitigated by verifying that no cell has been driven into reversal.

b. Initial conditioning of a nickel-cadmium cell shall be performed to stabilize a new cell and promote repeatable electrical performance after being in storage for an extended period of time. Any battery stored for over one month after the first charge shall undergo this conditioning.

1. This process "wakes-up" a previously unused cell, or a cell that's been unused and in storage for greater than 1 month.
2. The following procedure shall be used to provide cell initial conditioning. Each cell shall undergo a first charge at a charging rate of no greater than its capacity divided by 20 (C/20), to initialize the chemistry within the cell.
   a. Charge and discharge the cell at room temperature (20 °C). Charging equipment used shall be voltage limited to no greater than 1.55 volts/cell. Note: A cell may not have inherent overcharge protection. Hence, if a cell is over-charged without external voltage protection, cadmium hydroxide will be completely converted to cadmium metal and then H2 gas will be generated. Excessive O2 gas will also evolve from the positive plate. This mixture of H2 and O2 may result in a catastrophic explosion of the cell. The problem is aggravated at elevated temperatures. It is recommended to limit charging voltages below 1.55 for additional safety.
   b. The cell shall be charged with an applied direct current no greater than its specified capacity in Ampere-hours divided by 20 hours (C/20) for at least 2 hours.
      Note: When charging a new NiCd cell, the surface chemistry of the fresh plates will provided initial resistance to charging. If the initial applied current is too high, the cell will respond with a high voltage, greater than 1.55 due to high initial impedance.
   c. Complete cell charging at C/10 for at least 15 hours.
      (1) After the initial 2 hours at C/20, cell chemistry is sufficiently stabilized to safely handle a higher current. This decreases the time for completing this charge cycle.
      (2) However, the Range User may elect to complete the entire initial charge by continuing with C/20 for 30 hours instead of the C/10 for 15 hours.

d. Wait at least 1 hour after charging with cell open circuit.
e. Discharge at a rate of C/2 or slower until cell voltage reaches 1.0 volts. Continue discharging at a rate of C/10 or slower until cell voltage is between 0.2 and 0.4 volts.

3. The two-step charge and two-step deep discharge helps to fully distribute the electrolyte throughout the cell and into the porous plates.
4. Repeating the initial conditioning cycle may improve performance. However, most of the benefit is gained from the first cycle.

4.25.5 Cell Characterization. Characterization testing shall stabilize the cell chemistry and determine the cell's capacity. A cell characterization shall satisfy the following:

a. Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive cycles agree to a precision that shows the cell has stabilized.

1. Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive charge/discharge cycles agree within 1 percent. Cutoff voltage shall be 0.9V to 1.0V. In general, charge and discharge cycling is repeated 5 to 6 times before consecutive cycles agree.
2. Capacity stability may be achieved in fewer cycles if discharge is continued at a C/10 rate from 0.9V to 0.4V after the C/2 discharge.
3. Repeatable capacity performance provides uniform charging of all cells and acts as a status of health indicator for lot consistency.

Mathematical Representation of Individual Cell Characterization:

$$[3 \times (C_{n\text{-}max} - C_{n\text{-}min})] / (C_n + C_{n\text{-}1} + C_{n\text{-}2}) < 0.01$$

Where:

C_n = Capacity of the last charge/discharge cycle.
$C_{n\text{-}1}$ = Capacity of the charge/discharge cycle prior to last.
$C_{n\text{-}2}$ = Capacity of the charge/discharge cycle 2nd from last.
$C_{n\text{-}max}$ = Maximum capacity from the last 3 cycles.
$C_{n\text{-}min}$ = Minimum capacity from the last 3 cycles.

b. During characterization, each cell shall be maintained at a temperature to ensure that the cell is not overstressed and to allow repeatable performance.

Cell Characterization tests shall be performed at 20 °C ± 2 °C or at manufacturer's data sheet values.

4.25.6 Charge Retention. A charge retention test shall demonstrate that a battery or cell consistently retains its charge and contains no high impedance shorts. The controls and procedures, including minimum stand-time, shall allow measurable and repeatable determination of charge retention. Cell manufacturer's data for self-discharge shall be used for developing the criteria for this test.

Charge retention testing shall satisfy all of the following steps in the following order.

a. The test shall begin with the battery or cell fully charged. The battery or cell shall undergo capacity discharge to develop a baseline capacity for comparison to its charge retention performance.
b. Undergo complete charging and then storage at 20 °C ± 2 °C for 72 hours.
c. Undergo discharging to determine its capacity.
d. Demonstrate the capacity is greater than 90 percent of the baseline capacity of step 1 and the capacity retention is in-family.

4.25.7 Performance At Low Temperature. The test shall stress the cell's chemistry performance, overcharge protection, capacity variation over low temperature and pulse load repeatability when subjected to a low temperature high charge efficiency temperature. This test also serves as a pressure integrity test of the cell.

1. The following process shall be used to validate the above requirements at 0 °C ± 2 °C:
   a. Charge cell at a rate of C/10 for at least 16 hours. Applied voltage should be limited to less than 1.55 volts for charging for safety.
   b. Measure and record end-of-charge-voltage (EOCV). If EOCV is greater than expected (typically EOCV is 1.53 to 1.55 volts) or out of family, then consider cell for rejection
   c. Wait at least 1 hour.
   d. Discharge cell at a rate of C/2 until voltage is 0.9 volts.
   e. Measure and record capacity.
   f. Repeat until three consecutive cycles agree to within 1 percent of each other.
      Note: In general, charge and discharge cycling is repeated 6 to 10 times before consecutive cycles agree.
2. The following load testing is recommended at 0 °C to screen out bad cells prior to being assembled into the battery.
   a. Charge cell at a rate of C/10 for at least 16 hours.
      Note: Applied charging voltage should be limited to less than 1.55 volts for safety.
   b. Measure and record end-of-charge-voltage (EOCV). If EOCV is greater than expected (typically EOCV is 1.53 to 1.55 volts) or out of family, then consider cell for rejection
   c. Wait at least 1 hour.
   d. Discharge cell at a steady state rate of C/2 until 50 percent of the manufacturer's specified capacity is removed.
   e. Without interruption (less than 5 seconds), apply a pulse load of 2C discharge rate for 100mS.
   f. Measure and record voltage drop during pulse load. Cells unable to maintain voltage regulation after comparison to a majority of cells within the lot shall be considered for rejection.
   g. Resume steady state discharge until voltage is 0.9 volts.

3. A summary of the major performance parameters tested in this section:
   a. Each cell shall undergo repeated charge and discharge cycles at 0 °C ± 2 °C until all the capacities for three consecutive cycles agree to within 1 percent of each other.
   b. Performing charging at low temperature creates a high internal pressure to test the seals that will be checked in paragraph 4.25.19.
   c. Charging at 0 °C temperature creates a stressing condition. By demonstrating an end of charge voltage less than 1.55 V at 0 °C and benign cell response (does not explode), the overcharge protection is validated.

WARNING: A defective cell is likely to generate very high pressures during this test. Precautions should be taken to protect personnel from leaking or possibly exploding cells.

4.25.8 Post Acceptance Storage. Post acceptance storage of a battery or cell shall ensure in-specification performance for the specified lifetime of the cell or battery.

1. For long-term storage, the battery and/or cell shall be stored at approximately 1.0 V per cell open circuit to minimize aging degradation.
2. Batteries and cells shall be stored long-term at less than 5 °C in a humidity controlled environment state.
3. Storage of the cells shall not exceed the cell storage life specified by the cell manufacturer.

4.25.9 Cycle and Pulse Cycle Life. The battery shall demonstrate that it meets all its performance specifications for the number of pulses and operating charge and discharge cycles expected of the flight battery, including acceptance testing, preflight checkout, and flight plus a margin.

1. The minimum number of charge discharge cycles shall be twice the worst case expected number of cycles on the battery throughout its lifetime. Charge/discharge cycles used during other tests may be credited to meet this requirement.
2. Periodic electrical performance tests shall be performed throughout cycle life tests
   a. Electrical performance testing shall be performed in accordance with paragraph 4.25.14.
   b. Capacity shall be measured.
3. Pulse testing shall be performed in accordance with paragraph 4.25.14c. The minimum number of high current pulses applied during testing shall be twice the worst case expected number of pulses. Pulses used during other tests may be credited to meet this requirement.

4.25.10 Continuity, Isolation and Insulation Resistance. The test shall demonstrate that all battery wiring and connectors are installed according to the manufacturer specifications. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each measurement satisfies its performance specifications and is in-family.

1. Pin-to-pin continuity shall be 0.05 ohms or less
2. Pin-to-pin and pin-to-case isolation shall be 2 MΩ or more.
3. Pin-to-case insulation resistance shall be 2 MΩ or greater when measured at a potential of 500 ±25 Vdc.

4.25.11 Battery Case Integrity. A battery case integrity test shall demonstrate that:

a. The battery will not lose structural integrity or create a hazardous condition when subjected to all predicted operating conditions with margin to account for lot performance variations
b. The battery's leak rate satisfies all its performance specifications.

1. The test shall monitor the battery's pressure while subjecting the battery case to no less than 1.5 times the greatest operating pressure differential that could occur under qualification testing, preflight, or flight conditions, whichever is greater.
2. The pressure monitoring shall have a resolution and sample rate that allows accurate determination of the battery's leak rate.
3. The test shall demonstrate that the battery's leak rate is no greater than the equivalent of 10^{-4} standard cubic centimeters/seconds of helium.
4. The battery shall undergo examination to identify any condition that indicates that the battery might lose structural integrity or create a hazardous condition.

4.25.12 Monitoring Capability. A monitoring capability test shall demonstrate that each device that monitors a battery's voltage, current, or temperature satisfies all its performance specifications.

4.25.13 Heater Circuit Verification. The test must demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications.

The battery shall be tested at a temperature that allows the heater circuit to cycle at least 5 times.

4.25.14 Electrical Performance. An electrical performance test of a battery or cell shall demonstrate that the battery or cell satisfies all its performance specifications and is in-family while the battery or cell is subjected to flight electrical load profile plus a margin. The test shall verify that the battery or cell meets its performance requirements throughout the specified operational capacity.

a. The test shall measure and record a battery or cell's no-load voltage to ensure it is within the manufacturer specification limits.
b. The test shall demonstrate that the battery or cell voltage meets the manufacturer specification limits while the battery or cell is subjected to the steady-state flight load.

The test shall also demonstrate that the battery provides the minimum acceptance voltage for each electronic component that it powers.

c. The test shall demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specification. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage for each electronic component that it powers while the battery or cell is subjected to the pulse portion of the load profile. The test shall subject the battery or cell to one of the following load profiles:

1. The load profile shall begin with a steady-state flight load followed without interruption by a current pulse.
2. The pulse width shall be no less than 10 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds, whichever is greater.
3. The 10 times initiator pulse test shall meet voltage regulation requirements.
4. The 200 ms minimum workmanship voltage regulation shall be used to determine battery health and does not need to meet voltage regulation requirements.
5. The pulse amplitude shall be no less than 1.5 times the worst-case operational high current pulse.

6. After the pulse, the load profile shall end with a steady state flight load that lasts for no less than 15 seconds.
7. Electrical performance throughout the specified operational capacity shall be performed at different depths of discharge and/or worst-case capacity. This testing requires specific tailoring for each test.
8. The test shall subject the battery or cell to a final discharge that determines the remaining capacity.

4.25.15 Acceptance Thermal Cycle. An acceptance thermal cycle test shall demonstrate that a nickel-cadmium battery satisfies all it performance specifications when subjected to workmanship and maximum predicted thermal cycle environments. This shall include each of the following:

a. The test shall subject each component to no less than eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays and recycling, whichever is greater.
b. The acceptance thermal cycle high temperature shall be a 30 °C workmanship screening level or the MPE high temperature, whichever is higher. The acceptance thermal cycle low temperature shall be a -24 °C workmanship screening temperature or the predicted environment low temperature, whichever is lower.
c. When heating or cooling the battery during each cycle, the temperature shall change at a rate that reflects the maximum predicted thermal transition rate. The dwell time

at each high and low temperature shall be long enough for the battery to achieve internal thermal equilibrium and shall be no less than one hour.

The thermal transition rate shall be a minimum of 1 °C per minute.

d. The test shall measure a battery's performance parameters at the thermal extremes and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least once every 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies paragraph 4.25.14 while the battery is at the high and low temperatures, during the first and last thermal cycles. If the battery is not capable of passing the electrical performance test at either the high workmanship temperature or the low workmanship temperature, the battery may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following:
   (1) The intermediate high temperature shall be no less than the maximum predicted high temperature.
   (2) The intermediate low temperature shall be no greater than the minimum predicted low temperature.
   (3) The dwell-time at the intermediate temperatures shall be long enough for the battery to reach thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (4) After electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (5) The battery must undergo an electrical performance test while the battery is at ambient temperature before the first and after the last thermal cycles.

4.25.16 Qualification Thermal Cycle. A qualification thermal cycle test shall demonstrate that a battery satisfies all its performance specifications when subjected to preflight, acceptance test, and flight thermal cycle environments. This shall include each of the following:

a. The test shall subject the fully charged battery to no less than three times the acceptance-number of thermal cycles

b. The qualification thermal cycle high temperature shall be a 40 °C workmanship screening level or the MPE high temperature plus 10 °C, whichever is higher. The qualification thermal cycle low temperature shall be a -34 °C workmanship screening temperature or the predicted environment low temperature minus 10 °C, whichever is lower.

If the minimum hot and cold workmanship temperature extremes exceed the manufacturer specification, then the maximum and minimum specification shall be used. However, additional thermal cycles shall be added to account for thermal fatigue equivalence.

c. The thermal transition rate shall be the same used for acceptance testing.
d. The test shall measure a battery's performance parameters at the thermal extremes and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least once every 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies paragraph 4.25.14 while the battery is at the high and low temperatures, during the first, middle and last thermal cycles. If the battery is not capable of passing the electrical performance test at either the high workmanship temperature or the low workmanship temperature, the battery may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following:
   (1) The intermediate high temperature shall be no less than the maximum predicted high temperature plus 10 °C.
   (2) The intermediate low temperature shall be no greater than the minimum predicted low temperature minus 10 °C.
   (3) The dwell-time at the intermediate temperatures shall be long enough for the battery to reach thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (4) After electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve internal thermal equilibrium.
   (5) The battery must undergo an electrical performance test while the battery is at ambient temperature before the first and after the last thermal cycles.

4.25.17 Operational Stand Time. An operational stand time test shall demonstrate that the battery will maintain its required capacity, including all required margins, from the final charge that the battery receives before flight. This test shall be use to verify CS, (Self-Discharge in Amp-Hrs). This shall include the following:

a. The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.
b. The battery must undergo a charge to full capacity. The test shall then subject the battery to the maximum predicted preflight temperature for the maximum operating stand time while in an open circuit configuration. The maximum operating stand time shall account for all launch processing and launch delay contingencies that could occur after the battery receives its final charge.
c. After the maximum operating stand time has elapsed, the battery must undergo a capacity discharge to determine the remaining capacity that will meet the flight requirement.

1. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
2. Discharge battery IAW 4.25.1b.
3. Determine total capacity, C_T.
4. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
5. Expose battery to the maximum expected temperature allowed between final charging and launch.
6. Expose battery to the maximum expected time allowed between final charging and launch.
7. Discharge battery IAW 4.25.1b.
8. Measure and record remaining capacity, C_r.
9. Determine amount of capacity loss due to self discharge, $C_S = C_T - C_r$
10. Factor C_S into battery budget.

4.25.18 Internal Inspection. An internal inspection of a battery must identify any excessive wear or damage to the battery, including any of its cells, after the battery is exposed to all the qualification test environments. An internal inspection shall satisfy 4.11.7.

1. An internal examination to verify that there was no movement of any component within the battery that stresses that component beyond its design limit
2. An examination to verify the integrity of all cell and wiring interconnects
3. An examination to verify the integrity of all potting and shimming materials
4. The cells shall be removed and examined for any physical damage
5. Test each cell for leaks.
6. One cell from each corner and one cell from the middle of the Qualification battery shall undergo Destructive Physical Analysis (DPA). The destructive physical analysis must verify the integrity of all connections between all plate tabs and cell terminals, and the integrity of each plate and separator. X-ray may be used as an alternate method.
7. The remaining cells shall be X-rayed at 0° and 90° to verify tab and cell terminal integrity. Each cell's X-ray shall be compared with its cell lot acceptance X-ray.

4.25.19 Cell Leakage. A leakage test of a cell shall demonstrate the integrity of the cell case seal.

1. After the Performance At Low Temperature test of 4.25.7, the cell shall undergo a full charge (C/10 for 16 hours) and then inspected with a chemical indicator. If the chemical indicator shows that the cell has a leak, the cell is disqualified for use in any further test or flight.
2. The procedure for detecting leaks is as follows:
   a. Phenolphthalein solution shall be applied by cotton swab to the vent and crimp areas of the cell.
   b. Inspect for color change. If there is a color change, reject the cell or retest if cross contamination between cells is suspected. Clean and retest in accordance with paragraph 4.25.7 for one charge cycle and re-inspect for leaks. If leakage is indicated a second time, remove the cell from screening.
   c. All cells that pass leak testing shall be cleaned and dried.

4.25.20 Cell Selection.

a. Final Cell Screening. After completion of testing, data shall be reviewed. Any cell not meeting its performance requirements or exhibiting out of family performance shall not be used.

b. Final Cell Matching. Cells shall be selected for each battery by matching associated performance properties of individual cells from the lot. The Range User shall provide to Range Safety for approval, the variables, criteria and methodology used for matching cells into batteries.

1. Graphical Method for Final Cell Matching:
   a. Plot the 0 °C cell capacity measurements for each cell onto one plot.
   b. Divide the resulting scatter plot into clusters. Each cluster shall consist of a number of samples greater than necessary to assemble one battery. Only cells from the same cluster may be used for each battery.
   c. If load testing has been performed (optional), down select the cells to be assembled in the battery by choosing those with the best load performance.
2. The Range User shall provide a report that describes cell selection and out-of-family determination.
3. The rejection rate of cells and cause(s) for rejection shall be provided.

4.25.21 Flight Self-Discharge. A flight self discharge test shall be performed to demonstrate that the battery will maintain its required capacity, including all required margins, from launch to end of Range Safety responsibility. This test shall be use to verify C_{fs}, (Flight Self-Discharge in Amp-Hrs). This shall include the following:

a. The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.
b. The battery must undergo a charge to full capacity. The test shall then subject the battery to the maximum predicted flight temperature for the maximum flight time while in an open circuit configuration.
c. After the maximum flight time has elapsed, the battery must undergo a capacity discharge to determine the remaining capacity that will meet the flight requirement.

1. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
2. Discharge battery IAW 4.25.1b.
3. Determine total capacity, C_T.
4. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
5. Expose battery to the maximum predicted temperature allowed between launch and end of Range Safety responsibility.
6. Expose battery to the maximum expected time allowed between launch and end of Range Safety responsibility.
7. Discharge battery IAW 4.25.1b.
8. Measure and record remaining capacity, C_{rf}.
9. Determine amount of capacity loss due to self discharge, $C_{fs} = C_T - C_{rf}$.
10. Factor C_{fs} into battery budget.

4.26 Lithium Ion Batteries

TABLE 4.26-1. LITHIUM ION CELL LOT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination (2)	4.11	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Weight	4.11.4	100%
Cell Inspection and Preparation	4.26.3	100%
Cell Screening (1)		
Cell Characterization	4.26.5	100%
Charge Retention	4.26.4	100%
Performance at Low Temperature	4.26.6	100%
Cell Selection	4.26.7	
Final Cell Screening	4.26.7a	100%
Final Cell Matching (5)	4.26.7b	100%
X-ray Inspection (6)	4.11.6	100%
Lot Sample Testing (3)		
Non Reusable Venting Devices	4.26.2	Lot Sample(4)
Post Acceptance Storage	4.26.8	100%
Post-Storage Cell Processing	4.26.22	100%

Notes for Table 4.26-1:

(1) Cell screening shall begin only after all sub-assembly operations have been completed on the cells such as tab welding, ink/paint application, adhesive tape application, coatings, individual cell sleeving. Screening of each lot of cells shall be completed prior to being assembled into batteries.
(2) Unless otherwise annotated, if any cell fails any of these tests, the individual cell is disqualified for use.
(3) If any cell sample fails to pass these tests, the entire lot is disqualified for use.
(4) Lot sample shall 10 percent of the lot with a minimum of five units to a maximum of 15 samples.
(5) After final cell matching, cells shall be assembled into batteries or stored as a matched group.
(6) X-ray inspection shall demonstrate tab integrity at 0 degrees and 90 degree axes. These cells shall be used in the qualification test units and reinspected after qualification testing by X-ray.

TABLE 4.26-2. LITHIUM ION BATTERY ACCEPTANCE TEST REQUIREMENTS

Test (1), (5), (7)	**Paragraph**	**Quantity Tested**
Cell Lot Acceptance (2)	Table 4.26.1	100%
Component Examination	4.11.1	
Identification Check (8)	4.11.5	100%
Visual Examination (8)	4.11.2	100%
Dimensional Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Charge State	4.26.9	100%
Performance Verification	4.10.4	
Continuity and Isolation (8)	4.26.10	100%
Monitoring Capability (8)	4.26.12	100%
Heater Circuit Verification (8)	4.26.13	100%
Non-Reusable Venting Devices (Battery Only)	4.26.2b	Lot Sample **(6)**
Operating Environment Tests		
Acceptance Thermal Cycle	4.26.15	100%
Acoustic (4)	4.15.4	100%
Sinusoidal (4)	4.15.5	100%
Random Vibration (4)	4.15.6	100%
Performance Verification	4.10.4	
Charge Retention (8)	4.26.4	100%
Electrical Performance Test (8)	4.26.14	100%
Continuity, Isolation and Insulation Resistance	4.26.10	100%
Post Acceptance		
Visual Examination	4.11.2	100%
Reusable Venting Devices (3)	4.26.2	100%
Battery Case Integrity (3)	4.26.11	100%
Post Acceptance Storage	4.26.8	100%

Notes for Table 4.26-2:

(1) Each test that requires a battery to undergo a charge or discharge shall satisfy 4.26.1b. Unless otherwise specified, each test shall begin with the battery fully charged.
(2) All cells used in each qualification or flight battery shall be from a production lot that has successfully passed the cell lot acceptance tests. These tests do not need to be repeated for recertification service life testing.
(3) This test is required only for a sealed battery.
(4) The battery must undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load during the operating environment. An Electrical Performance Test IAW paragraph 4.26.14 shall be performed during the operating environment. The monitoring must have a sample rate of once every 0.1-millsecond or more, and demonstrate that the voltage does not experience any dropouts.
(5) If any cell failure occurs during or after operating environment testing, the battery and all cells within the battery shall be rejected. The battery case may be recycled, populated with all new cells and restart a new acceptance test. Cells that fail prior to operating environment testing may be replaced with a new cell from the same matched group.
(6) Lot sample shall be 10 percent of the lot with a minimum of three units to a maximum of nine samples.
(7) Initial service life of the battery shall be established based on data that demonstrates the battery will survive dynamic environment at the end of its initial service life. Recertification after the initial service life shall be conducted by re-performing acceptance testing. The timetable for recertification shall demonstrate that the battery will meet dynamic environments at the end of its extended service life.

1. Initial service life of the battery is 3 years from date of cell manufacturing.
2. Service life extension beyond 3 years can be performed using one of the following methods:
   a. Acceptance testing may be re-performed to extend the life of the flight battery for 1 year. Acceptance testing may only be re-performed two times on the same battery.
   b. Service Life Extension testing IAW Table 4.26.4

(8) These tests shall also be performed at the launch site just before installation.

TABLE 4.26-3. LITHIUM ION CELL LOT AND BATTERY QUALIFICATION TEST REQUIREMENTS

Test (1), (11), (12)	**Paragraph**	**Qualification** (10) **Quantity Tested X = 3 Batteries**	**Cell Lot Qualification** (1), (2) **Quantity Tested X = 3 Batteries**
Battery Acceptance Tests (3)	Table 4.26.2	X	X
Non-Operating Environment Tests	4.13.1		
Storage Temperature	4.13.2	X	X
Transportation Shock	4.13.4	X	X
Bench Shock	4.13.5	X	X
Transportation Vibration	4.13.6	X	X
Fungus Resistance	4.13.7	1	1
Fine Sand	4.13.8	1	1
Performance Verification	4.10.4		
Heater Qualification	4.26.19	X	X
Cycle Life and Pulse Margin	4.26.20	X	X
Operating Environment Tests			
Thermal Cycling	4.26.16	X	X
Thermal Vacuum (4)	4.14.3	X	X
Humidity (6)	4.14.4	X	1
Salt Fog (13)	4.14.5	X	X
Temperature/Humidity/Altitude (7)	4.14.6	X	1
Acceleration (5)	4.14.7	X	X
Shock (5)	4.14.8	X	X
Acoustic (5)	4.14.9	X	X
Sinusoidal Vibration (5)	4.14.10	X	X
Random Vibration (5)	4.14.11	X	X
EMI/EMC	4.14.12	1	1
Performance Verification	4.10.4		
Continuity, Isolation and Insulation Resistance	4.26.10	X	X
Electrical Performance	4.26.14	X	X
Charge Retention	4.26.4	X	X
Operational Stand Time	4.26.17	X	X
Flight Self-Discharge	4.26.18	X	X
Battery Case Integrity (8)	4.26.11	X	X
Explosive Atmosphere	4.14.13	1	1
Internal Inspection	4.26.21	1	1

Notes for Table 4.26-3:

(1) Each new lot of cells shall satisfy all the tests required by this table to demonstrate that any variation in parts, material, or processes between each lot does not affect cell performance. For each new cell lot, three battery assemblies that are made up of cells from the lot shall undergo each test required by this table to demonstrate that each battery and each cell satisfy all their performance specifications when in their packaged flight configuration.

(2) Cell lot qualification testing may not be required if the parts materials and processes for cell manufacturing are placed under configuration control including chemical sources and manufacturing equipment. A configuration audit shall be performed to demonstrate that each new lot of cells uses the same parts, materials, chemical sources, manufacturing equipment and processes as the lot of cells used for the original qualification.

(3) Each qualification test battery shall pass all the acceptance tests of Table 4.26.2.

(4) Electrical testing shall be performed IAW paragraph 4.26.16e.

(5) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load. Towards the end of testing, perform pulse testing IAW paragraph 4.26.14. Voltage and current shall be sampled at a 0.1 ms rate.

(6) Cycle 5 performance verification test shall be a capacity discharge test to determine charge retention IAW 4.26.4 followed by an electrical test IAW paragraph 4.26.14.

(7) Electrical performance testing shall be performed IAW paragraph 4.26.14.

(8) This test is only required for a sealed battery.

(9) Reserved.

(10) Qualification testing is a one time test as long as parts, materials and processes are maintained and under configuration control for the battery design.

(11) Batteries and cells initial service is 3 years after qualification testing is complete

(12) Each test that requires a battery to undergo a charge or discharge shall satisfy 4.26.1b. Unless otherwise specified, each test shall begin with the battery fully charged.

(13) Batteries shall begin fully charged. Upon completing exposure to the operating environment, determine charge retention at ambient conditions followed by a continuity and isolation test.

TABLE 4.26-4. LITHIUM ION BATTERY AND CELL SERVICE LIFE AND SURVEILLANCE

Test [(1)]	**Paragraph**	**Quantity X=1**
Acceptance Testing [(2), (6)]	Table 4.26.2	X
Cycle Life and Pulse Margin [(2)]	4.26.20	X
Service Life Extension [(5)]		
Thermal Cycle	4.26.16	X
Shock [(3)]	4.14.8	X
Sinusoidal Vibration [(3), (4)]	4.14.10	X
Random Vibration [(3), (4)]	4.14.11	X
Continuity, Isolation and Insulation Resistance	4.26.10	X
Electrical Performance	4.26.14	X
Charge Retention	4.26.4	X
Operational Stand Time	4.26.17	X
Flight Self-Discharge	4.26.18	X
Internal Inspection	4.26.21	X
Lithium Ion Cell Age Surveillance		
Cell Inspection and Preparation	4.26.3	4 cells/year
Non-Reusable Venting Devices	4.26.2b	4 cells/year

Notes for Table 4.26-4:

(1) The Age Surveillance battery and cells shall be stored in similar conditions or along with the flight batteries according to the Post Acceptance Storage requirements.
(2) Not required for existing qualification test assets.
(3) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a 0.1 ms rate.
(4) Towards the end of testing, perform pulse testing IAW paragraph 4.26.14.
(5) Service life of the cell lot may be extended by re-qualifying one battery representing that cell lot. Failure of service life testing invalidates all the flight batteries from that cell lot.
(6) Reacceptance testing is not required for service life extension testing.

4.26.1 General. This section applies to any battery that uses Lithium Ion cells and is part of a flight termination system.

a. Compliance. Any Lithium Ion battery must satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all its performance specifications when subjected to each non-operating and operating environment.

b. Charging and Discharging of Lithium Ion Batteries and Cells. Each test required by any table of this section that requires a lithium ion battery or cell to undergo a charge or discharge shall include all of the following:

(1) The rate of each charge or discharge shall prevent any damage to the battery or cell and provide for the battery or cell's electrical characteristics to remain consistent. Unless otherwise specified, the battery shall be charged and recharged during acceptance and qualification testing using the same procedure, equipment, and parameters as used during prelaunch. The specification for battery charging shall be provided to Range Safety prior to approval of any test procedures.

1. A discharge of a cell shall subject the cell to the discharge rate until the cell voltage is less than 2.8 volts or the cell manufacturer's specified end-of-discharge voltage.
2. A discharge of a battery, shall subject the battery to the discharge rate until the battery voltage is less than 2.8 volts or the cell manufacturer's specified end-of-discharge voltage times the number of series cells in the battery.
3. Each discharge shall include monitoring of voltage, current, temperature, and time with sufficient resolution and sample rate to determine capacity, assure safety and demonstrate that the battery or cell is in-family.
4. A charge of a battery or cell shall not cause any cell voltage to be greater than 4.4 volts or the cell manufacturer's specified end-of-charge voltage (EOCV). The cell manufacturer's charging specifications (temperature and current) and procedures shall not be violated.
5. If a cell is overcharged, carbon dioxide gas will be generated. Excessive gas may result in a catastrophic venting event of the cell. The hazard is increased at elevated temperatures.
6. EOCV is chemistry dependent. 4.4V is an estimate for most LiCoO2 cells. Do not exceed cell manufacturer's recommendation.

(2) If proprietary battery charging equipment is used, then the same equipment must be used in cell screening, and battery charging in acceptance, qualification, and vehicle processing

(3) The specification for battery charging shall be provided to Range Safety. A charge of a battery or cell shall satisfy the manufacturer charging specifications and procedures. When a battery or cell is required to be fully charged, charging shall ensure that the battery capacity will meet the specification. A battery or cell shall not be overcharged such that it will damage the cells or create a hazardous condition.

(4) During any test, the battery or cell's critical electrical performance parameters shall be monitored with a resolution, precision, accuracy and sample rate to detect any failure to satisfy a performance specification

During the current pulse portion of the load profile, the monitoring shall have a sample rate of 0.1 milliseconds or faster. Voltage monitoring during vibration shall have a minimum resolution of 10 mV.

(5) The number of charge/discharge cycles shall be recorded.

4.26.2 Venting Devices. Within a year of launch, a test of cell venting device shall demonstrate that the battery or cell will not experience a loss of structural integrity or create a hazardous condition when subjected to any electrical discharge, charging, or short-circuit condition. The vent shall protect the cell and battery from a catastrophic rupture that could injure personnel or disable adjacent FTS components.

a. Reusable Venting Devices. For a venting device that is capable of functioning repeatedly without degradation, such as a vent valve, the test shall exercise the device and demonstrate that it satisfies all its performance specifications.

This test may be performed on vents at the subassembly level. The test must demonstrate that each device sample vents within ± 10 percent of the manufacturer nominal specified vent pressure

b. Non-Reusable Venting Devices. For a venting device that does not function repeatedly without degradation, such as a burst disc, the test shall exercise a lot sample to demonstrate that the venting device satisfies all its performance specifications.

1. This test may be performed by subjecting the cell to slowly increasing temperature until venting occurs.
2. The vent shall function as follows:
   a. Functions at a consistent temperature from cell to cell
   b. Vent functions at a temperature that is 30 degrees C above the qualification temperature
   c. No thermal runaway occurs

4.26.3 Cell Inspection and Preparation. A cell removed from storage shall undergo inspection and preparation prior to undergoing any testing:

a. Record lot date code, part number and verify cells were manufactured consecutively as part of a single lot.

For limited production lot date codes, cell serial numbers shall be consecutive.

b. Demonstrate that the cell is clean and free of physical defects.

1. Inspect for missing or loose parts by shaking each cell by hand and listening for a rattling noise.
2. Demonstrate that the cell has no leakage of electrolyte.

c. Verify each cell was delivered within its expected state of charge. Record cell voltages.

1. Delivery voltages are usually around 3.2 to 3.4V This data may be used as the baseline for supporting the Charge Retention test.
2. For most cell designs, if delivered cells have an OCV less than 2.8V, then they shall be discarded. A low OCV indicates the delivered cell may not perform consistently.

d. Cells shall be serialized with indelible markings that will not damage the structural or electrical integrity of the cells. The serialization shall be a unique number for each cell and be traceable to the lot date code of the cell manufacturer.

4.26.4 Charge Retention. A charge retention test shall demonstrate that a battery or cell consistently retains its charge within the manufacturer's specified limits. The controls and procedures, including minimum stand-time to measure capacity loss, shall allow measurable and repeatable determination of charge retention. Cell manufacturer's data for self-discharge shall be used for developing the criteria for this test.

1. The test shall begin with the battery or cell fully charged.
   a. The battery or cell shall undergo capacity discharge with no stand-time to develop a baseline capacity for comparison to its charge retention performance. Data acquired during the cell characterization tests may be used for the baseline capacity.
   b. Undergo complete charging and record OCV of each cell
   c. Store at 20 °C ± 2 °C for 60 days
   d. Record OCV of each cell and discharge to determine remaining capacity of each cell.
2. Accelerated charge retention testing may be performed to shorten test time as follows:
   a. After battery or cell charging, the item shall stand for one week at 20 °C ± 2 °C before the initial OCV measurements of each cell are made.

   Note: The initial rate of self discharge may be erratic for the first few days after charging. The rate becomes very predictable, for a healthy cell, thereafter.

   b. Store at 30 ± 2 °C for 2 weeks.
   c. Stabilize temperature to 20 °C ± 2 °C for at least one hour.
   d. Measure OCV of each cell and discharge to determine remaining capacity of each cell.

3. Demonstrate the remaining capacity is greater than 95 percent of the baseline capacity and is in-family.
4. During cell screening the change in OCV of each cell shall be within acceptable limits and in-family with the lot. Individual cells showing excessive changes in OCV or capacity after comparison to a majority of cells within the lot shall be considered for rejection
5. During battery acceptance testing the change in OCV of each cell shall be within acceptable limits and in-family with the matched cells in the battery. Any cell showing excessive changes in OCV or capacity shall result in rejection of the battery.

4.26.5 Cell Characterization. Characterization testing shall verify repeatable capacity, stability of the cell's chemistry and determine the cell's capacity. A cell characterization shall satisfy the following:

a. Initial conditioning or charge cycling of a Lithium Ion cell shall follow manufacturer's recommendation
b. Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive charge/discharge cycles agree to a precision that shows the cell has stabilized.

Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive charge/discharge cycles agree within 1 percent.
Note: Repeatable capacity performance provides uniform charging of all cells and acts as a status of health indicator for lot consistency.

Mathematical Representation of Individual Cell Characterization:

$$[\,3 * (C_{n\text{-}max} - C_{n\text{-}min})] / (C_n + C_{n\text{-}1} + C_{n\text{-}2})] < 0.01$$

Where:

C_n = Capacity of the last charge/discharge cycle.
$C_{n\text{-}1}$ = Capacity of the charge/discharge cycle prior to last.
$C_{n\text{-}2}$ = Capacity of the charge/discharge cycle 2nd from last.
$C_{n\text{-}max}$ = Maximum capacity from the last 3 cycles.
$C_{n\text{-}min}$ = Minimum capacity from the last 3 cycles.

c. During characterization, each cell shall be maintained at a temperature to ensure that the cell is not overstressed and to allow repeatable performance.

Cell characterization tests shall be performed at 20 °C ± 2 °C or at manufacturer's data sheet values.

d. Cells showing difficulty in achieving consistent capacity levels between cycles after comparison to a majority of cells within the lot shall be considered for rejection

4.26.6 Performance at Low Temperature. The test shall stress the cell's chemistry performance, capacity variation and pulse load repeatability when subjected to low temperature. The cell shall be tested to ensure it can provide adequate voltage regulation when pulse loaded at its minimum (cold) operating temperature while in a partially charged condition.

Performance at low temperature testing shall satisfy all of the following steps in the following order at the minimum operating temperature:

a. Charge cells using the same procedure that will be used during prelaunch operations.
b. Discharge cell at a steady state rate no greater than recommended by cell manufacturer until 50 percent of the Operational Capacity is removed.
   Note: The goal is to be at the mid-capacity point of the discharge curve while the cells are at a cold temperature when the pulse is operationally applied. The minimum operating temperature shall be used to efficiently discriminate substandard cells.
c. Apply one operational pulse load for 100mS. Measure and record voltage drop during pulse load and recovery.
   Note: Any delay between the steady-state load and the operational pulse load shall be consistent from cell to cell testing.
d. Resume steady state discharge until voltage is 2.8 volts or the manufacturer's specification.

4.26.7 Cell Selection.

a. Final Cell Screening. After completion of testing, data shall be reviewed. Any cell not meeting its performance requirements or exhibiting out of family performance shall not be used.

b. Final Cell Matching. Cells shall be selected for each battery by matching associated performance properties of individual cells from the lot. The Range User shall provide to Range Safety for approval, the variables, criteria, and methodology used for matching cells into batteries.
   (1) The priority of the performance parameters use for matching shall be dependent on the cell/battery design and operational application. The priority for using Charge Retention, Cell Characterization and Cell Performance Test at Low Temperature for matching shall ensure the battery will meet its performance requirements. Other properties may also be considered.
   (2) The qualification batteries shall be assembled with cells representing the widest variation in performance properties possibly allowed for flight batteries. The qualification batteries shall be built with the worst case mix of cells to validate the cell matching strategy.

4.26.8 Post Acceptance Storage. Batteries or cells requiring storage shall be stored within the cell storage voltage limits and temperature limits defined by the cell manufacturer. Storage conditions shall also protect against any performance degradation and be consistent with those used during qualification testing.

a. Post Acceptance Storage is required for batteries and cells that will not be used for 6 months or more.

b. Storage shall be in an open circuit configuration.

c. The cumulative storage time shall not exceed manufacture's recommendations. It is recommended that time at ambient temperature be logged for ageing engineering data.

d. Cells and batteries shall be protected and safely stored with the appropriate state of charge at the manufacture's recommended temperature or at less than 5 °C.

e. Cells and batteries shall be stored in a low humidity controlled environment.

f. Care must be exercised in allowing cells and batteries to achieve room temperature prior to removal from storage container to avoid condensation and thermal shock.

g. Maintenance plan for batteries and cells in storage shall be provided to Range Safety for approval.

4.26.9 Charge State. The battery shall be tested to demonstrate that the open circuit voltage of each cell is within specification.

4.26.10 Continuity, Isolation, and Insulation Resistance. The test shall demonstrate that all battery wiring and connectors are installed according to the manufacturer specifications. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each measurement satisfies its performance specifications and is in-family.

1. Pin-to-pin continuity shall be 0.05 ohms or less
2. Pin-to-pin and pin-to-case isolation shall be 2 MΩ or more.
3. Pin-to-case insulation resistance shall be 2 MΩ or greater when measured at a potential of 500 ±25 Vdc.

4.26.11 Battery Case Integrity. A battery case integrity test of a sealed Lithium Ion battery must demonstrate the following:

a. The battery shall not lose structural integrity or create a hazardous condition when subjected to all predicted operating conditions with margin.
b. The battery's leak rate satisfies all its performance specifications.

1. The test shall monitor the battery's pressure while subjecting the battery case to no less than 1.5 times the greatest operating pressure differential that could occur under qualification testing, preflight, or flight conditions, whichever is greater.
2. The pressure monitoring shall have a resolution and sample rate that allows accurate determination of the battery's leak rate.
3. The test shall demonstrate that the battery's leak rate is no greater than the equivalent of 10^{-4} standard cubic centimeters/seconds of helium.
4. The battery shall undergo examination to identify any condition that indicates that the battery might lose structural integrity or create a hazardous condition.

4.26.12 Monitoring Capability. The test shall demonstrate that each monitoring device incorporated into a battery satisfies its performance specification. Monitoring devices include, but are not limited to, those used to monitor individual cell voltages, battery voltage, current, and/or temperature.

4.26.13 Heater Circuit Verification. The test must demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications.

The battery shall be tested at a temperature that allows the heater circuit to cycle at least 5 times.

4.26.14 Electrical Performance Test. An electrical performance test of a battery must demonstrate that the battery satisfies all battery performance specifications and is in-family while the battery is subjected to an electrical load profile. The test must also demonstrate that the battery satisfies all its electrical performance specifications during various states of charge of its operational capacity. The test must include and satisfy each of the following requirements:

a. The test shall measure and record battery and individual cell no-load voltage before applying any load to ensure it is within the manufacturer's specification limits.
b. The test shall demonstrate that the battery or cell voltage meets the manufacturer specification limits while the battery or cell is subjected to the steady-state flight load. The test shall also demonstrate that the battery provides the minimum acceptance voltage for each electronic component that it powers.
c. The test shall demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specification. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage for each electronic component that it powers while the battery or cell is subjected to the pulse portion of the load profile. The test shall be conducted at it's lowest operational state of charge.

The test load profile shall satisfy all of the following at each required discharge level:

a. The load profile shall begin with a steady-state flight load followed without interruption by a current pulse.
b. The pulse width shall be no less than 10 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds, whichever is greater.
c. The 10 times initiator pulse test shall meet voltage regulation requirements.
d. The 200 ms minimum workmanship voltage regulation shall be used to determine battery health and does not need to meet voltage regulation requirements.
e. The pulse amplitude shall be no less than 1.5 times the worst-case operational high current pulse.
f. After the pulse, the load profile shall end with a steady state flight load that lasts for no less than 15 seconds.
g. Electrical performance testing shall be performed starting at a fully charged state and every 10 percent State of Charge (SOC) until all of its operational capacity (CO) has been consumed.

4.26.15 Acceptance Thermal Cycle. An acceptance thermal cycle test shall demonstrate that a Lithium Ion battery satisfies all it performance specifications when subjected to workmanship and maximum predicted thermal cycle environments. This must include each of the following:

a. The test shall subject each component to no less than eight acceptance thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays and recycling, whichever is greater.
b. The acceptance thermal cycle high temperature shall be a workmanship screening level or the MPE high temperature, whichever is higher. The acceptance thermal cycle low temperature shall be a workmanship screening level or the MPE low temperature, whichever is lower.

1. If the minimum hot and cold workmanship temperature extremes exceed the manufacturer specification, then the maximum and minimum specification shall be used. However, additional thermal cycles shall be added to account for thermal fatigue equivalence.
2. The minimum acceptance high temperature workmanship level shall be 30 °C.
3. The maximum acceptance low temperature workmanship level shall be -14 °C.

c. When heating or cooling the battery during each cycle, the temperature shall change at a rate that reflects the maximum predicted thermal transition rate. The dwell time at each high and low temperature shall be long enough for the battery to achieve internal thermal equilibrium and shall be no less than one hour.

The thermal transition rate shall be a minimum of 1 °C per minute.

d. The test shall measure a battery's performance parameters at the thermal extremes and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least once every 10 seconds.

e. The battery must undergo an electrical performance test while the battery is at the high, and low temperatures, during the first and last thermal cycles. Battery shall be charged at ambient temperature as required prior to conducting each electrical performance test in accordance with paragraph 4.26.14. If the battery is not capable of passing the electrical performance test at either the workmanship screening high or the workmanship screening low temperatures, the battery may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following:
   (1) The intermediate high temperature shall be no less than the maximum predicted high temperature.
   (2) The intermediate low temperature shall be no greater than the minimum predicted low temperature.
   (3) The dwell-time at the intermediate temperatures shall be long enough for the battery to reach thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (4) After electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (5) The battery must undergo an electrical performance test while the battery is at ambient temperature before the first and after the last thermal cycles.

4.26.16 Qualification Thermal Cycle. A qualification thermal cycle test shall demonstrate that a battery satisfies all its performance specifications when subjected to preflight, acceptance test, and flight thermal cycle environments. This shall include each of the following:

a. The test shall subject the fully charged battery to no less than three times the acceptance-number of thermal cycles.
b. The qualification thermal cycle high temperature shall be a workmanship screening level or the MPE high temperature plus 10 °C, whichever is higher. The qualification thermal cycle low temperature shall be a workmanship screening level or the MPE low temperature minus 10 °C, whichever is lower. The minimum and maximum workmanship test levels shall not damage the battery.

1. If the minimum hot and cold workmanship temperature extremes exceed the manufacturer specification, then the maximum and minimum specification shall be used. However, additional thermal cycles shall be added to account for thermal fatigue equivalence.
2. The qualification high temperature shall be 40 °C or greater.
3. The qualification low temperature shall be -24 °C or less.

c. The thermal transition rate shall be the same used for acceptance testing.
d. The test shall measure a battery's performance parameters at the thermal extremes and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least once every 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies 4.26.14 while the battery is at the high and low temperatures, during the first, middle and last thermal cycles. If the battery is not capable of passing the electrical performance test at either the workmanship high temperature or the workmanship low temperature, the battery may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following:
   (1) The intermediate high temperature shall be no less than the maximum predicted high temperature plus 10 °C.
   (2) The intermediate low temperature shall be no greater than the minimum predicted low temperature minus 10 °C.
   (3) The dwell-time at the intermediate temperatures shall be long enough for the battery to reach internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (4) After electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (5) The battery must undergo an electrical performance test while the battery is at ambient temperature before the first and after the last thermal cycles.

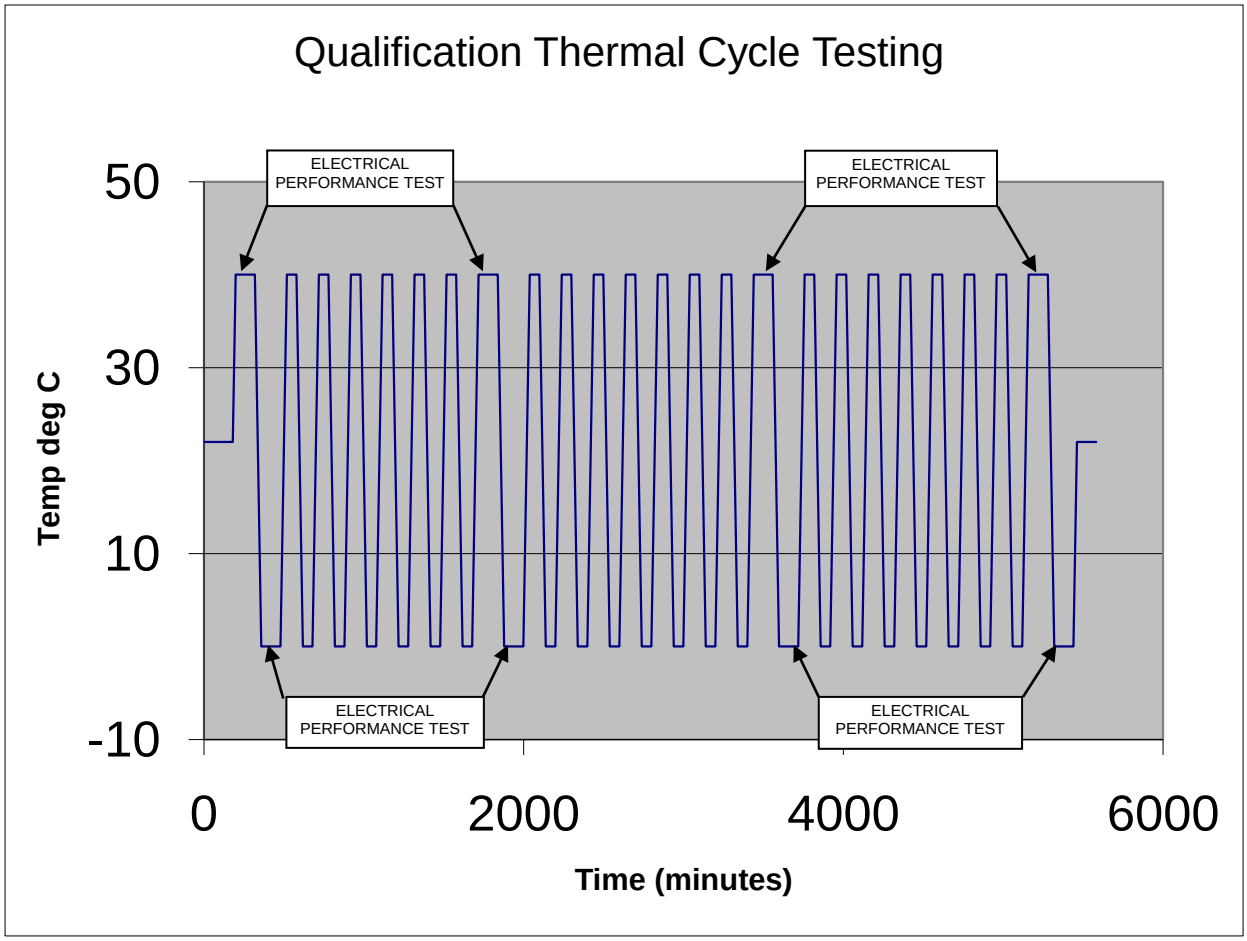


Figure 4.26-1. Qualification thermal cycle testing.

4.26.17 Operational Stand Time. An operational stand time test shall demonstrate that the battery will maintain its required capacity, including all required margins, from the final charge that the battery receives before flight. This test shall be use to verify CS, (Self-Discharge in Amp-Hrs). This shall include the following:

a. The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.
b. The battery must undergo a charge to full capacity. The test shall then subject the battery to the maximum predicted preflight temperature for the maximum operating stand time while in an open circuit configuration. The maximum operating stand time shall account for all launch processing and launch delay contingencies that could occur after the battery receives its final charge.
c. After the maximum operating stand time has elapsed, the battery must undergo a capacity discharge to determine the remaining capacity that will meet the flight requirement.

The following process will satisfy general requirements for charging and discharging for determining Operational Stand Time:

a. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
b. Discharge battery IAW 4.26.1b.
c. Determine total capacity, C_T.
d. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
e. Expose battery to the maximum expected temperature allowed between final charging and launch.
f. Expose battery to the maximum expected time allowed between final charging and launch.
g. Discharge battery IAW 4.26.1b.
h. Measure and record remaining capacity, C_r.
i. Determine amount of capacity loss due to self discharge, $C_S = C_T - C_r$
j. Factor C_S into battery budget.

4.26.18 Flight Self-discharge. A flight self discharge test shall be performed to demonstrate that the battery will maintain its required capacity, including all required margins, from launch to end of Range Safety responsibility. This test shall be use to verify C_{fs}, (Flight Self-Discharge in Amp-Hrs). This shall include the following:

a. The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.
b. The battery must undergo a charge to full capacity. The test shall then subject the battery to the maximum predicted flight temperature for the maximum flight time while in an open circuit configuration.
c. After the maximum flight time has elapsed, the battery must undergo a capacity discharge to determine the remaining capacity that will meet the flight requirement.

4.26.19 Heater Qualification. Batteries using battery heaters shall be tested to demonstrate that the heaters will not degrade battery performance after being subjected to worst-case operational heater cycle time plus a margin. The operational time used for this test shall include prelaunch and launch operations, as well as, accounting for potential launch schedule holds and launch attempts.

1. Battery shall be exposed to twice the maximum operational cycle time of heater operation.
2. This test shall be performed at a battery temperature to allow the heater circuit to continuously cycle on and off . At minimum, the heater circuit shall cycle at least three times the cycles used for acceptance heater circuit verification or 15 cycles, whichever is greater.

4.26.20 Cycle Life and Pulse Margin. The battery shall demonstrate that it meets all its performance specifications for the number of pulses and operating charge and discharge cycles expected of the flight battery, including acceptance testing, preflight checkout, and flight plus a margin. The depth of discharge used for each cycle shall represent worst-case operational discharge levels.

1. The minimum number of charge/discharge cycles shall be twice the worst case expected number of cycles on the battery throughout its lifetime. Charge/discharge cycles used during other tests may be credited to meet this requirement.
2. Periodic electrical performance tests shall be performed throughout cycle life tests
   a. Electrical performance testing shall be performed in accordance with paragraph 4.26.14.
   b. Capacity shall be measured
3. Pulse testing shall be performed in accordance with paragraph 4.26.14c. The minimum number of high current pulses applied during testing shall be twice the worst case expected number of pulses. Pulses used during other tests may be credited to meet this requirement.

4.26.21 Internal Inspection. An internal inspection of a battery must identify any excessive wear or damage to the battery, including any of its cells, after the battery is exposed to all the qualification test environments. An internal inspection shall satisfy 4.11.7.

1. An internal examination to verify that there was no movement of any component within the battery that stresses that component beyond its design limit.
2. An examination to verify the integrity of all cell and wiring interconnects
3. An examination to verify the integrity of all potting and shimming materials
4. The cells shall be removed and examined for any physical damage
5. Test each cell for leaks.
6. One cell from each corner and one cell from the middle of the Qualification battery shall undergo Destructive Physical Analysis (DPA). The destructive physical analysis must verify the integrity of all connections between all plate tabs and cell terminals, and the integrity of each plate and separator. Range User may propose alternative non-destructive methods.
7. The remaining cells shall be X-rayed at 0° and 90° to verify tab and cell terminal integrity. Each cell's X-ray shall be compared with its cell lot acceptance X-ray.

4.26.22 Post-storage Cell Processing. Just prior to assembling stored cells into a battery, the cells shall be tested to assure capacity and other characteristics have not changed during storage.

Revalidation of critical cell matching parameter(s) will satisfy this requirement. All performance parameters may not be required to be re-performed.

4.27 Lead Acid Batteries

TABLE 4.27-1. LEAD ACID CELL LOT ACCEPTANCE TEST REQUIREMENTS		
Test	Paragraph	Quantity Tested
Component Examination [2]	4.11	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Cell Inspection and Preparation	4.27.3	100%
Cell Screening [1], [2]		
Initial Cell Voltage	4.27.4	100%
Cell Reusable Venting Devices	4.27.2a	100%
Cell Characterization	4.27.5	100%
Performance At Low Temperature	4.27.6	100%
Cell leakage	4.27.8	100%
Cell Selection	4.27.9	
Final Cell Screening	4.27.9a	100%
Final Cell Matching [5]	4.27.9b	100%
X-ray Inspection [6]	4.11.6	100%
Lot Sample Tests [3]		
Cell Non-Reusable Venting Devices	4.27.2b	Lot Sample [4]
Post Acceptance Storage [5]	4.27.10	100%

Notes for Table 4.27-1:

(1) Cell screening shall begin only **after** all sub-assembly operations have been completed on the cells such as tab welding, ink/paint application, adhesive tape application, coatings, individual cell sleeving. Screening of each lot of cells shall be completed prior to being assembled into batteries.
(2) Unless otherwise annotated, if any cell fails any of these tests, the individual cell is disqualified for use.
(3) If any cell sample fails to pass these tests, the entire lot is disqualified for use.
(4) Lot sample shall 10 percent of the lot with a minimum of five units to a maximum of 15 samples.
(5) After final cell matching, cells shall be assembled into batteries or stored as matched groups.
(6) X-ray inspection shall demonstrate tab integrity at 0 degrees and 90 degree axes. These cells shall be used in the cell lot and/or battery qualification test units and re-inspected after qualification testing by X-ray.

TABLE 4.27-2. LEAD ACID BATTERY ACCEPTANCE TEST REQUIREMENTS

Test [1]	**Paragraph**	**Quantity Tested**
Cell Lot Acceptance [2]	Table 4.27.1	100% of Cells
Component Examination [7]	4.11.1	
Identification Check [8]	4.11.5	100%
Visual Examination [8]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Performance Verification [2]	4.10.4	
Continuity, Isolation and Insulation Resistance [8]	4.27.11	100%
Charge Retention [8]	4.27.16	100%
Monitoring Capability [8]	4.27.12	100%
Heater Circuit Verification [8]	4.27.13	100%
Non-Reusable Venting Devices (Battery Only)	4.27.2b	Lot Sample [6]
Operating Environment Tests [5], [7]	4.15.1	
Acceptance Thermal Cycle	4.27.15	100%
Acoustic [4]	4.15.4	100%
Sinusoidal [4]	4.15.5	100%
Random Vibration [4]	4.15.6	100%
Performance Verification [7]	4.10.4	
Charge Retention (Battery)	4.27.16	100%
Electrical Performance [8]	4.27.14	100%
Continuity, Isolation and Insulation Resistance [8]	4.27.11	100%
Component Examination [7]	4.11	
Visual Examination	4.11.2	100%
Reusable Venting Devices (Battery Only)	4.27.2a	100%
Battery Case Integrity [3]	4.27.23	100%
Post Acceptance Storage [7]	4.27.17	100%

Notes for Table 4.27-2:

(1) Each test that requires a battery to undergo a charge or discharge shall satisfy paragraph 4.27.3. Unless otherwise specified, each test shall begin with the battery fully charged.
(2) All cells used in each qualification or flight battery shall pass all the cell lot acceptance tests required by Table 4.27.1.
(3) This test is required only for a sealed battery.
(4) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load during the operating environment. An Electrical Performance Test IAW paragraph 4.27.14 shall be performed during the operating environment. The monitoring must have a sample rate of once every 0.1 millisecond or more, and demonstrate that the voltage does not experience any dropouts.
(5) If any cell failure occurs during environmental acceptance testing, the battery and all cells within the battery shall be rejected. The battery case may be recycled, populated with all new cells and restart a new acceptance test. Cells that fail prior to environmental testing may be replaced with a new cell from the same matched group.
(6) Lot sample shall be 10 percent of the lot with a minimum of three units to a maximum of nine samples.
(7) Initial service life of the battery shall be established based on data that demonstrates the battery will survive operating environments at the end of its initial service life. Recertification after the initial service life shall be conducted by re-performing these acceptance tests from this Table. The timetable for recertification shall demonstrate that the battery will survive operating environments at the end of its extended service life.

1. Initial service life of the battery is 4 years from date of cell manufacturing.
2. Service life extension beyond 4 years can be performed using one of the following methods:
   a. Acceptance testing may be re-performed to extend the life of the flight battery for 1 year. Acceptance testing may only be re-performed two times on the same battery.
   b. Service Life Extension testing IAW Table 4.27.4.

(8) These tests shall also be performed at the launch site just before installation.

TABLE 4.27-3. LEAD ACID CELL LOT AND BATTERY QUALIFICATION TEST REQUIREMENTS

Test (1), (12)	**Paragraph**	**Qualification** (10) **Quantity Tested X = 3 Batteries**	**Cell Lot Qualification** (1), (2) **Quantity Tested X = 3 Batteries**
Battery Acceptance Tests (3)	Table 4.27.2	X	X
Non-Operating Environment Tests	4.13.1		
Storage Temperature	4.13.2	X	X
Transportation Shock	4.13.4	X	X
Bench Shock	4.13.5	X	X
Transportation Vibration	4.13.6	X	X
Fungus Resistance	4.13.7	1	1
Fine Sand	4.13.8	1	1
Performance Verification	4.10.4		
Cycle Life and Pulse Margin	4.27.18	X	X
Operating Environment Tests	4.14.1		
Thermal Cycling	4.27.19	X	X
Thermal Vacuum (4)	4.14.3	X	X
Humidity (6)	4.14.4	X	1
Salt Fog (13)	4.14.5	X	X
Temperature/Humidity/Altitude (7)	4.14.6	X	1
Acceleration (5), (7)	4.14.7	X	X
Shock (5)	4.14.8	X	X
Acoustic (5), (7)	4.14.9	X	X
Sinusoidal Vibration (5), (7)	4.14.10	X	X
Random Vibration (5), (7)	4.14.11	X	X
EMI/EMC	4.14.12	1	1
Performance Verification	4.10.4		
Continuity, Isolation and Insulation Resistance	4.27.11	X	X
Electrical Performance	4.27.14	X	X
Charge Retention	4.27.16	X	X
Operational Stand Time	4.27.20	X	X
Flight Self-Discharge	4.27.22	X	X
Battery Case Integrity (8)	4.25.11	X	X
Explosive Atmosphere	4.14.13	1	1
Internal Inspection	4.27.21	1	1

Notes for Table 4.27-3:

(1) Each new lot of cells shall satisfy all the tests required by this table to demonstrate that any variation in parts, material, or processes between each lot does not affect cell performance. For each new cell lot, three battery assemblies that are made up of cells from the lot shall undergo each test required by this table to demonstrate that each battery and each cell satisfy all their performance specifications when in their packaged flight configuration.

(2) Cell lot qualification testing may not be required if the parts materials and processes for cell manufacturing are placed under configuration control including chemical sources and manufacturing equipment. . A configuration audit shall be performed to demonstrate that each new lot of cells uses the same parts, materials, chemical sources, manufacturing equipment and processes as the lot of cells used for the original qualification.

(3) Each qualification test battery shall pass all the acceptance tests of Table 4.27.2.

(4) Electrical testing shall be performed IAW paragraph 4.27.19e.

(5) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a 0.1 ms rate.

(6) Cycle 5 performance verification test shall be a capacity discharge test to determine charge retention IAW paragraph 4.27.16 followed by an electrical test IAW paragraph 4.27.14 at ambient temperature.

(7) Electrical performance testing shall be performed IAW paragraph 4.27.14.

(8) This test is only required for a sealed battery.

(9) Reserved.

(10) Qualification testing is a one time test as long as parts, materials and processes are maintained on the battery.

(11) Reserved.

(12) Each test that requires a battery to undergo a charge or discharge shall satisfy 4.27.3. Unless otherwise specified, each test shall begin with the battery fully charged.

(13) Batteries shall begin fully charged. Upon completing exposure to the operating environment, determine charge retention at ambient conditions followed by a continuity and isolation test.

TABLE 4.27-4. LEAD ACID BATTERY AND CELL SERVICE LIFE AND SURVEILLANCE		
Test (1)	**Paragraph**	**Quantity X=1**
Acceptance Testing (2), (6)	Table 4.27.2	X
Cycle Life and Pulse Margin (2)	4.27.18	X
Service Life Extension (5)		
Thermal Cycle	4.27.19	X
Shock (3)	4.14.8	X
Sinusoidal Vibration (3), (4)	4.14.10	X
Random Vibration (3), (4)	4.14.11	X
Continuity, Isolation and Insulation Resistance	4.27.11	X
Electrical Performance	4.27.14	X
Charge Retention	4.27.16	X
Operational Stand Time	4.27.20	X
Flight Self-Discharge	4.27.22	X
Internal Inspection	4.27.21	X

Notes for Table 4.27-4:

(1) The Age Surveillance batteries shall be stored in similar conditions or along with the flight batteries according to the Post Acceptance Storage requirements.
(2) Not required for existing qualification test assets.
(3) The battery shall undergo continuous monitoring of its voltage while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a 0.1 ms rate.
(4) Towards the end of testing, perform pulse testing IAW 4.27.14.
(5) Service life of the cell lot may be extended by re-qualifying one battery representing that lot. Failure of service life testing invalidates all the flight batteries from that cell lot.

1. Service life extension of the batteries is 3 years from the completion date of life extension testing.
2. Battery used for service life extension may be from newly assembled batteries or existing qualification test assets.
   Note: For newly assembled batteries, acceptance testing shall be performed prior to service life extension testing.

(6) Reacceptance testing is not required for service life extension testing.

4.27.1 General. This section applies to any lead-acid battery that uses commercially produced lead-acid cells and is part of a flight termination system.

a. Compliance. Any commercial lead-acid battery must satisfy each test or analysis identified by any table of this section to demonstrate the battery satisfies all its performance specifications when subjected to each non-operating and operating environment.
b. Charging and Discharging of Batteries and Cells. Each test required by any table of this section that requires a battery or cell to undergo a charge or discharge shall include all of the following:
   (1) A charge of a battery or cell must satisfy the manufacturer's charging specifications and procedures.
   (2) The rate of each charge/discharge must not create a hazardous condition or cause damage or to the battery or cell and provide for the battery or cell's electrical characteristics to remain consistent.
   (3) Unless otherwise specified, the battery shall be charged and recharged during acceptance and qualification testing using the same procedure, equipment, and parameters as used during prelaunch. The specification for battery charging shall be provided to Range Safety prior to approval of any test procedures.
   (4) Rate of discharge must prevent cell damage. Each discharge must include monitoring of voltage, current, and time with sufficient resolution and sample rate to determine capacity and demonstrate that the battery meets its performance requirements.

1. The charging input to the battery or cell shall be no less than 105 percent of the manufacturer specified room temperature capacity.
2. The following process will satisfy general charging requirements using the Constant Voltage (CV) / Float Charging method:
   a. The applied voltage shall be 2.4 – 2.5 volts per cell.
   b. Current shall be limited according to power supply used.
   c. Apply CV until current drops below C/10. Discontinue CV charging.
   d. Apply float charge 2.27 – 2.35 volts per cell @ 25 ˚C or 2.28 – 2.36 volts per cell @ 22 ˚C.
   e. Float charge can be discontinued when 100 percent SOC has been achieved (2.15 OCV per cell).
3. The following process will satisfy general charging requirements using the Constant Current (CC) Charging method:
   a. The applied current shall be C/5.
   b. Current shall be time limited to protect against excessive over-charging.
   c. Apply CC until peak voltage is detected. About 2.83 volts per cell @ 25 ˚C. Discontinue CC charging.
4. The battery shall be discharged until the voltage reaches its manufacturer's specified end of discharge voltage. End Of Discharge Voltage may vary by discharge rate.

(5) The battery or cell's critical electrical performance parameters shall be monitored with a resolution, precision, accuracy and sample rate to detect any failure to satisfy a performance specification.

1. During the current pulse portion of the load profile, the monitoring must have a sample rate of once every 0.1 millisecond or better.
2. Voltage monitoring during vibration must have a minimum resolution of 10 mV.

(6) The number of charge/discharge cycles shall be recorded.

4.27.2 Venting Devices. A test of a battery or cell venting device shall demonstrate that the battery or cell will not experience a loss of structural integrity or create a hazardous condition when subjected to any electrical discharge, charging, or short-circuit condition. The vent shall protect the cell or battery from a catastrophic rupture that could injure personnel or disable adjacent FTS components.

a. Reusable Venting Devices. For a venting device that is capable of functioning repeatedly without degradation, such as a vent valve, the test shall exercise the device and demonstrate that it satisfies all its performance specifications.

1. This test may be performed on vents at the subassembly level.
2. Testing that results in the destruction of the cell or battery may be conducted on a representative sample to meet the intent of this requirement. The test shall demonstrate that each device sample vents within ± 10 percent of the manufacturer specified vent pressure.

b. Non-Reusable Venting Devices. For a venting device that does not function repeatedly without degradation, such as a burst disc, the test shall exercise a lot sample to demonstrate that the venting device satisfies all its performance specifications.

1. The test shall demonstrate that each device sample vents within ± 10 percent of the manufacturer specified vent pressure.
2. Test is not applicable for unsealed battery cases.

4.27.3 Cell Inspection and Preparation. A cell removed from storage shall undergo inspection and preparation prior to undergoing any testing.

a. Cells shall be serialized with indelible markings that will not damage the structural or electrical integrity of the cells. The serialization shall be a unique number for each cell and include or be traceable to the lot date code of the cell manufacturer.

b. Record lot date code and part number, and verify cells were manufactured as part of a continuous run from a single lot.

c. Demonstrate that the cell is clean and free of manufacturing defects

Inspect for missing/loose parts by shaking each cell by hand and listening for a rattling noise

d. Demonstrate that the cell has no leak IAW paragraph 4.27.8.

e. Weigh each cell and record to verify it meets the manufacturer's specification.

Weigh and record each cell to within ±2 percent of the expected nominal.

4.27.4 Initial Cell Voltage. As part of receiving inspection, verify each cell was delivered in its expected charged state.

1. Cells shall be stored and shipped in a partially charged state in accordance with manufacturer's specification. This specification is normally more than 2.1 volt. 2. If delivered cells have an OCV greater than 2.6, then they should be discharged at a rate that will not cause damage to the cells (usually less than C/20) to a voltage less than 2.6 volts. 3. If any delivered cell has an OCV less than 2.08, then it should be discarded. This indicates a short circuit within the cell. 4. Record each cell voltage for use in cell matching procedure. Note: OCV upon delivery may be useful for cell matching criteria.

4.27.5 Cell Characterization. Characterization testing shall stabilize the cell chemistry and determine the cell's ambient temperature capacity. A cell characterization shall satisfy the following:

a. Each cell shall repeatedly undergo charge/discharge cycles until the measured capacities for three consecutive cycles agree to a precision that shows the cell has stabilized.

1. Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive charge/discharge cycles agree to within 1 percent. The following process shall be used to validate the above requirement at ambient temperature.
   a. Charge IAW 4.27.1b.
   b. Monitor and record cell voltage during charge. If End-of-Charge OCV does not meet specification or is out-of-family, then cell is considered for rejection.
   c. Wait 1 hour prior to discharge.
   d. Discharge at C/5 to end of discharge voltage.
   e. Measure and record cell capacity at end of discharge.
   f. Repeat steps a through e for a minimum of 3 charge/discharge cycles until cell capacities agree within 1 percent.
2. Cells unable to demonstrate repeatable capacity after comparison to a majority of cells within the lot shall be considered for rejection.

Mathematical Representation of Individual Cell Characterization:

$$[\,3 * (C_{n\text{-}max} - C_{n\text{-}min})] / (C_n + C_{n\text{-}1} + C_{n\text{-}2}) < 0.01$$

Where:

C_n = Capacity of the last charge/discharge cycle.
$C_{n\text{-}1}$ = Capacity of the charge/discharge cycle prior to last.
$C_{n\text{-}2}$ = Capacity of the charge/discharge cycle 2nd from last.
$C_{n\text{-}max}$ = Maximum capacity from the last 3 cycles.
$C_{n\text{-}min}$ = Minimum capacity from the last 3 cycles.

b. During cell characterization, each cell must remain at a constant ambient temperature to ensure that the cell is not overstressed and to allow repeatable performance.

Cell Characterization tests shall be performed at 20 °C ± 2 °C or at the manufacturer's specification.

4.27.6 Performance at Low Temperature. The test shall stress the cell's chemistry performance, overcharge protection, capacity variation over low temperature and pulse load repeatability when subjected to a low temperature.

a. Each cell shall be repeatedly discharged at cold temperature until the capacity for three consecutive discharges agrees to a precision that shows consistent cell performance.

1. Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive charge/discharge cycles agree to within 1 percent. The following process shall be used to validate the above requirement at 0 °C ± 2 °C:
   a. Charge cell IAW 4.27.1b.
   b. Monitor and record cell voltage during charge. If End-of-Charge OCV does not meet specification or is out-of-family, then cell is considered for rejection.
   c. Thermally condition the cell at 0 °C ± 2 °C for at least 1 hour prior to discharge.
   d. Discharge cell at a rate of C/5 until to end of discharge voltage.
   e. Measure and record capacity at end of discharge voltage.
   f. Repeat steps "a" thru "e" until three consecutive cycles agree to within 1 percent of each other. In general, charge and discharge cycling is repeated 6 to 10 times before consecutive cycles agree.
2. Cells unable to demonstrate repeatable capacity after comparison to a majority of cells within the lot shall be considered for rejection.

b. During performance at low temperature, each cell must remain at a constant cold temperature to ensure that the cell is not overstressed and to allow repeatable performance.

4.27.7 Pulse Load Performance at Low Temperature. The cell shall be tested to ensure it can provide adequate voltage regulation when pulse loaded at a low temperature in a partially charged condition.

a. A pulse load test of a lead acid cell is used to identify out-of-family cells. A pulse load test under stressing conditions shall be used to verify lot consistency and identify substandard cells.

1. The following load testing is recommended at 0 °C to screen potentially bad cells prior to being assembled into the battery.
   a. Charge cell at a rate of C/5 at ambient temperature for at least 6.25 hours or until voltage peaks.
   b. Measure and record end-of-charge-voltage (EOCV). If EOCV is greater than expected or out of family, then consider cell for rejection.
   c. Thermally condition the cell at 0 °C ± 2 °C for at least 1 hour prior to discharge.
   d. Discharge cell at a rate of C/2 until 50 percent of the manufacturer's specified capacity is removed.
   e. Without interruption (less than 5 seconds), apply a pulse load of 2C discharge rate for 200mS.
   f. Measure and record voltage drop during pulse load.
   g. Resume steady state discharge until end of discharge voltage

2. Cells unable to maintain voltage regulation after comparison to a majority of cells within the lot shall be considered for rejection.

b. During pulse load performance at low temperature, each cell must remain at a constant cold temperature during discharge to ensure that the cell is not overstressed and to allow repeatable performance.

4.27.8 Cell Leakage. Demonstrate that the cell has no leak.

1. Check for leaks using chemical indicators such as Methyl Orange, Bromocresol Green or Methyl Red.
2. Cells that fail leak testing shall not be used.

4.27.9 Cell Selection.

a. Final Cell Screening. After completion of testing, data shall be reviewed.
   (1) Any cell unable to demonstrate consistent capacity at ambient and cold temperature shall not be used.
   (2) Any cell with out-of-family data for initial cell voltage and pulse load voltage regulation at ambient and cold temperature shall not be used.

b. Final Cell Matching. Cells shall be selected for each battery by matching associated performance properties of individual cells from the lot. The Range User shall provide to Range Safety for approval, the variables, criteria and methodology used for matching cells into batteries.

1. The priority of the performance parameters use for matching shall be dependent on the cell/battery design and operational application. The priority for using Initial cell voltage, cell conditioning at ambient temperature, cell characterization at cold temperature and cell pulse load performance at cold temperature tests shall ensure the battery will meet its performance requirements. Other properties may also be considered.
2. The qualification batteries shall be assembled with cells representing the widest variation in performance properties possibly allowed for flight batteries. The qualification batteries shall be built with the worst case mix of cells to validate the cell matching strategy.

4.27.10 Post Acceptance Test Storage. Batteries or cells requiring storage shall be stored within the cell storage voltage limits and temperature limits defined by the cell manufacturer. Storage conditions shall also protect against any performance degradation and be consistent with those used during qualification testing.

1. Post Acceptance Storage is required for batteries and cells that will not be used for 6 months or more.
2. Storage shall be in an open circuit configuration.
3. The cumulative storage time shall not exceed manufacture's recommendations. It is recommended that time at ambient temperature be logged for ageing engineering data.
4. Cells and batteries shall be protected and safely stored with the appropriate state of charge at the manufacture's recommended temperature or at less than 5 °C.
5. Cells and batteries shall be stored in a low humidity controlled environment.
6. Care must be exercised in allowing cells and batteries to achieve room temperature prior to removal from storage container to avoid condensation and thermal shock.
7. Periodic cell voltage monitoring and partial recharge shall be performed to maintain all cells within acceptable voltage limits.

4.27.11 Continuity, Isolation, and Insulation Resistance. The test shall demonstrate that all battery wiring and connectors are installed according to the manufacturer specifications. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each measurement satisfies its performance specifications and is in-family.

1. Pin-to-pin continuity shall be 0.05 ohms or less.
2. Pin-to-pin and pin-to-case isolation shall be 2 megohms or more.
3. Pin-to-case insulation resistance shall be 2 megohms or greater when measured at a potential of 500 ±25 Vdc.

4.27.12 Monitoring Capability. A monitoring capability test must demonstrate that each device that monitors a battery's voltage, current, or temperature satisfies all its performance specifications.

4.27.13 Heater Circuit Verification. The test must demonstrate that any battery heater, including its control circuitry, satisfies all its performance specifications.

The battery shall be tested at a temperature that allows the heater circuit to cycle at least 5 times.

4.27.14 Electrical Performance Test. An electrical performance test of a battery or cell shall demonstrate that the battery or cell satisfies all its performance specifications and is in-family while the battery or cell is subjected to flight electrical load profile plus a margin. The test shall verify that the battery or cell meets its performance requirements throughout the specified operational capacity.

a. The test shall measure and record a battery or cell's no-load voltage to ensure it is within the manufacturer specification limits.

b. The test shall demonstrate that the battery or cell voltage meets the manufacturer specification limits while the battery or cell is subjected to the steady-state flight

load. The test shall also demonstrate that the battery provides the minimum acceptance voltage for each electronic component that it powers.

c. The test shall demonstrate that the battery or cell supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specification. The test shall demonstrate that the battery or cell voltage does not fall below the voltage needed to provide the minimum acceptance voltage for each electronic component that it powers while the battery or cell is subjected to the pulse portion of the load profile. The test shall be conducted at it's lowest operational state of charge.

1. The load profile shall begin with a steady-state flight load followed without interruption by a current pulse.
2. The pulse width shall be no less than 10 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 milliseconds, whichever is greater.
3. The 10 times initiator pulse test shall meet voltage regulation requirements.
4. The 200 ms minimum workmanship voltage regulation shall be used to determine battery health and does not need to meet voltage regulation requirements.
5 The pulse amplitude shall be no less than 1.5 times the worst-case operational high current pulse.
6. After the pulse, the load profile shall end with a steady state flight load that lasts for no less than 15 seconds.
7. Electrical performance throughout the specified operational capacity shall be performed at different depths of discharge including it's lowest state of charge at the end of it's operational capacity.
8. The test shall subject the battery or cell to a final discharge that determines the remaining capacity.

4.27.15 Acceptance Thermal Cycle. An acceptance thermal cycle test shall demonstrate that a battery satisfies all it performance specifications when subjected to workmanship and maximum predicted thermal cycle environments. This shall include each of the following:

a. The test shall subject each component to no less than eight thermal cycles or 1.5 times the maximum number of thermal cycles that the component could experience during launch processing and flight, including all launch delays and recycling, whichever is greater.
b. The acceptance thermal cycle high temperature shall be a 61 °C workmanship screening level or the MPE high temperature, whichever is higher. The acceptance thermal cycle low temperature shall be a 0 °C workmanship screening temperature or the predicted environment low temperature, whichever is lower.
c. When heating or cooling the battery during each cycle, the temperature shall change at a rate that reflects the maximum predicted thermal transition rate. The dwell time at each high and low temperature shall be long enough for the battery to achieve internal thermal equilibrium and shall be no less than one hour.

The thermal transition rate shall be a minimum of 1 °C per minute.

d. The test shall measure a battery's performance parameters at the thermal extremes and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least once every 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies 4.27.14 while the battery is at the high and low temperatures, during the first and last thermal cycles. If the battery is not capable of passing the electrical performance test at either the workmanship high temperature or the low workmanship temperature, the battery may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following:
(1) The intermediate high temperature shall be no less than the maximum predicted high temperature.
(2) The intermediate low temperature shall be no greater than the minimum predicted low temperature.
(3) The dwell-time at the intermediate temperature shall be long enough for the battery to reach internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

(4) After electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

(5) The battery must undergo an electrical performance test while the battery is at ambient temperature before the first and after the last thermal cycles.

4.27.16 Charge Retention. A charge retention test shall demonstrate that a battery consistently retains its charge and contains no high impedance shorts. The controls and procedures, including minimum stand-time, shall allow measurable and repeatable determination of charge retention. Cell manufacturer's data for self-discharge shall be used for developing the criteria for this test.

1. The test shall begin with the battery or cell fully charged. The battery or cell shall undergo capacity discharge to develop a baseline capacity for comparison to its charge retention performance.
2. Undergo complete charging and then storage at 45 °C ± 2 °C for 7 days.
3. Undergo discharging to determine its capacity.
4. Demonstrate the capacity is greater than 90 percent of the baseline capacity of step 1 and the capacity retention is in-family.

4.27.17 Post Acceptance Storage. Post acceptance storage of a battery or cell shall ensure in-specification performance for the specified lifetime of the cell or battery.

1. For long-term storage, the battery and/or cell shall be stored fully charged in an open circuit condition to minimize aging degradation.
2. Batteries and cells shall be stored long-term between 0 °C to 5 °C in a humidity controlled environment state.
3. Storage of the cells shall not exceed the cell storage life specified by the cell manufacturer.

4.27.18 Cycle and Pulse Cycle Life. The battery shall demonstrate that it meets all its performance specifications for the number of pulses and operating charge and discharge cycles expected of the flight battery, including acceptance testing, preflight checkout, and flight plus a margin.

1. The minimum number of charge discharge cycles shall be twice the worst case expected number of cycles on the battery throughout its lifetime. Charge/discharge cycles used during other tests may be credited to meet this requirement.
2. Periodic electrical performance tests shall be performed throughout cycle life tests
   a. Electrical performance testing shall be performed in accordance with paragraph 4.27.14.
   b. Capacity shall be measured.
3. Pulse testing shall be performed in accordance with paragraph 4.27.14c. The minimum number of high current pulses applied during testing shall be twice the worst case expected number of pulses. Pulses used during other tests may be credited to meet this requirement.

4.27.19 Qualification Thermal Cycle. A qualification thermal cycle test shall demonstrate that a battery satisfies all its performance specifications when subjected to preflight, acceptance test, and flight thermal cycle environments. This shall include each of the following:

a. The test shall subject the fully charged battery to no less than three times the acceptance-number of thermal cycles
b. The qualification thermal cycle high temperature shall be a 71 °C workmanship screening level or the MPE high temperature plus 10 °C, whichever is higher. The qualification thermal cycle low temperature shall be a -10 °C workmanship

screening temperature or the predicted environment low temperature minus 10 °C, whichever is lower.

If the minimum hot and cold workmanship temperature extremes exceed the manufacturer specification, then the maximum and minimum specification shall be used. However, additional thermal cycles shall be added to account for thermal fatigue equivalence.

c. The thermal transition rate shall be the same used for acceptance testing.
d. The test shall measure a battery's performance parameters at the thermal extremes and during thermal transition to demonstrate that the battery satisfies all its performance specifications. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least once every 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies paragraph 4.27.14 while the battery is at the high and low temperatures, during the first, middle and last thermal cycles. If the battery is not capable of passing the electrical performance test at either the workmanship high or low temperature, the battery may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following:
   (1) The intermediate high temperature shall be no less than the maximum predicted high temperature plus 10 °C.
   (2) The intermediate low temperature shall be no greater than the minimum predicted low temperature minus 10 °C.
   (3) The dwell-time at the intermediate temperature shall be long enough for the battery to reach internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (4) After electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve internal thermal equilibrium.

Dwell time shall be a minimum of 1 hour.

   (5) The battery must undergo an electrical performance test while the battery is at ambient temperature before the first and after the last thermal cycles.

4.27.20 Operational Stand Time. An operational stand time test shall demonstrate that the battery will maintain its required capacity, including all required margins, from the final charge that the battery receives before flight. This test shall be use to verify CS, (Self-Discharge in Amp-Hrs). This shall include the following:

a. The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.
b. The battery must undergo a charge to full capacity. The test shall then subject the battery to the maximum predicted preflight temperature for the maximum operating stand time while in an open circuit configuration. The maximum operating stand time shall account for all launch processing and launch delay contingencies that could occur after the battery receives its final charge.
c. After the maximum operating stand time has elapsed, the battery must undergo a capacity discharge to determine the remaining capacity that will meet the flight requirement.

1. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
2. Discharge battery IAW paragraph 4.27.3.
3. Determine total capacity, CT.
4. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
5. Expose battery to the maximum expected temperature allowed between final charging and launch.
6. Expose battery to the maximum expected time allowed between final charging and launch.
7. Discharge battery IAW paragraph 4.27.3.
8. Measure and record remaining capacity, Cr.
9. Determine amount of capacity loss due to self discharge, $C_S = C_T - C_r$.
10. Factor C_S into battery budget.

4.27.21 Internal Inspection. An internal inspection of a battery must identify any excessive wear or damage to the battery, including any of its cells, after the battery is exposed to all the qualification test environments. An internal inspection shall satisfy paragraph 4.11.7.

1. An internal examination to verify that there was no movement of any component within the battery that stresses that component beyond its design limit
2. An examination to verify the integrity of all cell and wiring interconnects
3. An examination to verify the integrity of all potting and shimming materials
4. The cells shall be removed and examined for any physical damage
5. Test each cell for leaks.
6. One cell from each corner and one cell from the middle of the Qualification battery shall undergo Destructive Physical Analysis (DPA). The destructive physical analysis must verify the integrity of all connections between all plate tabs and cell terminals, and the integrity of each plate and separator. Range User may propose alternative non-destructive methods .
7. The remaining cells shall be X-rayed at 0° and 90° to verify tab and cell terminal integrity. Each cell's X-ray shall be compared with its cell lot acceptance X-ray.

4.27.22 Flight Self-Discharge. A flight self discharge test shall be performed to demonstrate that the battery will maintain its required capacity, including all required margins, from launch to end of Range Safety responsibility. This test shall be use to verify C_{fs}, (Flight Self-Discharge in Amp-Hrs). This shall include the following:

a. The battery must undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.
b. The battery must undergo a charge to full capacity. The test shall then subject the battery to the maximum predicted flight temperature for the maximum flight time while in an open circuit configuration.
c. After the maximum flight time has elapsed, the battery must undergo a capacity discharge to determine the remaining capacity that will meet the flight requirement.

1. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
2. Discharge battery IAW 4.27.3.
3. Determine total capacity, C_T.
4. Charge battery under nominal pre-launch operating conditions per launch operations procedures. Wait 1 hour.
5. Expose battery to the maximum predicted temperature allowed between launch and end of Range Safety responsibility.
6. Expose battery to the maximum expected time allowed between launch and end of Range Safety responsibility.
7. Discharge battery IAW 4.27.3.
8. Measure and record remaining capacity, C_{rf}.
9. Determine amount of capacity loss due to self discharge, $C_{fs} = C_T - C_{rf}$
10. Factor C_{fs} into battery budget.

4.27.23 Battery Case Integrity. A battery case integrity test shall demonstrate that:

a. The battery will not lose structural integrity or create a hazardous condition when subjected to all predicted operating conditions with margin to account for lot performance variations
b. The battery's leak rate satisfies all its performance specifications.

1. The test shall monitor the battery's pressure while subjecting the battery case to no less than 1.5 times the greatest operating pressure differential that could occur under qualification testing, preflight, or flight conditions, whichever is greater.
2. The pressure monitoring shall have a resolution and sample rate that allows accurate determination of the battery's leak rate.
3. The test shall demonstrate that the battery's leak rate is no greater than the equivalent of 10^{-4} standard cubic centimeters/seconds of helium.
4. The battery shall undergo examination to identify any condition that indicates that the battery might lose structural integrity or create a hazardous condition.

4.28 S&A Devices, LVIs, Rotor Leads, and Booster Charges

TABLE 4.28-1. S&A DEVICE ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Inspection (1)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check(1)	4.11.5	100%
Performance Verification	4.10.4	
Functional Tests (1)	4.28.2	100%
Safety Tests	4.28.5	
Manual Safing (1)	4.28.5d	100%
Safing-Interlock Test	4.28.5e	100%
Abbreviated Performance Verification	4.10.5	
Dynamic Performance	4.28.7	100%
Thermal Performance	4.28.6	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic	4.15.4	100%
Sinusoidal	4.15.5	100%
Random Vibration	4.15.6	100%
X-ray	4.11.6	100%
Leakage	4.11.8	100%

Note for Table 4.28-1:

(1) These tests shall also be performed at the launch site just before installation.

TABLE 4.28-2. S&A DEVICE QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested			
		X=Statistical Sample	X=1 (1)	X=6 (2)	X=3 (3)
Acceptance Tests	Table 4.28.1	-	X	X	-
Barrier Alignment	4.28.16	X	-	-	-
Safety Tests	4.28.5				
Extended Stall	4.28.5c	-	X	-	-
Abnormal Drop	4.13.11	-	X	-	-
Containment	4.28.5a	-	-	-	1
Barrier Functionality	4.28.5b	-	-	-	2
Safing Verification	4.28.5f	-	-	X	-
Performance Verification	4.10.4				
Functional Tests	4.28.2	-	-	X	-
Safety Tests	4.28.5	-	-	X	-
Manual Safing	4.28.5d	-	-	X	-
Safing-Interlock Test	4.28.5e	-	-	X	-
Abbreviated Performance Verification	4.10.5				
Dynamic Performance	4.28.7	-	-	X	-
Thermal Performance	4.28.6	-	-	X	-
Cycle Life	4.28.3	-	-	2	-
Non-Operating Environment Tests	4.13.1				
Storage Temperature	4.13.2	-	-	X	-
Transportation Shock	4.13.4	-	-	X	-
Bench Handling Shock	4.13.5	-	-	X	-
Transportation Vibration	4.13.6	-	-	X	-
Fungus Resistance	4.13.7	-	-	1	-
Fine Sand	4.13.8	-	-	1	-
Handling Drop	4.13.10	-	-	X	-
Operating Environment Tests	4.14.1				
Thermal Cycling	4.14.2	-	-	X	-
Humidity	4.14.4	-	-	X	-
Salt Fog	4.14.5	-	-	X	-
Temperature/Humidity/Altitude	4.14.6			X	
Acceleration	4.14.7	-	-	X	-
Shock	4.14.8	-	-	X	-
Acoustic	4.14.9	-	-	X	-
Sinusoidal Vibration	4.14.10	-	-	X	-
Random Vibration	4.14.11	-	-	X	-
Explosive Atmosphere (4)	4.14.13	-	-	2	-
Stall	4.28.4	-	-	X	-
X-ray	4.11.6	-	-	X	-
Leakage	4.11.8	-	-	X	-
Internal Inspection	4.11.7	-	-	2	-
Firing Tests	4.28.11				
Operating Current	4.28.11c	-	-	-	-
High Temperature	4.28.11f	-	-	2	-
Low Temperature	4.28.11g	-	-	2	-

Notes for Table 4.28-2:

(1) One S&A device shall undergo the extended stall and abnormal drop tests designated with an X.
(2) The same six sample S&A devices shall undergo each test designated with an X. For a test designated with a quantity of less than six, each S&A device tested shall be one of the original six sample components.
(3) One S&A device shall undergo the containment test and two S&A devices shall under go the barrier functionality test. The S&A device samples used for these tests need not be flight S&A devices. The test samples shall duplicate all dimensions of a flight S&A device, including gaps between explosive components, free-volume, and diaphragm thickness.
(4) A shall be cycled from Safe/Arm and Arm/Safe 5 times for this test.

TABLE 4.28-3. LVI LOT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination (5)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification	4.10.4	
Insulation Resistance (5)	4.28.8	100%
Bridgewire Resistance (5)	4.28.9	100%
Static Discharge	4.28.10	100%
Non-Operating Environment Tests and Operating Environment Tests (1)	4.13.1 4.14.1	Lot Sample (3)
Thermal Cycling	4.14.2	Lot Sample
High Temperature Storage (2)	4.13.3	Lot Sample
Shock	4.14.8	Lot Sample
Sinusoidal Vibration	4.14.10	Lot Sample
Random Vibration	4.14.11	Lot Sample
No Fire Verification	4.28.17	Lot Sample
Component Examination	4.11.1	
Visual Examination	4.11.2	Lot Sample
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests (4)	4.28.11a	
Ambient Temperature	4.28.11e	
All-Fire Current	4.28.11b	1/6 Lot Sample
Operating Current	4.28.11c	1/6 Lot Sample
High Temperature	4.28.11f	
All-Fire Current	4.28.11b	1/6 Lot Sample
Operating Current	4.28.11c	1/6 Lot Sample
Low Temperature	4.28.11g	
All-Fire Current	4.28.11b	1/6 Lot Sample
Operating Current	4.28.11c	1/6 Lot Sample

Notes for Table 4.28-3:

(1) This test shall subject each LVI sample to the qualification environmental test level. For an LVI that is internal to an S&A device, the test level shall be no less than the environment that the LVI experiences when installed and the S&A device is subjected to its qualification environment. No monitoring is required during environmental testing.
(2) A high temperature storage test is optional. A lot will have an initial service-life of three years if high temperature storage is performed. A lot will have an initial service-life of one year if high temperature storage is not performed.
(3) The lot sample quantity shall be no less than 10 percent of the production lot or 30 sample LVIs, whichever is greater.
(4) When the lot cannot be evenly divided, any extra samples will be fired at low temperature at all-fire current.
(5) These tests shall also be performed at the launch site.

TABLE 4.28-4. LVI QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [5] X=				
		5	SS [6]	SS [7]	SS [8]	105
Component Examination	4.11.1					
Visual Examination	4.11.2	X	X	X	X	X
Dimension Measurement	4.11.3	X	X	X	X	X
Leakage	4.11.8	X	X	X	X	X
X-ray and N-ray	4.11.6	X	X	X	X	X
Performance Verification	4.10.4					
Bridgewire Resistance	4.28.9	X	X	X	X	X
Insulation Resistance	4.28.8	X	X	X	X	X
Static Discharge	4.28.10	X	X	X	X	X
RF Impedance	4.28.12	-	10	-	-	-
RF Sensitivity	4.28.13	-	X	-	-	-
Statistical No-Fire Level	4.28.14	-	-	X	-	-
Statistical All-Fire Level	4.28.15	-	-	-	X	-
Non-Operating Environment Tests and Operating Environment Tests [2]	4.13.1 4.14.1					
Thermal Cycling	4.14.2	-	-	-	-	X
High Temperature Storage [3]	4.13.3	-	-	-	-	30
Shock	4.14.8	-	-	-	-	X
Random Vibration	4.14.11	-	-	-	-	X
No-Fire Verification	4.28.17	-	-	-	-	30
Tensile Load [4]	4.13.9	-	-	-	-	30
Auto-Ignition	4.28.18	X	-	-	-	-
Component Examination	4.11.1					
Visual Examination	4.11.2	-	-	-	-	X
Leakage	4.11.8	-	-	-	-	X
X-ray and N-ray	4.11.6	-	-	-	-	X
Firing Tests	4.28.11a					
Ambient Temperature	4.28.11e					
All-Fire Current [1]	4.28.11b	-	-	-	-	15
Operating Current [1]	4.28.11c	-	-	-	-	15
2X Operating Current	4.28.11d	-	-	-	-	5
High Temperature	4.28.11f					
All-Fire Current [1]	4.28.11b	-	-	-	-	15
Operating Current [1]	4.28.11c	-	-	-	-	15
2X Operating Current	4.28.11d	-	-	-	-	5
Low Temperature	4.28.11g					
All-Fire Current [1]	4.28.11b	-	-	-	-	15
Operating Current [1]	4.28.11c	-	-	-	-	15
2X Operating Current	4.28.11d	-	-	-	-	5

Notes for Table 4.28-4:

(1) All the LVI samples that undergo the high temperature storage test, no-fire verification test, or tensile load test shall be evenly distributed between each all-fire current and operating current firing test.
(2) This test shall subject each LVI sample to the qualification environmental test level. For an LVI that is internal to an S&A device, the test level shall be no less than the environment that the LVI experiences when installed and the S&A device is subjected to its qualification environment. No monitoring is required during environmental testing.
(3) A high temperature storage test is optional. A lot will have an initial service-life of three years if high temperature storage is performed. A lot will have an initial service-life of one year if high temperature storage is not performed.
(4) This test is not required if any other test verifies that each LVI is not damaged during installation.
(5) For each column, the quantity required at the top of the column shall be from the same production lot and shall be subjected to each test designated with an X. For a test designated with a lesser quantity, each sample tested shall be one of the original samples for that column.
(6) For the designated column, SS (statistical sample) shall be the quantity of sample components needed to perform a statistical firing series to determine the RF sensitivity of the LVI. Each sample component shall undergo each test designated with an X.
(7) For the designated column, the SS shall be the quantity of sample components needed to perform a statistical firing series to determine the LVI NO-FIRE energy level. Each sample component shall undergo each test designated with an X.
(8) For the designated column, SS shall be the quantity of sample components needed to perform a statistical firing series to determine the LVI all-fire energy level. Each sample component shall undergo each test designated with an X.

TABLE 4.28-5. LVI SERVICE-LIFE EXTENSION TEST REQUIREMENTS(5)

Test	Paragraph	Quantity Tested (2)	
		1 Year (3) X=5	3 Years (4) X=10
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Performance Verification	4.10.4		
Bridgewire Resistance	4.28.9	X	X
Insulation Resistance	4.28.8	X	X
Static Discharge	4.28.10	X	X
Non-Operating Environment Tests and Operating Environment Tests (1)	4.13.1 4.14.1		
Thermal Cycling	4.14.2	X	X
High Temperature Storage	4.13.3	-	X
Shock	4.14.8	X	X
Sinusoidal Vibration	4.14.10	X	X
Random Vibration	4.14.11	X	X
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.28.11a		
All-Fire Current	4.28.11b		
Ambient Temperature	4.28.11c	1	3
High Temperature	4.28.11d	2	3
Low Temperature	4.28.11e	2	4

Notes for Table 4.28-5:

(1) This test shall subject each LVI sample to the qualification environmental test level. For an LVI that is internal to an S&A device, the test level shall be no less than the environment that the LVI experiences when installed and the S&A device is subjected to its qualification environment. No monitoring is required during environmental testing.

(2) For each column, the quantity of sample LVIs required at the top of the column shall be from the same production lot and shall undergo each test designated with an X. For a test designated with a lesser quantity, each LVI tested shall be one of the original samples for that column.

(3) Five LVIs from the same lot shall undergo the tests required by this column to extend the service-life of the remaining LVIs from the same lot for one year.

(4) Ten LVIs from the same lot shall undergo the tests required by this column to extend the service-life of the remaining LVIs from the same lot for three years.

(5) In order to extend the service-life of an LVI, the device shall undergo the tests required by the one-year column or the three-year column. Service life extension samples shall be stored with the flight ordnance component or in an environment that duplicates the storage conditions of the flight ordnance component.

TABLE 4.28-6. S&A ROTOR LEAD AND BOOSTER CHARGE LOT ACCEPTANCE TEST REQUIREMENTS (1)

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1	
Thermal Cycling (2)	4.14.2	Lot Sample (4)
High Temperature Storage (3)	4.13.3	Lot Sample
Component Examination	4.11.1	
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests (5), (6)	4.28.11a	
High Temperature	4.28.11f	½ Lot Sample
Low Temperature	4.28.11g	½ Lot Sample

Notes for Table 28-6:

(1) This table applies to any rotor lead or booster charge that is used inside an S&A device.
(2) This test shall subject each ordnance sample to the qualification environmental test level. (3) The test level shall be no less than the environment that the ordnance experiences when installed and the S&A device is subjected to its qualification environment. No monitoring is required during environmental testing.
(4) A high temperature storage test is optional. A lot will have an initial service-life of five years if high temperature storage is performed. A lot will have an initial service-life of one year if high temperature storage is not performed.
(5) The lot sample quantity shall be no less than 10 percent of the lot or nine sample units from the lot, whichever is greater.
(6) When the lot cannot be evenly divided, any extra samples will be fired at low temperature.

TABLE 4.28-7. S&A ROTOR LEAD & BOOSTER CHARGE QUALIFICATION TEST REQUIREMENTS (1)

Test	Paragraph	Quantity Tested (4) X=21
Component Examination	4.11.1	
Visual Examination	4.11.2	X
Dimension Measurement	4.11.3	X
Leakage	4.11.8	X
X-ray and N-ray	4.11.6	X
Non-Operating and Operating Environment Tests (2)	4.13.1 4.14.1	
Thermal Cycling	4.14.2	X
High Temperature Storage (3)	4.13.3	10
Shock	4.14.8	X
Sinusoidal Vibration	4.14.10	X
Random Vibration	4.14.11	X
Component Examination	4.11.1	
X-ray and N-ray	4.11.6	X
Leakage	4.11.8	X
Firing Tests	4.28.11a	
Ambient Temperature	4.28.11e	7
High Temperature	4.28.11f	7
Low Temperature	4.28.11g	7

Notes for Table 4.28-7:

(1) This table applies to any rotor lead or booster charge that is used inside an S&A device.
(2) This test shall subject each ordnance sample to the qualification environmental test level. The test level shall be no less than the environment that the ordnance experiences when installed and the S&A device is subjected to its qualification environment. No monitoring is required during environmental testing.
(3) A high temperature storage test is optional. A lot will have an initial service-life of five years if high temperature storage is performed. A lot will have an initial service-life of one year if high temperature storage is not performed.
(4) The same 21 sample components, from the same production lot, shall undergo each test designated with an X. For a test designated with a quantity of less than 21, each component sample tested shall be one of the original 21 samples.

TABLE 4.28-8. S&A ROTOR LEAD AND BOOSTER CHARGE SERVICE-LIFE EXTENSION TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested (3)	
		1 Year (4) X=5	5 Years (5) X=10
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Non-Operating and Operating Environment Tests	4.13.1 4.14.1		
Thermal Cycling (2)	4.14.2	X	X
High Temperature Storage	4.13.3	-	X
Component Examination	4.11.1		
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.28.11a		
High Temperature	4.28.11f	2	5
Low Temperature	4.28.11g	3	5

Notes for Table 4.28-8:

(1) This table applies to any rotor lead or booster charge that is used by an S&A device. In order to extend the service-life of a rotor lead or booster charge, the rotor lead or charge shall undergo each test required by the one-year column or the five-year column. Service life extension samples shall be stored with the flight ordnance component or in an environment that duplicates the storage conditions of the flight ordnance component.

(2) This test shall subject each ordnance sample to the qualification environmental test level. (3) For ordnance that is internal to an S&A device, the test level shall be no less than the actual environment that the ordnance experiences when installed and the S&A device is subjected to its qualification environment.

(3) For each column, the quantity of sample components required at the top of the column shall be from the same production lot and shall undergo each test designated with an X. For a test designated with a lesser quantity, each component tested shall be one of the original samples for that column.

(4) Five ordnance samples from the same lot shall undergo the tests required by this column to extend the service-life of the remaining ordnance from the same lot for one year.

(5) Ten ordnance samples from the same lot shall undergo the tests required by this column to extend the service-life of the remaining ordnance from the same lot for five years.

4.28.1 General.

a. This section applies to an electromechanical S&A with an internal LVI, external low voltage initiator's rotor lead, or booster charge.
b. Acceleration Armed S&As will require additional tailoring not included in the tables of this section.
c. Any S&A device, LVI, rotor lead, or booster charge shall satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

4.28.2 Functional Tests. An S&A shall be tested to demonstrate it meets its performance requirements and shall include the following:

a. An insulation resistance test shall measure mutually insulated pin-to-pin and pin-to-case points using maximum operating voltage plus a margin. The test shall demonstrate that the internal wiring and other insulation material are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 500 VDC between the mutually-insulated points or between insulated points and ground immediately after a 1-minute period of uninterrupted test voltage application. The voltage used for this test shall not damage or degrade the component.
2. The measurement error at the required insulation resistance value shall not exceed 10 percent.
3. The insulation resistance between all insulated parts shall be greater than 2 MΩ.

b. S&A transition time from Safe/Arm and Arm/Safe through multiples S&A transition cycles.
c. Low voltage initiator firing circuit (i.e. bridgewire resistance) consistency through multiple S&A transition cycles.

For electrically armed S&As, the transition and firing circuit tests shall be performed using 25 Arm/Safe cycles with measurements taken every 5 cycles.

d. The test shall demonstrate that the S&A monitors accurately determine S&A transition and whether the S&A device is in the proper configuration.

1. The presence of the arm indication when the S&A is armed.
2. The presence of the safe indication when the S&A is safed.

e. Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications.

1. Isolation resistance shall be 2 MΩ.
2. The test shall measure the continuity of the internal circuits to demonstrate that the continuity resistances satisfy their performance specifications.

4.28.3 Cycle Life. This test shall demonstrate that the S&A transition, such as rotational or sliding operation, satisfies all its performance specifications.

The test shall demonstrate the ability of an S&A device to satisfy all its performance specifications when subjected to five times the maximum predicted number of safe-to-arm and arm-to-safe cycles.

1. For S&As that are electrically armed, the unit shall withstand repeated cycling from the armed to the disarmed position for at least 1000 cycles without any malfunction, failure, or deterioration in electromechanical performance.
2. If less than 1000 cycles are used, the Range User shall provide:
   a. The S&A shall be qualified for an cycle life of at least two times the total expected cycles that will include acceptance, bench tests, prelaunch checkout and launch attempts.
   b. Data sheets shall accompany each S&A that provides the number of times the device has been cycled, QA stamp or initials of the person performing the test, and the results of the test where applicable. S&As that exceed 50 percent of the qualification number of cycles will not be allowed for flight. S&As that do not have an accompanying data sheet for review by Range Safety personnel will not be allowed for flight.
3. Perform a functional test in accordance with paragraph 4.28.2 at every 1/3 interval of cycle time.

4.28.4 Stall. A stall test shall demonstrate that an S&A device satisfies all its performance specifications after being locked in its safe position and subjected to an operating arming voltage for the greater of 5 minutes or the maximum time that could occur inadvertently and the device still be used for flight.

4.28.5 Safety Tests. The following safety tests shall demonstrate that an S&A device can be handled safely:

a. Containment. A containment test shall demonstrate that an S&A device will not fragment when any internal low voltage initiator or rotor charge is initiated. An S&A device shall undergo the test in the arm position and with any shipping cap or plug installed in each output port.
b. Barrier Functionality. A barrier functionality test shall demonstrate that, when in the safe position, if an S&A device's internal low voltage initiator is fired, the ordnance output will not propagate to an ETS. This demonstration shall include all of the following:
   (1) The test shall consist of firings at high and low temperature extremes, the ETS shall be configured for flight.

(2) The high temperature firing shall be initiated at the maximum predicted high temperature or a 71 °C workmanship screening level, whichever is higher.
(3) The low temperature firing shall be initiated at the maximum predicted low temperature or a -54 °C workmanship screening level, whichever is lower.

c. Extended Stall. An extended stall test shall demonstrate that an S&A device does not initiate when locked in its safe position and is subjected to a continuous operating arming voltage for the maximum predicted time that could occur accidentally or one hour, whichever is greater.

d. Manual Safing. A manual safing test shall demonstrate that an S&A device can be manually safed in accordance with all its performance specifications.

When the safing interlock is inserted and rotated, it shall manually safe the device.

e. Safing-interlock. A safing-interlock test shall demonstrate that an S&A device's safing-interlock prevents arming in accordance with all the performance specifications when operational arming current is applied.

Removal of the safing interlock shall not be possible if the arming circuit is energized. The retention mechanism of the safing pin shall be capable of withstanding an applied force of at least 100-pounds tension or a torque of 100 in-pounds without failure.

f. Safing Verification. A safing verification test shall demonstrate that, while an S&A device is in the safe position, any internal LVI will not initiate if the S&A device input circuit is accidentally subjected to a firing voltage.

4.28.6 Thermal Performance. Thermal performance test shall demonstrate that an S&A device satisfies all its performance specifications when subjected to operating and workmanship thermal environments including thermal cycle, thermal vacuum, humidity and salt-fog. The test shall include all of the following:

a. The test shall continuously monitor the S&A firing circuit (bridgewire) continuity with the S&A device in its arm position to detect variations in amplitude. Any variation outside the performance specification constitutes a test failure.
b. The test shall measure the S&A firing circuit (bridgewire) resistance for the first and last thermal cycle during the high and low temperature dwell times to demonstrate that the firing circuit resistance satisfies its performance specification.
c. The test shall subject the S&A device to multiple Safe/Arm cycles and measure the bridgewire continuity during each cycle to demonstrate that the continuity is consistent.

For electrically armed S&As, the transition and firing circuit tests shall be performed using 25 Arm/Safe cycles with measurements taken every 5 cycles.

d. The test shall measure the S&A Safe/Arm and Arm/Safe cycle time to demonstrate that it satisfies the manufacturer specification.

4.28.7 Dynamic Performance. A dynamic performance test shall demonstrate that an S&A device satisfies all its performance specifications when subjected to the dynamic operational environments, including random vibration, sinusoidal vibration, acoustic and shock. This demonstration shall include all of the following:

a. The S&A device shall undergo the test while subjected to each required dynamic operational environment.
b. The test shall continuously monitor the S&A device firing circuit (bridgewire) for continuity with the S&A device in the arm position to detect variation in amplitude. Any amplitude variation constitutes a test failure.
c. The test shall continuously monitor the S&A device monitor circuit for continuity. Any dropouts constitute a test failure.
d. The test shall continuously monitor the S&A device to demonstrate that it remains in the fully armed position throughout all dynamic environment testing.

4.28.8 Insulation Resistance. An insulation resistance test shall measure mutually insulated pin-to-case points using maximum operating voltage plus a margin. The test shall demonstrate that the internal wiring and other insulation material are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 500 VDC between insulated points and case immediately after a 1-minute period of uninterrupted test voltage application. The voltage used for this test shall not damage or degrade the component.
2. The measurement error at the required insulation resistance value shall not exceed 10 percent.
3. The insulation resistance between all insulated parts shall be greater than 2 MΩ.

4.28.9 Bridgewire Resistance. An bridgewire resistance test shall be performed to demonstrate that the low voltage initiator meets its performance requirements.

1. An accuracy of 2 percent of the true value or better is required.
2. Apply a maximum current of 10 milliamps or 10 percent of the NO-FIRE current (as determined by the Bruceton Test) whichever is less, and measure the bridgewire resistance.

4.28.10 Static Discharge. A static discharge test shall demonstrate that an LVI can withstand an electrostatic discharge that it could experience from personnel or conductive surfaces without firing and still satisfy all its performance specifications.

The test shall subject the LVI to the greater of:

a. A 25k-volt, 500-picofarad pin-to-pin discharge through a 5k-ohm resistor and a 25k-volt, 500-picofarad pin-to-case discharge with no resistor
b. The maximum predicted pin-to-pin and pin-to-case electrostatic discharges. See Figure 4.28-1 for the test setup.
c. Pins shall be shorted for pin-to-case mode

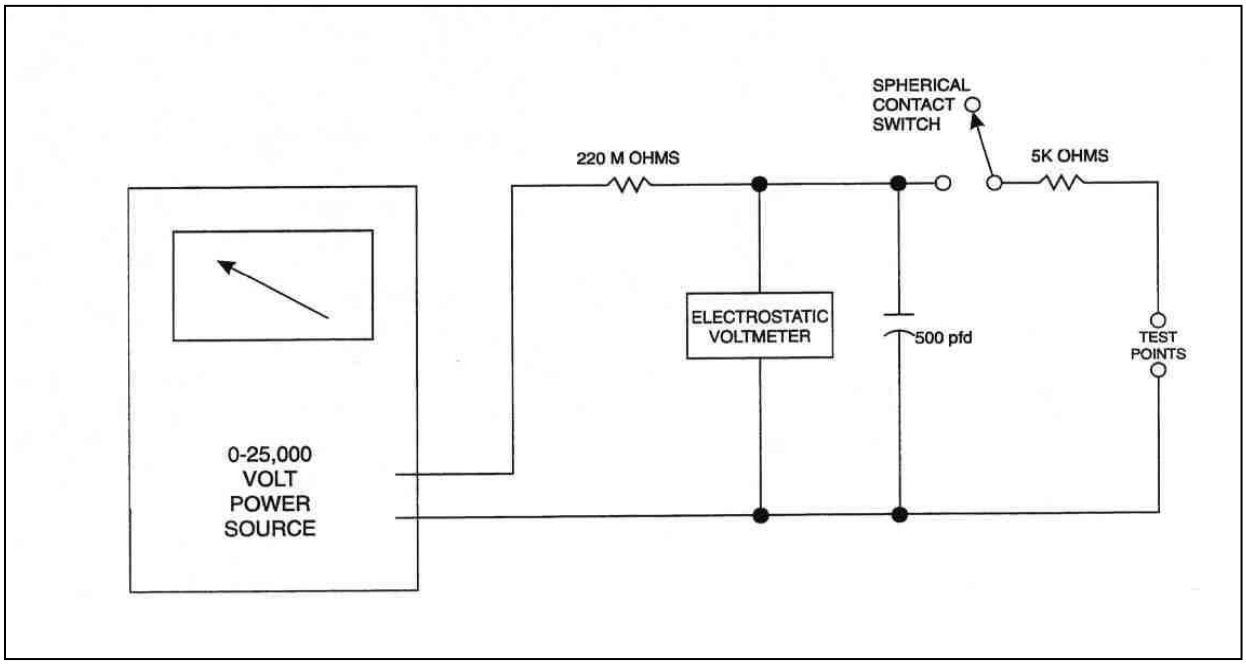


Figure 4.28-1. Static discharge test.

4.28.11 Firing Tests.

a. General. Each firing test of an S&A device, LVI, rotor lead, or booster charge shall satisfy all of the following:
   (1) The test shall demonstrate the initiation and transfer of all ordnance charges. For an S&A device that has more than one internal LVI, each firing test shall also demonstrate that the initiation of one internal LVI does not adversely affect the performance of any other internal LVI.
   (2) For a low voltage initiator not installed internally within an S&A, testing shall demonstrate that the initiator body does not fragment when fired.
   (3) Before initiation, each component sample shall experience the required temperature for enough time to achieve thermal equilibrium.

(4) Each low voltage initiator test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all its performance specifications.

Gas producing LVIs shall be fired in a closed bomb. The following parameters shall be measured:

a. Time from application of current to bridgewire burnout.
b. Time from application of current to first indication of pressure.
c. Time from first indication of pressure to peak pressure.
d. Peak pressure.
e. Detonating explosives shall be tested using a metal witness plate to record output through a dent depth measurement technique.
f. The device shall meet the requirements of the component qualification.

(5) The S&A shall use a flight-representative configured interface to verify the output meets its performance requirements.

The S&A shall use an ETS on the S&A output.

(6) Each test of an S&A device or LVI shall subject each sample device to a current source that duplicates the operating output waveform and impedance of the flight current source.

A maximum 30-millisecond current pulse is required for ALL-FIRE level testing.

(7) Each test of a rotor lead or booster charge shall subject the component to an energy source that simulates the flight energy source. The test shall measure ordnance output using a measuring device, such as a dent block, to demonstrate that the output satisfies all its performance specifications.

b. <u>All-Fire Current</u>. Each all-fire current test shall subject the component sample to the manufacturer specified all-fire current value.

c. <u>Operating Current</u>. Each operating current test shall subject each component sample to the launch vehicle operating current value.

d. <u>2X Operating Current</u>. Each operating current test shall subject each component sample to a minimum of twice the vehicle operating current value.

This test shall subject each component sample to a firing current of 22 amps.

e. <u>Ambient Temperature</u>. Each sample shall be fired at ambient temperature.

f. High Temperature. Each sample shall be fired at the qualification high temperature level or at +71 °C, whichever is higher.

g. Low Temperature. Each sample shall be fired at the qualification low temperature level or at -54 °C, whichever is lower.

4.28.12 RF Impedance. This test shall determine the RF impedance of an LVI for use in the FTS RF susceptibility analysis.

1. During a worst-case analysis of the susceptibility of the system to its electromagnetic environment, a worst-case parameter such as the dc resistance is used for the impedance. If this worst-case resistance parameter causes a rejection of the worst-case analysis results, RF impedance can be used to reduce predicted analytical results.
2. All tests shall be performed at room temperature (approximately 25°C).
3. A minimum of 10 LVIs shall be used in the impedance measurements. These items may be reused in the RF sensitivity or RF dudding testing.
4. The impedance measuring equipment shall be able to function at extremely low RF power levels so that the LVIs are not subjected to heating effects. Automatic equipment is preferred. It is suggested that no more than 1 milliwatt be applied to the LVI in any firing mode during the measurements. The mounting apparatus used to connect the LVI to the impedance measuring apparatus will be constructed so that the impedance measurements refer to a point as close to the base of the LVI (exterior surface of the LVI header) as is possible.
5. For 2-pin conventional hot-wire LVIs, pin-to-pin and pin-to-case impedances shall be measured. For dual bridgewire LVIs, pin-to-pin, pin-to-case, and bridge-to-bridge firing modes shall be measured.
6. Measure impedances at 10 frequencies from 1 to 1200 MHz and should include any frequency corresponding to a known high power density in the LVIs operational environment.
7. The individual measurement frequencies should be selected so that neighboring frequencies differ from each other by an approximately equal logarithmic increment.

4.28.13 RF Sensitivity. This test shall consist of a statistical firing series of samples to determine the RF no-fire energy level. The firing series shall determine the highest continuous RF energy level to which the device can be subjected and not fire with a reliability of 0.999 at a 95 percent confidence level.

1. At each RF frequency to be used in the test, the RF power to be applied to the LVIs is determined from the mean dc firing current measured in the Bruceton Test and dc bridgewire resistance. This level shall be applied to the devices in each configuration (pin-to-pin, pin-to-case, and bridgewire-to-bridgewire).
2. The equipment used in the tests shall provide a means to account for loss in the power supplying system. Applied powers shall be demonstrated to be those that are actually delivered to the input of the LVI.

3. Mounting hardware for the LVI shall be constructed to allow measurement of power as close to the LVI base (exterior surface of the LVI header) as possible.
4. A statistical sampling scheme, such as Bruceton, Langley, or Neyer, shall be used to demonstrate the required reliability.
5. At least 10 frequencies shall be used in the probing tests. These frequencies should be chosen to cover the frequency range from 1 MHz to 32 GHz and should include any frequency corresponding to a known high power density in the LVIs operational environment.
6. Special consideration should be given to the frequencies that correspond to the transmitters that are associated with the overall system.
7. If there are no specific requirements, the approximate frequency and modulation stimuli shown in the following table shall be used.
8. Probing Test.
   a. At each test frequency, test 10 LVIs for 5 minutes in the pin-to-pin configuration and 10 LVIs in the pin-to-case configuration. If the LVI has dual bridgewires, test 10 more in the bridgewire-to-bridgewire configuration.
   b. Up to five LVIs that did not fire in the pin-to-pin test can be reused in the pin-to-case test. Thus, RF probing tests require 15 items at each frequency for a two-pin single bridge device and 25 items for a dual bridge device.

Default Test Frequencies and Modulation

Frequency (MHz)	Modulation (1), (2)
1.5	CW
27.0	CW
154.0	CW
250.0	CW
900.0	CW
2,700.0	P
5,400.0	P
8,900.0	P
15,000.0	CW
32,000.0	P

Notes: (1) C = Continuous Wave
(2) P = Pulsed modulation with pulse width of 1 microsecond and pulse repetition rate of 1 kHz

9. Analysis.
   a. Count the number of firings at each frequency.
      (1) At any particular frequency, if two or less fire, the direct current sensitivity level can be used for subsequent analysis.
      (2) If three or more fire, the RF sensitivity level can be used for subsequent analysis.
   b. From the data that was obtained in the probing tests, determine the most sensitive frequency/modulation stimulus for each firing configuration.

10. Statistical RF NO-FIRE Level.
    a. Perform a 5-minute, 40-item, NO-FIRE Bruceton Test at the most sensitive frequency/ modulation stimulus for each configuration. The same equipment shall be used in the probing tests.
    b. Forty items are required for each firing configuration of the device being tested. Thus, 80 items are required for a two-pin single bridge device and 120 items for a dual bridge device.
    c. RF dudding tests are not required if the LVIs will not be exposed to RF greater than the RF NO-FIRE level, as determined by the RF sensitivity testing. The maximum RF exposure level is that maximum level determined by a worst-case electromagnetic hazard analysis approved by Range Safety. If the LVI will be exposed to an RF level higher than the RF NO-FIRE LEVEL, then an RF dudding test shall be performed in accordance with tailored requirements using MIL-STD-1576, Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems, method 2208, as a baseline.

4.28.14 No-Fire Level. This test shall consist of a statistical firing series of samples to determine the no-fire energy level. The firing series shall determine the highest electrical energy level at which the device will not fire with a reliability of 0.999 at a 95 percent confidence level when subjected to a continuous current pulse.

1. A statistical sampling scheme, such as Bruceton, Langley or Neyer, shall be used to demonstrate the required reliability.
2. Firing pulse shall be a minimum of 5 minutes.
3. Testing shall be performed at worst-case hot temperature operational conditions.

4.28.15 All-Fire Level. This test shall consist of a statistical firing series to determine the all-fire energy level. This firing series shall determine the lowest electrical energy level at which the device will fire with a reliability of 0.999 at a 95 percent confidence level.

1. The firing pulse shall use a constant current pulse of 30 milliseconds.
2. A statistical sampling scheme, such as Bruceton, Langley or Neyer, shall be used to demonstrate the required reliability.

4.28.16 Barrier Alignment. A barrier alignment test shall consist of a statistical test firing series that demonstrate that the device's safe to arm transition motion provides for ordnance initiation with a reliability of 0.999 at a 95 percent confidence level. The test shall also demonstrate that the device's arm to safe transition motion provides for no ordnance initiation with a reliability of 0.999 at a 95 percent confidence level. This test may employ a reusable S&A subassembly that simulates the flight configuration.

4.28.17 No-Fire Verification. An ordnance initiator shall demonstrate its specified no-fire energy level. An ordnance initiator shall not fire when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level.

This test shall demonstrate that a flight configured LVI will not inadvertently initiate or degrade in performance when exposed to the maximum predicted circuit leakage current plus a margin and will still satisfy all its performance specifications.

The test shall subject each sample LVI to the greater of:

a. The maximum predicted leakage current level and duration plus a 20 dB margin that could occur in an operating condition for five minutes, or
b. One amp/one watt for five minutes. If the DC sensitivity does not represent worst case, then an RF induced no-fire level shall be used for this test.

4.28.18 Auto-Ignition. This test shall demonstrate that an LVI shall not auto-ignite, exhibit density variations or melt when subjected to any high temperature environment during handling, testing, storage, transportation, installation, or flight.

1. The test environment shall be no less than 30° C higher than the highest non-operating or operating temperature that the device could experience.
2. The test shall last the maximum predicted high temperature duration or one hour, whichever is greater.
3. After exposure to the test environment, each sample device shall undergo external and internal examination, including any dissection needed to identify any auto-ignition, density variations or melting.

4.29 High Energy Firing Units

This section applies to any firing unit and ordnance system that is part of an FTS that uses voltages higher than 500V to directly initiate a secondary explosive.

TABLE 4.29-1. HIGH ENERGY FIRING UNIT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination (3)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check (3)	4.11.5	100%
Performance Verification (3)	4.10.4	
Continuity and Isolation	4.29.2	100%
Input Current (1)	4.29.3	100%
High Voltage Circuitry (1)	4.29.4	100%
High Voltage Charging Circuit (1)	4.29.5	100%
Command Processing (1)	4.29.6	100%
Output Monitoring (1)	4.29.8	100%
Abbreviated Performance Verification (2)	4.10.5	
Input Current	4.29.3	100%
Abbreviated Command Processing	4.29.7	100%
Output Monitoring	4.29.8	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic (2)	4.17.4	100%
Sinusoidal Vibration (2)	4.15.5	100%
Random Vibration (2)	4.15.6	100%
Leakage	4.11.8	100%

Notes for Table 4.29-1:

(1) A component shall undergo these tests at the first and last hot and cold thermal dwell cycles for thermal cycle and thermal vacuum tests. A component shall undergo an input current and output monitor test during all thermal cycles and transitions.
(2) Abbreviated performance verification tests shall be performed during dynamic operating environments.
(3) These tests shall also be performed as part of preflight testing at the launch site.

TABLE 4.29-2. HIGH ENERGY FIRING UNIT QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested X=3
Acceptance Tests	Table 4.29.1	X
Performance Verification	4.10.4	
Resistance	4.29.2	X
Input Current (1)	4.29.3	X
High Voltage Circuitry (1)	4.29.4	X
High Voltage Charging Circuit (1)	4.29.5	X
Command Processing (1)	4.29.6	X
Output Monitoring (1)	4.29.8	X
Abbreviated Performance Verification (2)	4.10.5	X
Input Current (4)	4.29.3	X
Abbreviated Command Processing	4.29.7	X
Output Monitoring (4)	4.29.8	X
Non-Operating Environment Tests	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Handling Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Fungus Resistance	4.13.7	1
Fine Sand	4.13.8	1
Operating Environment Tests	4.14.1	
Thermal Cycling	4.14.2	X
Thermal Vacuum	4.14.3	X
Humidity	4.14.4	X
Salt Fog	4.14.5	X
Temperature/Humidity/Altitude	4.14.6	X
Acceleration (2)	4.14.7	X
Shock (3)	4.14.8	X
Acoustic (2)	4.14.9	X
Sinusoidal Vibration (2)	4.14.10	X
Random Vibration (2)	4.14.11	X
Electromagnetic Interference and Compatibility	4.14.12	2
Explosive Atmosphere	4.14.13	2
Repetitive Functioning	4.29.9	X
Circuit Protection	4.29.10	1
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

Notes for Table 4.29-2:

(1) These tests shall be performed for thermal cycle, humidity Temperature/Humidity/Altitude, and thermal vacuum tests. A component shall undergo an input current and output monitor test during all thermal cycles and transitions.
(2) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
(3) A firing unit's flight critical functions shall be monitored while the unit is subjected to the operating shock environment. At a minimum, the input current, ARM and output monitors shall be monitored during the shock test for variations in performance.
(4) These tests shall be performed during shock testing.

TABLE 4.29-3. EBW AND EFI LOT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination (1)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification	4.10.4	
Bridgewire Resistance (1)	4.29.12	100%
Insulation Resistance (1)	4.29.13	100%
Static Discharge	4.29.11	100%
Non Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1	
Thermal Cycling (2)	4.14.2	Lot Sample (4)
High Temperature Storage (3)	4.13.3	Lot Sample
Shock (2)	4.14.8	Lot Sample
Sinusoidal Vibration (2)	4.14.10	Lot Sample
Random Vibration (2)	4.14.11	Lot Sample
No Fire Verification	4.29.15	Lot Sample
Component Examination	4.11.1	
Visual Examination	4.11.2	100%
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests	4.29.16a	
Ambient Temperature	4.29.16e	
All-Fire Voltage	4.29.16b	1/6 Lot Sample
Operating Voltage	4.29.16c	1/6 Lot Sample
High Temperature	4.29.16f	
All-Fire Voltage	4.29.16b	1/6 Lot Sample
Operating Voltage	4.29.16c	1/6 Lot Sample
Low Temperature	4.29.16g	
All-Fire Voltage	4.29.16b	1/6 Lot Sample
Operating Voltage	4.29.16c	1/6 Lot Sample

Notes for Table 4.29.3:

(1) These tests shall also be performed at the launch site.
(2) This test shall subject a component sample to the qualification test environmental level.
(3) A high temperature storage test is optional. A lot will have an initial service-life of three years if it passes all the required tests including high temperature storage. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo high temperature storage.
(4) The lot sample quantity shall be no less than 10 percent of the production lot or 30 sample EBWs, whichever is greater.

TABLE 4.29-4. EBW AND EFI QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [1], [4] X=						
		SS [8]	5	5	SS [5]	SS [6]	SS [7]	105
Component Examination	4.11.1							
Visual Examination	4.11.2	X	X	X	X	X	X	X
Dimension Measurement	4.11.3	X	X	X	X	X	X	X
Leakage	4.11.8	X	X	X	X	X	X	X
X-ray and N-ray	4.11.6	X	X	X	X	X	X	X
Performance Verification	4.10.4							
Bridgewire Resistance	4.29.12	X	X	X	X	X	X	X
Insulation Resistance	4.29.13	X	X	X	X	X	X	X
Static Discharge	4.29.11	X	X	X	X	X	X	X
RF Impedance	4.29.17	-	-	-	10	-	-	-
RF Sensitivity	4.29.18	-	-	-	X	-	-	-
Statistical No-Fire Energy Level	4.29.19	-	-	-	-	X	-	-
Statistical All-Fire Energy Level	4.29.20	-	-	-	-	-	X	-
Safety No-Fire	4.29.22	-	X	-	-	-	-	-
Bridgewire Degradation Test	4.29.14	X		-	-	-	-	-
Non-Operating and Operating Environment Tests	4.13.1 4.14.1							
Storage Temperature	4.13.2	-	-	-	-	-	-	X
Transportation Shock	4.13.4	-	-	-	-	-	-	X
Bench Handling Shock	4.13.5	-	-	-	-	-	-	X
Transportation Vibration	4.13.6	-	-	-	-	-	-	X
Fungus Resistance	4.13.7	-	-	-	-	-	-	X
Fine Sand	4.13.8	-	-	-	-	-	-	X
Thermal Cycling	4.14.2	-	-	-	-	-	-	X
Humidity	4.14.4	-	-	-	-	-	-	X
Salt Fog	4.14.5	-	-	-	-	-	-	X
High Temperature Storage [3]	4.13.3	-	-	-	-	-	-	30
Acceleration	4.14.7	-	-	-	-	-	-	X
Shock	4.14.8	-	-	-	-	-	-	X
Acoustic	4.14.9	-	-	-	-	-	-	X
Sinusoidal Vibration	4.14.10	-	-	-	-	-	-	X
Random Vibration	4.14.11	-	-	-	-	-	-	X
No-Fire Verification Test	4.29.15	-	-	-	-	-	-	X
Handling Drop	4.13.10	-	-	-	-	-	-	X
Tensile Load	4.13.9	-	-		-	-	-	30
Abnormal Drop	4.13.11	-	-	X	-	-	-	-
Auto-Ignition	4.29.21	-	-	X	-	-	-	-

Table 4.29-4: EBW and EFI Qualification Test Requirements. (Continued)

Test	Paragraph	Quantity Tested (1), (4) X=						
		SS (8)	5	5	SS (5)	SS (6)	SS (7)	105
Component Examination	4.11.1							
Visual Examination	4.11.2	-	-	-	-	-	-	X
Leakage	4.11.8	-	-	-	-	-	-	X
X-ray and N-ray	4.11.6	-	-	-	-	-	-	X
Firing Tests	4.29.16a							
Ambient Temperature	4.29.16e							
All-Fire Voltage	4.29.16b	-	-	-	-	-	-	15
Operating Voltage	4.29.16c	-	-	-	-	-	-	15
High Operating Voltage	4.29.16d	-	-	-	-	-	-	5
High Temperature	4.29.16f							
All-Fire Voltage	4.29.16b	-	-	-	-	-	-	15
Operating Voltage	4.29.16c	-	-	-	-	-	-	15
High-Operating Voltage	4.29.16d	-	-	-	-	-	-	5
Low Temperature	4.29.16g							
All-Fire Voltage	4.29.16b	-	-	-	-	-	-	15
Operating Voltage	4.29.16c	-	-	-	-	-	-	15
High-Operating Voltage	4.29.16d	-	-	-	-	-	-	5

Notes for Table 4.29-4:

(1) All sample-initiator samples used in qualification testing shall be from a production lot that has passed the lot acceptance tests required by Table 4.29.3.
(2) Reserved.
(3) A high temperature storage test is optional. A qualified lot will have an initial service-life of three years if it passes all the required tests including high temperature storage. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo high temperature storage.
(4) For each column, the quantity required at the top of the column shall be from the same production lot and shall undergo each test designated with an X. For a test designated with a lesser quantity, each sample initiator tested shall be one of the original samples for the column.
(5) The statistical sample (SS) shall be the quantity of sample components needed to perform a statistical firing series to determine the RF sensitivity of the. Each sample component shall undergo each test designated with an X. The SS quantity shall be no less than 10 sample components, which is the minimum required to undergo the RF impedance test.
(6) The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the no-fire energy level. Each sample component shall undergo each test designated with an X.
(7) The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the all-fire energy level. Each sample component shall undergo each test designated with an X.
(8) The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the degradation current. Each sample component shall undergo each test designated with an X.

TABLE 4.29-5. EBW AND EFI SERVICE-LIFE EXTENSION TEST REQUIREMENTS(6)

Test	Paragraph	Quantity Tested (3)	
		1 Year (4) X=5	3 Years (5) X=10
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Performance Verification	4.10.4		
Bridgewire Resistance	4.29.12	X	X
Insulation Resistance	4.29.13	X	X
Static Discharge	4.29.11	X	X
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1		
Thermal Cycling (1)	4.14.2	X	X
High Temperature Storage (1)	4.13.3	-	X
Shock (1)	4.14.8	X	X
Sinusoidal Vibration (1)	4.14.10	X	X
Random Vibration (1)	4.14.11	X	X
No Fire Verification	4.29.15	X	X
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.29.16a		
All-Fire Voltage	4.29.16b		
Ambient Temperature	4.29.16e	1	3
High Temperature	4.29.16f	2	3
Low Temperature	4.29.16g	2	4

Notes for Table 4.29-5:

(1) This test shall subject each component sample to the qualification environmental level.
(2) Reserved.
(3) A high temperature storage test is optional. The component shall undergo the tests required by the one-year column or the three-year column to extend its service-life.
(4) Five initiators from the same lot shall undergo each test designated with an X to extend the service-life of the remaining initiators from the same lot for one year.
(5) Ten initiators from the same lot shall undergo each test designated with an X to extend the service-life of the remaining initiators from the same lot for three years.
(6) In order to extend an initiator's service-life, the bridgewire shall undergo the tests required by the one-year column or the three-year column before its initial service-life or any previous service-life extension expires.

4.29.1 General. Any firing unit or ordnance initiator shall satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

1. High voltage ordnance initiators include EFIs and EBWs.
2. The terminology EAFD versus ESAD depends on whether the device is purely for range safety purposes (EAFD) or purely a tactical device (ESAD). The requirements specified here shall apply to both devices if the tactical ESAD is used for range safety purposes.

4.29.2 Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications.

Isolation resistance shall be 2 MΩ.

4.29.3 Input Current. Input current of the firing unit shall be monitored to demonstrate that it meets all performance requirements.

Input current to the firing unit's input power and arm power shall be monitored.

4.29.4 High Voltage Circuitry. This test shall demonstrate that a firing unit's high voltage circuitry satisfies all its performance specifications for firing the initiator when subjected to any variation in input that the circuitry could experience during flight. The test shall demonstrate all of the following:

a. The firing unit satisfies all its performance specifications when subjected to the worst-case high and low arm voltages that it could experience during bench testing, prelaunch checkout and flight.

1. The current draw of the firing unit shall be within the requirements of the component specification during the ARM command at maximum and minimum input voltages, and the arming current wave shape is correct.
2. Each high-energy trigger circuit used to initiate the main firing capacitor has an output signal that delivers no less than a 50 percent voltage margin with an input to the circuit at the nominal trigger threshold level.

b. The firing unit's output circuitry shall produce an output waveform, rise-time, and amplitude that meets all performance requirements when fired into a load that simulates the flight-representative high voltage initiator circuit.

The firing unit shall deliver a minimum of 150 percent of the initiator all-fire qualification voltage level.

c. The firing unit shall not arc or exhibit corona effects.
d. The firing unit shall be tested to demonstrate that the high voltage circuits bleed-down within the specified time when the unit is powered off.
e. The firing unit shall be tested to demonstrate that its output leakage current meets performance requirements during transient start-up and steady state operation.

4.29.5 High Voltage Charging Circuit. The charging circuits of the firing unit shall be tested to demonstrate that it meets all performance requirements.

Where applicable, trigger circuit threshold, capacitor charge time, and arming time shall be tested.

4.29.6 Command Processing. An command processing test shall demonstrate that an initiator firing unit's input trigger circuit satisfies all its performance specifications when subjected to any variation in input that it could experience during flight. The test shall demonstrate all of the following:

a. The firing unit's command and firing circuits shall demonstrate that they function at a margin over the worst-case signal that could be delivered on the launch vehicle.

1. The firing unit's command and firing circuits shall trigger at 75 percent of the amplitude and 50 percent of the pulse duration of the lowest firing signal that could be delivered during flight.
2. The firing unit's command and firing circuits shall trigger at 125 percent amplitude and 150 percent of the pulse duration of the highest firing signal that could be delivered during flight.

b. The firing unit shall be tested to demonstrate that it does not degrade in performance when subjected to the maximum input voltage of the OCV of the power source, ground or airborne, and the minimum input voltage of the loaded voltage of the power source.
c. Each control and switching circuit that is critical to the reliable operation of an initiator firing unit does not change state when subjected to a minimum input power drop-out for a period of 50 milliseconds.
d. The firing unit shall be tested to demonstrate that its response time is in accordance with its performance specification with an input at the specified minimum and maximum vehicle supplied trigger signal.
e. If the firing unit has differential input, the unit satisfies all its performance specifications with all input combinations at the specified trigger amplitude input signals.
f. The firing unit's command and firing circuitry shall be tested to demonstrate that it will not trigger inadvertently when subjected to the guaranteed no-fire trigger performance levels. The maximum guaranteed no-fire trigger threshold shall be at least 20 dB above the worst-case noise or current leakage environment.

The firing unit's command and firing circuits shall not trigger when a 5 volt signal is applied for 5 minutes.

4.29.7 Abbreviated Command Processing. An abbreviated command processing test shall exercise a firing unit's flight critical functions while the unit is subjected to each required operating environment. This shall include subjecting the firing unit to the fire command throughout each environment while monitoring function time and the high voltage output waveform to demonstrate that each satisfies all its performance specifications. The firing unit's output circuitry shall fire into a load that simulates the flight-representative high voltage initiator circuit.

4.29.8 Output Monitoring. An output-monitoring test shall measure all output monitors to demonstrate that they satisfy their performance requirements.

4.29.9 Repetitive Functioning. This test shall demonstrate that a firing unit satisfies all its performance specifications when subjected to repetitive functioning for five times the worst-case number of cycles required for acceptance, checkout and operations, including any retest due to schedule delays. The firing unit shall also function within its performance specification, without degradation for 50 percent longer than worst-case total required operating time.

1. The worst-case total operating time shall include an additional 30-minute wait period for solid rocket motors.
2. Firing units shall have an operating life of 1000 firings without degradation.
3. If the firing unit cannot meet the required number of firings, the ranges shall approve the total number of expected firings (acceptance test, bench test, prelaunch test and launch attempts) based on the following:
   a. The firing unit shall be qualified for an operating life of at least two times the total expected firings that will include some firings into flight loads. The ranges shall also approve the actual load(s) used for testing.
   b. Data sheets shall accompany each firing unit that provides, at a minimum, the number of times the device has been fired, the load conditions, the date, a QA stamp or initials of the person performing the test, and the results of the test. EAFDs (or ESADs) that exceed 50 percent of the qualification number of firings, at full load, will not be allowed for flight. In addition, firing units that do not have an accompanying data sheet for review by Range Safety personnel will not be allowed for flight.

4.29.10 Circuit Protection. A circuit protection test shall demonstrate that any circuit protection allows a firing unit to satisfy all its performance specifications, when subjected to any improper launch processing, abnormal flight condition, or any failure of another vehicle component. The demonstration shall include all of the following:

a. Any circuit protection allows an initiator firing unit to satisfy all its performance specifications when subjected to the maximum input voltage of the unit's ground or airborne power source.

The firing unit will not be damaged when it is subjected to the application of up to 45 Vdc or the OCV of the power source, whichever is greater, to the power input port for a period not less than 5 minutes.

b. The firing unit shall not degrade in performance or produce an inadvertent output command when subjected to voltages below the specified level.

The firing unit shall be tested from 0 volts to the maximum specified voltage back to 0 volts without damage or producing a spurious output regardless of the rate of transition between the voltage present.

c. In the event of an input power dropout, any control or switching circuit that contributes to the reliable operation of an firing unit shall not change state for at least 50 milliseconds.
d. Any watchdog circuit satisfies all its performance specifications.
e. Demonstrate that failures in output monitors will not degrade the performance of the firing unit, including monitoring circuits. Each output monitor shall be subjected to a short circuit or the highest positive or negative voltage capable of being supplied by the monitor batteries or other power supplies.

1. During qualification testing the monitor outputs shall be shorted and connected to +45 Vdc in both the unpowered and powered state to show that the unit is not degraded or damaged.
2. Voltage shall be applied for a duration of no less than five minutes.

f. The firing unit satisfies all its performance specifications when subjected to any reverse polarity voltage that could occur during launch processing.

4.29.11 Static Discharge. A static discharge test shall demonstrate that an initiator can withstand an electrostatic discharge that it could experience from personnel or conductive surfaces without firing and still satisfy all its performance specifications.

The test shall subject the initiator to the greater of:

a. A 25k-volt, 500-picofarad pin-to-pin discharge through a 5k-ohm resistor and a 25k-volt, 500-picofarad pin-to-case discharge with no resistor
b. The maximum predicted pin-to-pin and pin-to-case electrostatic discharges. See Figure 4.29-1 for the test setup.
c. Pins shall be shorted for pin-to-case mode

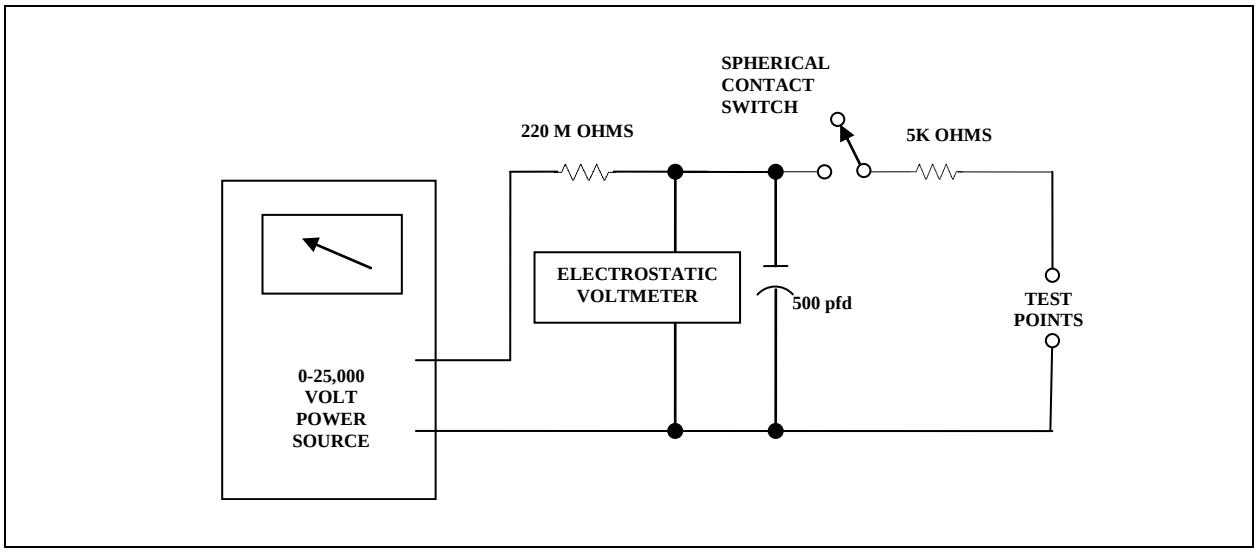


Figure 4.29-1. Static discharge test.

4.29.12 Bridgewire Resistance. A bridgewire resistance test shall be performed to demonstrate that the initiator meets its performance requirements.

1. Bridgewire resistance shall be measured at an accuracy of 2 percent of the true value. A maximum current of 10 milliamps or 10 percent of the bridge degradation current, whichever is less, is required.
2. Initiators with voltage blocking gaps that cannot be subjected to bridgewire resistance tests shall be subjected to the following:
   a. Bridgewire continuity tests shall use a grid dip test instead of resistance measurements.
   b. Gap Breakdown. Perform EBW gap breakdown voltage tests to verify compliance with the component specification.

4.29.13 Insulation Resistance. An insulation resistance test shall measure mutually insulated pin-to-case points using maximum operating voltage plus a margin. The test shall demonstrate that the internal wiring, connectors and other insulation material are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 1000 VDC between the between insulated points and case immediately after a 1-minute period of uninterrupted test voltage application. The voltage used for this test shall not damage or degrade the component.
2. The measurement error at the required insulation resistance value shall not exceed 10 percent.
3. The insulation resistance between all insulated parts shall be greater than 20 MΩ.

4.29.14 Bridgewire Degradation Test. This test shall determine the dc current level that will not damage or degrade the initiator with a reliability of at least 0.999 with a 95-percent confidence

level at worst case predicted operating temperature plus a margin. The worst-case current that a flight initiator experiences shall be a minimum of 20 dB below the bridgewire degradation test level.

1. Known statistical methods (such as Langlie, Bruceton, and Neyer) shall be used.
2. The initiator shall be temperature conditioned to +71°C or the hottest system temperature, whichever is greater.
3. The initiator shall be connected to a suitable power source and instrumented to measure dc current through the device.
4. The variable in the test is the direct current level applied across the input pins to the initiator for a minimum of five minutes.
5. The direct current (at the Neyer, Bruceton, or Langlie test level) is switched to the initiator and held for five minutes, and then an ALL-FIRE test is performed. The initiator shall function within its performance requirements with an ALL-FIRE input.

4.29.15 No-fire Verification. An ordnance initiator shall demonstrate its specified no-fire energy level. An ordnance initiator shall not fire when exposed to continuous application of the no-fire energy level, with a reliability of no less than 0.999 at a 95 percent confidence level.

1. The initiator shall be capable of being exposed to the bridge degradation current for five minutes and one 45-volt firing pulse without dudding or degrading.
2. If the DC sensitivity does not represent worst case, then an RF induced no-fire level shall be used for this test.

4.29.16 Firing Tests.

a. General. Each firing test of an initiator shall satisfy all of the following:
   (1) Each test shall demonstrate that the initiator satisfies all its performance specifications when subjected to qualification stress conditions.
   (2) The number of initiator samples that each test shall fire and the test conditions, including firing voltage and temperature, shall satisfy each table of this section.
   (3) Before initiation, each component sample shall experience the required temperature for enough time to achieve thermal equilibrium.

Heat sink (as applicable) - the heat sink environment of the initiator shall approximate the predicted operational thermal environment. If the thermal environments for the initiator usage are multiple or unknown, the minimum heat sink should be used during the test. If hazards related to "hand held" environments are to be evaluated, the initiator should be mounted in a fixture that effectively insulates the initiator against heat transfer to the environment.

   (4) Each test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications.

b. All-Fire Voltage. Each all-fire voltage test shall subject each initiator sample to the manufacturer specified all-fire energy level for voltage, current, and pulse duration.
c. Operating Voltage. Each operating voltage test shall subject each initiator sample to the firing unit's manufacturer specified operating voltage, current, and pulse duration.

1. If the operating energy is unknown, the test shall use no less than 200 percent of the all-fire voltage.
2. The operating energy test shall subject each initiator sample to a high voltage initiation source that duplicates the initiator firing unit output waveform and impedance, including high voltage cabling.

d. High-Operating Voltage. This test shall subject each initiator to the firing unit's manufacturer specified operating voltage, current, and pulse duration plus a margin.

Initiators shall be tested to 150 percent of the operating voltage

e. Ambient Temperature. This test shall initiate each initiator sample while at ambient temperature.
f. High Temperature. Each high temperature test shall initiate each initiator sample while it is subjected to the qualification high temperature level or at 71 °C, whichever is higher.
g. Low Temperature. Each low temperature test shall initiate each initiator sample while it is subjected to the qualification low temperature level or at -54 °C, whichever is lower.

4.29.17 RF Impedance. An RF impedance test shall determine an initiator's RF impedance for use in any system RF susceptibility analysis.

1. During a worst-case analysis of the susceptibility of the system to its electromagnetic environment, a worst-case parameter such as the dc resistance is used for the impedance. If this worst-case resistance parameter causes a rejection of the worst-case analysis results, RF impedance can be used to reduce predicted analytical results.
2. All tests shall be performed at room temperature (approximately 25°C).
3. A minimum of 10 initiators shall be used in the impedance measurements. These items may be reused in the RF sensitivity or RF dudding testing.
4. The impedance measuring equipment shall be able to function at extremely low RF power levels so that the initiators are not subjected to heating effects. Automatic equipment is preferred. It is suggested that no more than 1 milliwatt be applied to the initiators in any firing mode during the measurements. The mounting apparatus used to connect the initiators to the impedance measuring apparatus will be constructed so that the impedance measurements refer to a point as close to the base of the initiators (exterior surface of the initiator header) as is possible.

5. Measure impedances at periodic frequency intervals throughout the operational spectrum. At a minimum, 10 frequencies shall be uniformly selected from 1 to 1200 MHz. The test spectrum shall include any frequency corresponding to any known high power density in the initiators operational environment.
6. The individual measurement frequencies should be selected so that neighboring frequencies differ from each other by an approximately equal logarithmic increment.

4.29.18 RF Sensitivity. This test shall consist of a statistical firing series of samples to determine the RF no-fire energy level. The firing series shall determine the highest continuous RF energy level to which the device can be subjected and not fire with a reliability of 0.999 at a 95 percent confidence level.

1. Analysis in Lieu of Tests. An analysis may be used in lieu of these tests if the RF impedance shows that DC represents the worst-case condition. The expected operating RF level into the initiator shall be a minimum of 20 dB below the level determined by the bridgewire degradation test.
2. RF Power. At each RF frequency to be used in the test, the RF power to be applied to the initiator is determined from the mean dc firing current measured in the Bruceton Test and dc bridgewire resistance. This level shall be applied to the devices in each mode (pin-to-pin, pin-to-case, and bridgewire-to-bridgewire). The power level used for testing shall be a minimum of 20 dB greater than the operating RF environment that would be induced into the initiator.
3. Power Delivery/Loss. The equipment used in the tests shall provide a means to account for loss in the power supplying system. Applied powers shall be demonstrated to be those that are actually delivered to the input of the initiator.
4. Mounting Hardware. Mounting hardware for the initiator shall be constructed to allow measurement of power as close to the initiator base (exterior surface of the initiator header) as possible.
5. Statistical Sampling Scheme. A statistical sampling scheme, such as Bruceton, Langley or Neyer, shall be used to demonstrate the required reliability.
6. Frequencies for Probing Tests. At least ten frequencies shall be used in the probing tests. These frequencies should be chosen to cover the frequency range from 1 MHz to 32 GHz and should include any frequency corresponding to a known high power density in the initiator's operational environment.
7. Transmitter Frequencies. Special consideration should be given to the frequencies that correspond to the transmitters that are associated with the overall system.
8. Default Test Frequencies and Modulation Stimuli. If there are no specific requirements, the approximate frequency and modulation stimuli shown in the following table shall be used.

Default Test Frequencies and Modulation

Frequency (MHz)	Modulation [(1), (2)]
1.5	CW
27.0	CW
154.0	CW
250.0	CW
900.0	CW
2,700.0	P
5,400.0	P
8,900.0	P
15,000.0	CW
32,000.0	P

Note: (1) C = Continuous Wave
(2) P = Pulsed modulation with pulse width of 1 microsecond and pulse repetition rate of 1 kHz

9. Probing Test.
   a. At each test frequency, test 10 initiators for 5 minutes in the pin-to-pin configuration and 10 initiators in the pin-to-case configuration.
   b. Initiators that do not fire in the pin-to-pin test can be reused in the pin-to-case test.
10. Analysis.
   a. Count the number of firings at each frequency.
      (1) At any particular frequency, if two or less fire, the direct current sensitivity level can be used for subsequent analysis.
      (2) If three or more fire, the RF sensitivity level can be used for subsequent analysis.
   b. From the data that was obtained in the probing tests, determine the most sensitive frequency/modulation stimulus for each firing configuration.
11. Statistical RF NO-FIRE Level.
   a. Perform a 5-minute, 40-item, NO-FIRE Bruceton Test at the most sensitive frequency/ modulation stimulus for each configuration. The same equipment shall be used in the probing tests.
   b. Forty items are required for each firing configuration of the device being tested.
   c. RF dudding tests are not required if the initiators will not be exposed to RF greater than the RF NO-FIRE level, as determined by the RF sensitivity testing. The maximum RF exposure level is that maximum level determined by a worst-case electromagnetic hazard analysis approved by Range Safety. If the initiator will be exposed to an RF level higher than the RF NO-FIRE LEVEL, then an RF dudding test shall be performed in accordance with tailored requirements using MIL-STD-1576, Electroexplosive Subsystem Safety Requirements and Test Methods For Space Systems, method 2208 as a baseline.

4.29.19 No-Fire Energy Level. A no-fire energy level test shall consist of a statistical firing series of initiator lot samples to determine the highest electrical energy level at which the

initiator will not fire with a reliability of 0.999 with a 95 percent confidence level when subjected to a continuous energy. The test shall demonstrate that the no-fire energy level is no less than the no-fire energy level used in the FTS design and analysis. The worst-case current that a flight initiator experiences shall be a minimum of 20 dB below the no-fire test level.

1. Expose 40 units to a constant current pulse for 5 minutes.
2. The current pulse amplitudes used for this test are to be chosen so that neighboring tests vary by a logarithmic increment approximately equal (0.5 to 1.25) to the standard deviation. Improper selection of the mean and standard deviation will cause a failure of the Bruceton Test and will require another forty items.
3. Any deviation exceeding 10 percent between the fire (x) sigma and the no-fire (0) sigma will void the test. The deviation is computed by the ratio of the larger sigma to the smaller. Testing shall showing less than 4 levels or greater than 7 levels shall also void the test.
4. Calculate the confidence levels using the average of the standard deviations and the average of the means (log) as determined by the fire and no-fire data.
5. Compute the 0.001 (0.1 percent) firing level of the LVI, in amperes with a 95-percent confidence level, from the Bruceton Test results.

4.29.20 <u>All-Fire Energy Level</u>. An all-fire energy level test shall consist of a statistical firing series of initiator lot samples to determine the lowest electrical energy level at which the initiator will fire with a reliability of 0.999 with a 95 percent confidence level when subjected to a current pulse simulating the firing unit output waveform and impedance characteristics. Each initiator sample shall be in its flight configuration, and shall possess any internal safety devices such as a spark gap. The test shall demonstrate that the all-fire energy level does not exceed the all-fire energy level used in the FTS design and analysis.

1. Firing tests shall be performed using firing sets with identical components for the high voltage capacitor, trigger circuit, and electronic switches in addition to having the same characteristics as the high energy firing unit.
2. Expose 40 units to a constant current pulse of 30 milliseconds.
3. Improper selection of the mean and standard deviation will cause a failure of the Bruceton Test and will require another forty items.
4. Any deviation exceeding 10 percent between the fire (x) sigma and the no-fire (0) sigma will void the test. The deviation is computed by the ratio of the larger sigma to the smaller. Testing shall showing less than 4 levels or greater than 7 levels shall also void the test.
5. Calculate the confidence levels using the average of the standard deviations and the average of the means (log) as determined by the fire and no-fire data.
6. Compute the 99.9 percent firing level of the LVI, in volts with a 95-percent confidence level, from the Bruceton Test results.

4.29.21 <u>Auto-Ignition</u>. This test shall demonstrate that an initiator shall not auto-ignite, exhibit density variations or melt when subjected to any high temperature environment during handling, testing, storage, transportation, installation, or flight.

1. The test environment shall be no less than 30° C higher than the highest non-operating or operating temperature that the device could experience.
2. The test shall last the maximum predicted high temperature duration or one hour, whichever is greater.
3. After exposure to the test environment, each sample device shall undergo external and internal examination, including any dissection needed to identify any auto-ignition, density variations or melting.

4.29.22 Safety No-Fire Test. This test shall demonstrate that the initiator shall not fire when exposed to the worst-case voltage from ground support equipment or vehicle systems plus a margin.

The initiator shall be exposed to 500 VDC for 5 minutes without firing.

4.30 LFUs, Fiber Optic Cable Energy Transfer Systems, and LIDS

This section applies to LFUs, fiber optic cable energy transfer systems, and LIDs.

TABLE 4.30-1. LFU ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Inspection	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification	4.10.4	
Resistance	4.30.8	100%
Input Current (1)	4.30.7	100%
Command Processing (1)	4.30.2	100%
Output Firing Circuit (1)	4.30.3	100%
Inhibit/Safing Circuitry (1)	4.30.4	100%
Output Monitors (1)	4.30.5	100%
Built-In-Test (BIT) (1)	4.30.6	100%
Abbreviated Performance Verification (2)	4.10.5	
Input Current	4.30.7	100%
Abbreviated Functional Test	4.30.9	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic (2)	4.15.4	100%
Sinusoidal Vibration (2)	4.15.5	100%
Random Vibration (2)	4.15.6	100%
Leakage	4.11.8	100%

Notes for Table 4.30-1:

(1) A component shall undergo these tests at the first and last hot and cold thermal dwell cycles for thermal cycle and thermal vacuum tests. Input current and optical output shall be continuously monitored during all other thermal cycles and transitions.

(2) Abbreviated performance verification tests shall be performed during dynamic operating environments.

TABLE 4.30-2. LFU QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested X=3
Acceptance Tests (1)	Table 4.30.1	X
Performance Verification	4.10.4	
Resistance	4.30.8	X
Input Current (4)	4.30.7	X
Command Processing (4)	4.30.2	X
Output Firing Circuit (4)	4.30.3	X
Inhibit/Safing Circuitry (4)	4.30.4	X
Output Monitors (4)	4.30.5	X
Built-In-Test (BIT) (4)	4.30.6	X
Abbreviated Performance Verification (3)	4.10.5	
Input Current	4.30.7	X
LFU Abbreviated Functional Test	4.30.9	X
Non-Operating Environment Tests	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Bench Handling Shock	4.13.5	X
Transportation Vibration	4.13.6	X
Fungus Resistance	4.13.7	1
Fine Sand	4.13.8	1
Operating Environment Tests	4.14.1	
Thermal Cycling	4.14.2	X
Thermal Vacuum	4.14.3	X
Humidity	4.14.4	X
Salt Fog	4.14.5	2
Temperature/Humidity/Altitude	4.14.6	X
Acceleration (3), (6)	4.14.7	X
Shock (5), (6)	4.14.8	X
Acoustic (3), (6)	4.14.9	X
Sinusoidal Vibration (3), (6)	4.14.10	X
Random Vibration (3), (6)	4.14.11	X
Electromagnetic Interference and Compatibility	4.14.12	2
Explosive Atmosphere	4.14.13	2
Repetitive Functioning	4.30.11	X
Output Monitoring	4.30.5	1
BIT Verification (2)	4.30.22	-
Circuit Protection	4.30.10	2
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

Notes for Table 4.30-2:

(1) Each qualification test component shall successfully complete all acceptance tests before undergoing qualification testing.
(2) This test shall include all optical components of the system in a flight configuration including the fiber optic cable and LID. Special tests that validate this requirement shall be approved by Range Safety.
(3) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
(4) These tests shall be performed for thermal cycle, humidity, temperature/humidity/altitude, and thermal vacuum tests. Input current and optical output shall be continuously monitored during all other thermal cycles and transitions.
(5) A firing unit's flight critical functions shall be monitored while the unit is subjected to the operating shock environment. At a minimum, the input current, ARM and output monitors shall be monitored during the shock test for variations in performance.
(6) Optical continuity shall be monitored using a flight fiber optical cable in a flight configuration during all operating environmental tests.

TABLE 4.30-3. LID LOT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination [(6), (9)]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification	4.10.4	
Optical Reflectivity [(9)]	4.30.13	100%
Static Discharge	4.30.12	100%
Abbreviated Performance Verification [(8)]	4.10.5	
Optical Continuity	4.30.23	Lot Sample
Tensile Load [(4)]	4.13.9	Lot Sample
Non Operating Environment Tests and Operating Environment Tests [(5)]	4.13.1 4.14.1	Lot Sample [(3)]
Thermal Cycling [(1), (7)]	4.14.2	Lot Sample
High Temperature Storage [(2)]	4.13.3	Lot Sample
Shock [(1), (8)]	4.14.8	Lot Sample
Sinusoidal Vibration [(1), (8)]	4.14.10	Lot Sample
Random Vibration [(1), (8)]	4.14.11	Lot Sample
Safety No-fire Test	4.30.24	Lot Sample
Optical Reflectivity	4.30.13	Lot Sample
Component Examination	4.11.1	
Visual Examination[(6)]	4.11.2	Lot Sample
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests	4.30.14	
Ambient Temperature	4.30.14e	
All-Fire Power Energy	4.30.14b	1/6 Lot Sample
Operating Power Energy	4.30.14c	1/6 Lot Sample
High Temperature	4.30.14f	
All-Fire Power Energy	4.30.14b	1/6 Lot Sample
Operating Power Energy	4.30.14c	1/6 Lot Sample
Low Temperature	4.30.14g	
All-Fire Power Energy	4.30.14b	1/6 Lot Sample
Operating Power Energy	4.30.14c	1/6 Lot Sample

Notes for Table 4.30-3:

(1) These environmental tests shall be performed at the qualification test levels.
(2) The high temperature storage test is optional. If performed, the lot will have an initial service life of three years. If not performed, the lot will have an initial service life of one year.
(3) The lot sample shall be 10 percent of the production lot but not less than 30 LIDs.
(4) LIDs using fiber optic pigtails shall be pull tested to specification value and function within their performance requirements.
(5) Optical continuity shall be monitored using a flight-like fiber optical cable during all operating environmental tests.
(6) Visual inspection shall include magnified inspection of the LIDs optical window for cracks, de-laminations or misalignment.
(7) The optical reflectivity test in paragraph 4.30.13 shall be performed at the first, middle and last hot and cold thermal dwell cycles for thermal cycle, humidity and thermal vacuum tests. Optical continuity shall be continuously monitored during all other thermal cycles and transitions.
(8) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
(9) These tests shall also be performed at the launch site.

TABLE 4.30-4. LID QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [3] X=					
		SS[10]	5	5	SS [5]	SS [6]	105
Component Examination	4.11.1						
Visual Examination [11]	4.11.2	X	X	X	X	X	X
Dimension Measurement	4.11.3	X	X	X	X	X	X
Leakage	4.11.8	X	X	X	X	X	X
X-Ray and N-Ray	4.11.6	X	X	X	X	X	X
Performance Verification	4.10.4						
Optical Reflectivity	4.30.13	X	X	X	X	X	X
Static Discharge	4.30.12	X	X	X	X	X	X
Abbreviated Performance Verification [12]	4.10.5						
Optical Continuity	4.30.23	-	-	-	-	-	X
Statistical No-Fire Level	4.30.17	-	-	-	-	X	-
Statistical All-Fire Level	4.30.18	-	-	-	X	-	-
RF sensitivity	4.30.25	-	-	-	-	-	X
Safety No-Fire	4.30.24	-	X	-	-	-	-
Optical Degradation Test	4.30.26	X	X	-	-	-	X
Non-Operating Environment and Operating Environment Tests [9]	4.13.1 4.14.1						
Storage Temperature	4.13.2	-	-	-	-	-	X
Transportation Shock	4.13.4	-	-	-	-	-	X
Bench Handling Shock	4.13.5	-	-	-	-	-	X
Transportation Vibration	4.13.6	-	-	-	-	-	X
Fungus Resistance	4.13.7	-	-	-	-	-	X
Fine Sand	4.13.8	-	-	-	-		X
Thermal Cycling [8]	4.14.2	-	-	-	-	-	X
Humidity [8]	4.14.4	-	-	-	-	-	X
Salt Fog	4.14.5	-	-	-	-	-	X
High Temperature Storage [2]	4.13.3	-	-	-	-	-	30
Acceleration [12]	4.14.7	-	-	-	-	-	X
Shock [12]	4.14.8	-	-	-	-	-	X
Acoustic [12]	4.14.9	-	-	-	-	-	X
Sinusoidal Vibration [12]	4.14.10	-	-	-	-	-	X
Random Vibration [12]	4.14.11	-	-	-	-	-	X
Handling Drop	4.13.10	-	-	-	-	-	X
Tensile Load [7]	4.13.9	-	-	-	-	-	30
Abnormal Drop	4.13.11	-	-	X	-	-	-
Auto-Ignition	4.30.20	-	-	X	-	-	-
Component Examination	4.11.1						
Visual Examination [11]	4.11.2	-	X	-	-	-	X
Leakage	4.11.8	-	X	-	-	-	X
X-Ray and N-Ray	4.11.6	-	X	-	-	-	X

Table 4.30.4: LID Qualification Test Requirements. (Continued)

Test	Paragraph	Quantity Tested (3) X=					
		SS(10)	5	5	SS (5)	SS (6)	105
Firing Tests Ambient Temperature	4.30.14 4.30.14e						
All-Fire Energy	4.30.14b	-	1	-	-	-	15
Operating Energy	4.30.14c	-	-	-	-	-	15
High-Operating Energy	4.30.14d	-	-	-	-	-	5
High Temperature	4.30.14f						
All-Fire Energy	4.30.14b	-	2	-	-	-	15
Operating Energy	4.30.14c	-	-	-	-	-	15
High-Operating Energy	4.30.14d	-	-	-	-	-	5
Low Temperature	4.30.14g						
All-Fire Energy	4.30.14b	-	2	-	-	-	15
Operating Energy	4.30.14c	-	-	-	-	-	15
High-Operating Energy	4.30.14d	-	-	-	-	-	5

Notes for Table 4.30-4:

(1) The optical reflectivity test in paragraph 4.30.13 shall be performed at the first, middle and last hot and cold thermal dwell cycles for thermal cycle, humidity and thermal vacuum tests. Optical continuity shall be continuously monitored during all other thermal cycles and transitions.

(2) The high temperature storage test is optional. If performed, the lot will have an initial service life of three years. If not performed, the lot will have an initial service life of one year.

(3) For each column, the quantity required at the top of the column shall be selected from the same production lot and shall be subjected to each test designated with an X. For a test designated with a lesser quantity, each sample LID tested shall be selected from the original samples for column.

(4) The statistical sample (SS) quantity needed to perform a statistical firing series to determine the RF sensitivity of the LID shall be subjected to each test designated with an X. The quantity shall be greater than the 10 samples needed for the RF impedance tests.

(5) The SS quantity needed to perform a statistical firing series to determine the optical LID no-fire energy shall be subjected to each test designated with an X.

(6) The SS quantity needed to perform a statistical firing series to determine the LID all-fire energy level shall be subjected to each test designated with an X.

(7) LIDs using fiber optic pigtails shall be pull tested to specification value and function within their performance requirements.

(8) The optical reflectivity test in paragraph 4.30.13 shall be performed at the first, middle and last hot and cold thermal dwell cycles for thermal cycle, humidity and thermal vacuum tests. Optical continuity shall be continuously monitored during all other thermal cycles and transitions.

(9) Optical continuity shall be monitored using a flight fiber optical cable in a flight configuration during all operating environmental tests.

(10) The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the optical degradation energy. Each sample component shall undergo each test designated with an X.

(11) Visual inspection shall include magnified inspection of the LIDs optical window for cracks, delaminations, scratches, cleanliness and misalignment.

(12) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.

TABLE 4.30-5. LID AGE SURVEILLANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested (2)	
		1 Year (3) X=5	3 Years (4) X=10
Component Examination	4.11.1		
Visual Inspection (6)	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Performance Verification	4.10.4		
Optical Reflectivity	4.30.13	X	X
Static Discharge	4.30.12	X	X
Abbreviated Performance Verification (5)	4.10.5		
Optical Continuity	4.30.23	X	X
Non-Operating Environment Tests and Operating Environment Tests (1)	4.13.1 4.14.1		
Thermal Cycling	4.14.2	X	X
High Temperature Storage	4.13.3	-	X
Shock (5)	4.14.8	X	X
Random Vibration (5)	4.14.11	X	X
No-fire Verification	4.30.24	X	X
Component Examination	4.11.1		
Visual Examination (6)	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.30.14		
All Fire Energy	4.30.14b		
Ambient Temperature	4.30.14e	1	3
High Temperature	4.30.14f	2	3
Low Temperature	4.30.14g	2	4

Notes for Table 4.30-5:

(1) All environmental tests shall be performed at qualification levels.
(2) A high temperature storage test is optional. The component shall undergo the tests required by the one-year column or the three-year column to extend its service-life.
(3) Reserved.
(4) Reserved.
(5) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests. Optical continuity shall be monitored using a flight-like fiber optical cable during all operating environmental tests.
(6) Visual inspection shall include magnified inspection of the LIDs optical window for cracks, delaminations, scratches, cleanliness and misalignment.
(7) The optical reflectivity test in paragraph 4.30.13 shall be performed at the first, middle, and last hot and cold thermal dwell cycles for thermal cycle, humidity and thermal vacuum tests. Optical continuity shall be continuously monitored during all other thermal cycles and transitions.

TABLE 4.30-6. FIBER OPTIC CABLE ASSEMBLY ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Inspection (3)	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification	4.11.5	100%
X-ray/N-ray (4)	4.11.6	100%
Performance Verification (1)	4.10.4	
Optical Transmission	4.30.16	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%

Notes for Table 4.30-6:

(1) This test shall be performed during first and last hot and cold thermal dwell at the main laser and BIT frequencies and power levels.
(2) Reserved.
(3) Visual inspection shall include magnified inspection for cracks, delaminations, scratches, cleanliness and misalignment.
(4) X-ray and/or N-ray are only required where applicable to adequately screen fiber optic cable and connectors.

TABLE 4.30-7. FIBER OPTIC CABLE ASSEMBLY QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested (4)
		X=21
Acceptance Tests (1)	Table 4.30.6	X
Performance Verification (2)	4.10.4	
Optical Transmission (3)	4.30.16	X
Tensile Load (6)	4.13.9	X
Repetitive Function	4.30.19	X
Connector Mate/Demate	4.30.21	X
Abbreviated Performance Verification (5)	4.10.5	X
Continuity	4.30.15	X
Non-Operating Environment Tests	4.13.1	
Storage Temperature	4.13.2	X
Transportation Shock	4.13.4	X
Transportation Vibration	4.13.6	X
Fungus Resistance	4.13.7	X
Fine Sand	4.13.8	X
Operating Environment Tests	4.14.1	
Thermal Cycling (3)	4.14.2	X
Thermal Vacuum (3)	4.14.3	X
Humidity (3)	4.14.4	X
Salt Fog	4.14.5	X
Temperature/Humidity/Altitude (3)	4.14.6	X
Acceleration (5)	4.14.7	X
Shock (5)	4.14.8	X
Acoustic (5)	4.14.9	X
Sinusoidal Vibration (5)	4.14.10	X
Random Vibration (5)	4.14.11	X
Component Examination	4.11.1	
Visual Inspection	4.11.2	X
X-ray/N-ray (7)	4.11.6	X

Notes for Table 4.30-7:

(1) Each sample component to undergo qualification testing shall first successfully complete all applicable acceptance tests.
(2) These tests shall be performed before the first and after the last non-operating environment test. Additionally, the tests shall be performed before the first and after the last operating environment test.
(3) An optical transmission test shall be performed for these tests.
(4) The same three sample components shall be subjected to each test designated with an X. For each test designated with a quantity of less than three, each component tested shall be selected from the original three sample components.
(5) Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
(6) Fiber optic cables and connectors shall be pull tested to specification value and function within their performance requirements.
(7) X-ray and/or N-ray are only required where applicable to adequately screen fiber optic cable and connectors.

4.30.1 General. All LFUs, fiber optic cable energy transfer systems and LIDs shall be tested to demonstrate that they satisfy their performance specifications when subjected to non-operating and operating environments. This testing shall be conducted in accordance with the acceptance, qualification, and age surveillance test matrices and accompanying requirements of this section.

4.30.2 Command Processing. The firing unit's electrical input processing circuitry shall be tested to demonstrate that the input trigger circuit will function within performance specifications when subjected to any variation in input that it could experience during flight. The test shall demonstrate all of the following:

a. The firing unit's command and firing circuitry shall be tested to demonstrate that it will not trigger inadvertently when subjected to the guaranteed no-fire trigger performance levels. The maximum guaranteed no-fire trigger threshold shall be at least 20 dB above the worst-case noise or current leakage environment.

The firing unit's command and firing circuits shall not trigger when a 5 volt signal is applied for 5 minutes.

b. The firing unit command and firing circuits shall demonstrate they function at a margin over the worst-case signal that could be delivered on the launch vehicle.

1. The firing unit's command and firing circuits shall trigger at 75 percent of the amplitude and 50 percent of the pulse duration of the lowest firing signal that could be delivered during flight. 2. The firing unit's command and firing circuits shall trigger at 125 percent amplitude and 150 percent of the pulse duration of the highest firing signal that could be delivered during flight

c. Each control and switching circuit that is critical to the reliable operation of an initiator firing unit does not change state when subjected to a minimum input power drop-out for a period of 50 milliseconds.
d. An LFU shall be tested to demonstrate that its response time is in accordance with its performance specification with an input at the specified minimum and maximum vehicle supplied trigger signal.
e. An LFU with differential input shall be tested to demonstrate that it operates according to its performance specification with all input combinations at the specified trigger amplitude input signals.

4.30.3 Output Firing Circuit. An LFU shall be tested to demonstrate the optical firing output frequency, power and pulse duration meet specification output requirements.

a. The LFU optical output shall be tested to demonstrate that the firing unit delivers the required energy (power and pulse duration) at the unit's specified worst-case high and low arming voltages.

b. The optical output waveform power versus time shall demonstrate that it meets its performance requirement.
c. The laser firing output shall be monitored in the safe condition to verify that there is no optical leakage power being transmitted.

The firing unit's optical output power while in the safe condition shall be 60 dB less than the guaranteed no-fire level at the main firing and BIT frequencies.

4.30.4 Inhibit/Safing Circuitry. An LFU shall be tested to demonstrate that all inhibits are functioning correctly. At a minimum, the following functions shall be tested:

a. The master Arm/Safe command shall demonstrate it meets its performance requirements.

A fire command shall be sent while the unit is safed. There shall be no output during this test.

b. If differential input trigger circuits are used, all combinations shall be tested to ensure that the unit is functioning correctly.
c. The unit shall be tested to demonstrate that it powers up in a safe state.

The unit shall be armed, powered down for 3 seconds and powered up. The unit shall power-up in the safe state.

d. Manual safing plugs integral to the firing unit must be tested to ensure that they interrupt main laser firing power.
e. The status of all inhibits shall be monitored when the unit is in the safe and armed condition. The change of status of inhibits shall be verified when the unit is armed and fired.

4.30.5 Output Monitors. All monitoring circuits of the LFU shall be tested to demonstrate they provide the data for real-time checkout and determination of the firing unit's acceptability for flight.

At a minimum, the following measurements shall be tested: a. The 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 termination firing output. d. The status of the master arm/safe circuit. e. The status or result of a bit.

4.30.6 Built-In-Test (BIT). A BIT using a low power laser to verify the continuity of optical firing circuit, shall be tested to demonstrate that it is capable of detecting any condition that could prevent a specification-level firing pulse from reaching the LID ordnance.

a. BIT power shall be measured to ensure that it meets its performance specification. At a minimum, the bit power shall ensure a minimum 20 dB margin between the LID all fire level and the measured BIT power.
b. The BIT frequency and bandwidth shall demonstrate that the optical characteristics meet its performance specifications. Measurements shall be taken to ensure there is no spurious energy at the main laser firing frequency.
c. BIT testing shall be performed with flight fiber optic cable assemblies and flight-like LID simulator.

4.30.7 Input Current. Input current of the firing unit shall be monitored to demonstrate that it meets all its performance requirements.

Input current to the firing unit's input power and arm power shall be monitored at a 1 ms resolution.

4.30.8 Resistance. Pin-to-pin and pin-to-case resistances of the firing unit shall be measured to demonstrate that it meets all performance requirements.

4.30.9 LFU Abbreviated Functional Test. An abbreviated functional test shall exercise a firing unit's flight critical functions while the unit is subjected to each required operating environment. This shall include subjecting the firing unit to the fire command during each environment while monitoring function time and the optical output waveform to demonstrate that each satisfies all its performance specifications. The firing unit's output shall demonstrate that the power, frequency and pulse duration meets its performance requirements.

4.30.10 Circuit Protection. A circuit protection test shall demonstrate that any circuit protection allows a firing unit to satisfy all its performance specifications, when subjected to any improper launch processing, abnormal flight condition, or any failure of another vehicle component. The demonstration shall include all of the following:

a. Any circuit protection allows an initiator firing unit to satisfy all its performance specifications when subjected to the maximum input voltage of the unit's ground or airborne power source.

The firing unit will not be damaged when it is subjected to the application of up to 45 Vdc or the OCV of the power source, whichever is greater, to the power input port for a period not less than 5 minutes.

b. The firing unit shall not degrade in performance or produce an inadvertent output command when subjected to voltages below the specified level.

The firing unit shall be tested from 0 volts to the maximum specified voltage back to 0 volts without damage or producing a spurious output regardless of the rate of voltage change.

c. In the event of an input power dropout, any control or switching circuit that contributes to the reliable operation of a firing unit shall not change state for at least 50 milliseconds.
d. Any watchdog circuit satisfies all its performance specifications.
e. Demonstrate that failures in output monitors will not degrade the performance of the firing unit, including monitoring circuits. Each output monitor shall be subjected to a short circuit or the highest positive or negative voltage capable of being supplied by the monitor batteries or other power supplies.

1. During qualification testing, the monitor outputs shall be shorted and connected to +45 Vdc in both the unpowered and powered state to show that the unit is not degraded or damaged.
2. Voltage shall be applied for a duration of no less than five minutes.

f. The firing unit satisfies all its performance specifications when subjected to any reverse polarity voltage that could occur during launch processing.

4.30.11 LFU Repetitive Function. This test shall demonstrate that a firing unit satisfies all its performance specifications when subjected to repetitive functioning for five times the worst-case number of cycles required for acceptance, checkout and operations, including any retest due to schedule delays. The firing unit shall also function within its performance specification, without degradation for 50 percent longer than worst-case total required operating time.

1. The worst-case total operating time shall include an additional 30-minute wait period for solid rocket motors.
2. Firing units shall have an operating life of 1000 firings without degradation.
3. If the firing unit cannot meet the required number of firings, the ranges shall approve the total number of expected firings (acceptance test, bench test, prelaunch test and launch attempts) based on the following:
   a. The firing unit shall be qualified for an operating life of at least two times the total expected firings.
   b. Data sheets shall accompany each firing unit that provides, at a minimum, the number of times the device has been fired, the date, a QA stamp or initials of the person performing the test, and the results of the test. LFUs that exceed 50 percent of the qualification number of firings will not be allowed for flight. In addition, firing units that do not have an accompanying data sheet for review by Range Safety personnel will not be allowed for flight.

4.30.12 Static Discharge. A LID shall be tested to verify that it can withstand, without firing or degradation in performance, an electrostatic discharge that it could experience from personnel or conductive surfaces.

This test shall subject the LID to a 25k-volt, 500-picofarad discharge to any non-continuous conductive surface.

4.30.13 Optical Reflectivity. The LID firing window and pigtails shall demonstrate that the reflectivity and absorption versus optical frequency meet the LID's performance requirements. At a minimum, the optical reflectivity test shall be performed at the main firing and BIT laser frequencies.

4.30.14 Firing Tests.

a. General. Each firing test of an initiator shall satisfy all of the following:
   (1) Each test shall demonstrate that the initiator satisfies all its performance specifications when subjected to qualification stress conditions
   (2) The number of initiator samples that each test shall fire and the test conditions, including firing energy and temperature, shall satisfy each table of this section.
   (3) Before initiation, each component sample shall experience the required temperature for enough time to achieve thermal equilibrium.

Heat sink (as applicable) - the heat sink environment of the initiator shall approximate the predicted operational thermal environment. If the thermal environments for the initiator usage are multiple or unknown, the minimum heat sink should be used during the test. If hazards related to "hand held" environments are to be evaluated, the initiator should be mounted in a fixture that effectively insulates the initiator against heat transfer to the environment.

   (4) Each test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications.

b. All-Fire Energy. Each all-fire energy test shall subject each initiator sample to the specified all-fire energy level for frequency, power and pulse duration.

c. Operating Energy. Each operating energy test shall subject each initiator sample to the firing unit's manufacturer specified operating intensity, frequency, and pulse duration.

1. If the operating energy is unknown, the test shall use no less than 200 percent of the all-fire energy.
2. The operating energy test shall subject each initiator sample to an optical initiation source that duplicates the initiator firing unit output, including fiber optic cabling.

d. High-Operating Energy. This test shall subject each initiator to the firing unit's manufacturer specified operating energy and pulse duration plus a margin.

Initiators shall be tested to 150 percent of the operating energy

e. Ambient Temperature. This test shall initiate each initiator sample while at ambient temperature.

f. High Temperature. Each high temperature test shall initiate each initiator sample while it is subjected to the qualification high temperature level or at 71 °C, whichever is higher.

g. Low Temperature. Each low temperature test shall initiate each initiator sample while it is subjected to the qualification low temperature level or at -54 °C, whichever is lower.

4.30.15 Continuity. The fiber optic cable assembly attenuation loss shall be tested ensure there are no optical fluctuations or dropouts.

4.30.16 Optical Transmission. The optical transfer function characteristics such as pulse spreading and attenuation of the fiber optic cable assembly shall be tested to ensure they are within their performance specification.

4.30.17 No-Fire Level. A no-fire energy level test shall consist of a statistical firing series of initiator lot samples to determine the highest optical energy level at which the initiator will not fire with a reliability of 0.999 with a 95 percent confidence level when subjected to a continuous optical energy. The test shall demonstrate that the no-fire energy level is no less than the no-fire energy level used in the FTS design and analysis. The worst-case energy that a flight initiator experiences shall be a minimum of 20 dB below the no-fire test level.

4.30.18 All-Fire Level. An all-fire energy level test shall consist of a statistical firing series of initiator lot samples to determine the lowest optical energy level at which the initiator will fire with a reliability of 0.999 with a 95 percent confidence level when subjected to optical energy simulating the firing unit output waveform characteristics. Each initiator sample shall be in its flight configuration. The test shall demonstrate that the all-fire energy level does not exceed the all-fire energy level used in the FTS design and analysis.

4.30.19 Repetitive Function. The fiber optic cable assembly shall be tested to demonstrate the capability to withstand, without degradation in performance, repetitive functioning plus a margin for the total expected number of firings required for acceptance tests, preflight tests, and flight operations, including an allowance for potential retests due to schedule delays.

1. The fiber optic cable assembly shall be tested to demonstrate the capability to withstand, without degradation in performance, repetitive functioning for 5 times the maximum expected number of firings.
2. This test shall be performed at least two times the maximum firing optical power for no less than 10 times the duration of the maximum firing pulse

4.30.20 Auto-Ignition. This test shall demonstrate that an initiator shall not auto-ignite, exhibit density variations or melt when subjected to any high temperature environment during handling, testing, storage, transportation, installation, or flight.

1. The test environment shall be no less than 30° C higher than the highest non-operating or operating temperature that the device could experience.
2. The test shall last the maximum predicted high temperature duration or one hour, whichever is greater.
3. After exposure to the test environment, each sample device shall undergo external and internal examination, including any dissection needed to identify any auto-ignition, density variations or melting.

4.30.21 Connector Mate/Demate. All optical connectors shall demonstrate that they meet their performance requirements after being subjected to the maximum expected number of mate/demate cycles plus a margin.

1. All connectors shall be mated and demated five times the total expected number of cycles required for acceptance tests, preflight tests, and flight operations; these actions shall include an allowance for potential retests due to schedule delays.
2. The minimum number of mate/demates shall be 100.

4.30.22 BIT Verification. All optical connectors and interfaces shall be tested to ensure they meet their performance requirements when subjected to optical misalignment, contaminants or condensation. The BIT shall verify that it can detect any degradation that could prevent the required optical power from being input into the LID. This testing will determine the type of inspection necessary before field optical connections. If BIT testing is used to validate an interface, a correlation shall be established between BIT pass/fail criteria and the main laser firing pulse.

4.30.23 Optical Continuity. The LID firing window and pigtails shall demonstrate that the reflectivity meets the LID's performance requirements at the main firing laser frequency.

4.30.24 Safety No-Fire Test. This test shall demonstrate that the initiator shall not fire or degrade when exposed to the worst-case optical energy from ground processing environment or vehicle systems plus a margin.

The initiator shall be exposed to the following for 5 minutes.

a. Focused sunlight.
b. BIT laser energy 20 dB higher than maximum expected BIT power.
c. 20 dB higher than the maximum expected stray energy source.
d. The guaranteed no-fire level at the main firing and BIT frequencies.

4.30.25 RF Sensitivity. The test shall subject samples of initiators to the maximum expected RF level plus a margin. LIDs shall not fire or degrade in performance.

1. An analysis may be used in lieu of these tests if the LID can be shown to contain no RF electrical paths through any part of the LID or ordnance.
2. At each RF frequency to be used in the test, the RF power to be applied to the initiator is determined from the maximum expected operating power level plus 20 dB greater.
3. Mounting hardware for the initiator shall be constructed to allow measurement of power as close to the initiator base (exterior surface of the initiator header) as possible.
4. All qualification test units shall be subjected to the RF sensitivity test.
5. At least 10 frequencies shall be used in the probing tests. These frequencies should be chosen to cover the frequency range from 1 MHz to 32 GHz and should include any frequency corresponding to a known high power density in the initiator's operational environment.
6. Special consideration should be given to the frequencies that correspond to the transmitters that are associated with the overall system.
7. If there are no specific requirements, the approximate frequency and modulation stimuli shown in the following table shall be used.
8. LIDs exposed to testing shall not fire and meet all performance specifications.

Default Test Frequencies and Modulation

Frequency (MHz)	Modulation[(1), (2)]
1.5	CW
27.0	CW
154.0	CW
250.0	CW
900.0	CW
2,700.0	P
5,400.0	P
8,900.0	P
15,000.0	CW
32,000.0	P

Note: (1) C = Continuous Wave.
(2) P = Pulsed modulation with pulse width of 1 microsecond and pulse repetition rate of 1 kHz.

4.30.26 Optical Degradation Test. This test shall determine the optical power level and optical frequencies that will not damage or degrade the initiator with a reliability of at least 0.999 with a 95-percent confidence level using the worst case predicted operating temperature plus a margin. The worst-case energy that a flight initiator experiences shall be a minimum of 20 dB below the optical degradation test level.

1. Known statistical methods (such as Langlie, Bruceton, and Neyer) shall be used.
2. The initiator shall be temperature conditioned to +71°C or the hottest system temperature, whichever is greater.
3. The initiator shall be subjected to the test environment for 5 minutes.
4. The variables for this test are optical power and optical frequency. To limit the number of test samples expended, a sample may be subjected to each optical power level at all frequencies before firing at the all-fire energy level.
4. The LID shall be exposed to a sampling of optical frequencies that the LID could experience during storage, transportation, processing and flight for a minimum of five minutes. At a minimum, the frequency spectrum shall include 10 equally distributed samples from infrared to ultraviolet frequencies.

4.31 Ordnance Interrupters

This section applies to any ordnance interrupter that is part of an FTS, including any rotor lead or booster charge that is used by the interrupter

TABLE 4.31-1. ORDNANCE INTERRUPTER ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested
Component Examination (2)	4.11.1	
Visual Inspection	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification	4.10.4	
Functional Tests	4.31.2	100%
Safety Tests	4.31.5	
Manual Safing	4.31.5d	100%
Safing-Interlock Test	4.31.5e	100%
Abbreviated Performance Verification	4.10.5	
Dynamic Performance	4.31.7	100%
Thermal Performance	4.31.6	100%
Operating Environment Tests	4.15.1	
Thermal Cycling	4.15.2	100%
Thermal Vacuum	4.15.3	100%
Acoustic	4.15.4	100%
Sinusoidal	4.15.5	100%
Random Vibration	4.15.6	100%
X-ray	4.11.6	100%
Leakage	4.11.8	100%

TABLE 4.31-2. ORDNANCE INTERRUPTER QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested			
		X=Statistical Sample	X=1 (1)	X=6 (2)	X=3 (3)
Acceptance Tests	Table 4.31.1	-	X	X	-
Barrier Alignment	4.31.8	X	-	-	-
Safety Tests	4.31.5				
Extended Stall	4.31.5c	-	X	-	-
Abnormal Drop	4.13.11	-	X	-	-
Containment	4.31.5a	-	-	-	1
Barrier Functionality	4.31.5b	-	-	-	2
Safing Verification	4.31.5f	-	-	X	-
Performance Verification	4.10.4				
Functional Tests (5)	4.31.2	-	-	X	-
Safety Tests	4.31.5	-	-	X	-
Manual Safing	4.31.5d	-	-	X	-
Safing-Interlock Test	4.31.5e	-	-	X	-
Abbreviated Performance Verification	4.10.5				
Dynamic Performance	4.31.7	-	-	X	-
Thermal Performance	4.31.6	-	-	X	-
Cycle Life	4.31.3	-	-	2	-
Non-Operating Environment Tests	4.13.1				
Storage Temperature	4.13.2	-	-	X	-
Transportation Shock	4.13.4	-	-	X	-
Bench Handling Shock	4.13.5	-	-	X	-
Transportation Vibration	4.13.6	-	-	X	-
Fungus Resistance	4.13.7	-	-	1	-
Fine Sand	4.13.8	-	-	1	-
Handling Drop	4.13.10	-	-	X	-
Operating Environment Tests	4.14.1				
Thermal Cycling	4.14.2	-	-	X	-
Humidity	4.14.4	-	-	X	-
Salt Fog	4.14.5	-	-	X	-
Temperature/Humidity/Altitude	4.14.6			X	
Acceleration	4.14.7	-	-	X	-
Shock	4.14.8	-	-	X	-
Acoustic	4.14.9	-	-	X	-
Sinusoidal Vibration	4.14.10	-	-	X	-
Random Vibration	4.14.11	-	-	X	-
Explosive Atmosphere (4)	4.14.13	-	-	2	-
Stall	4.31.4	-	-	X	-
X-ray	4.11.6	-	-	X	-
Leakage	4.11.8	-	-	X	-
Internal Inspection	4.11.7	-	-	2	-

Notes for Table 4.31-2:

(1) One ordnance interrupter device shall undergo the extended stall and abnormal drop tests designated with an X.
(2) The same six sample ordnance interrupter devices shall undergo each test designated with an X. For a test designated with a quantity of less than six, each ordnance interrupter device tested shall be one of the original six sample components.
(3) One ordnance interrupter device shall undergo the containment test and two ordnance interrupter devices shall undergo the barrier functionality test. The ordnance interrupter device samples used for these tests need not be flight ordnance interrupter devices. The test samples shall duplicate all dimensions of a flight ordnance interrupter device, including gaps between explosive components, free-volume, and diaphragm thickness.
(4) The ordnance interrupter shall be cycled from Safe/Arm and Arm/Safe 5 times for this test.
(5) All ordnance transfer gaps within the ordnance interrupter shall meet paragraph 4.34 for ordnance interfaces.

TABLE 4.31-3. ORDNANCE INTERRUPTER ROTOR LEAD AND BOOSTER CHARGE LOT ACCEPTANCE TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1	
Thermal Cycling (2)	4.14.2	Lot Sample (4)
High Temperature Storage (3)	4.13.3	Lot Sample
Component Examination	4.11.1	
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests (5)	4.31.9	
High Temperature	4.31.9c(1)	½ Lot Sample
Low Temperature	4.31.9c(2)	½ Lot Sample

Notes for Table 4.31-3:

(1) This table applies to any rotor lead or booster charge that is used inside an ordnance interrupter device.

(2) This test shall subject each ordnance sample to the qualification environmental test level. The test level shall be no less than the environment that the ordnance experiences when installed and the ordnance interrupter device is subjected to its qualification environment. No monitoring is required during environmental testing.

(3) A high temperature storage test is optional. A lot will have an initial service-life of five years if high temperature storage is performed. A lot will have an initial service-life of one year if high temperature storage is not performed.

(4) The lot sample quantity shall be no less than 10 percent of the lot or nine sample units from the lot, whichever is greater.

(5) When the lot cannot be evenly divided, any extra samples will be fired at low temperature.

TABLE 4.31-4. ORDNANCE INTERRUPTER ROTOR LEAD AND BOOSTER CHARGE QUALIFICATION TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested (4) X=21
Component Examination	4.11.1	
Visual Examination	4.11.2	X
Dimension Measurement	4.11.3	X
Leakage	4.11.8	X
X-ray and N-ray	4.11.6	X
Non-Operating and Operating Environment Tests (2)	4.13.1 4.14.1	
Thermal Cycling	4.14.2	X
High Temperature Storage (3)	4.13.3	10
Shock	4.14.8	X
Sinusoidal Vibration	4.14.10	X
Random Vibration	4.14.11	X
Component Examination	4.11.1	
X-ray and N-ray	4.11.6	X
Leakage	4.11.8	X
Firing Tests	4.31.9	
Ambient Temperature	4.31.9b	7
High Temperature	4.31.9c(1)	7
Low Temperature	4.31.9c(2)	7

Notes for Table 4.31-4:

(1) This table applies to any rotor lead or booster charge that is used inside an ordnance interrupter device.

(2) This test shall subject each ordnance sample to the qualification environmental test level. The test level shall be no less than the environment that the ordnance experiences when installed and the ordnance interrupter device is subjected to its qualification environment. No monitoring is required during environmental testing.

(3) A high temperature storage test is optional. A lot will have an initial service-life of five years if high temperature storage is performed. A lot will have an initial service-life of one year if high temperature storage is not performed.

(4) The same 21 sample components, from the same production lot, shall undergo each test designated with an X. For a test designated with a quantity of less than 21, each component sample tested shall be one of the original 21 samples.

TABLE 4.31-5. ORDNANCE INTERRUPTER ROTOR LEAD AND BOOSTER CHARGE SERVICE-LIFE EXTENSION TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested (3)	
		1 Year (4) X=5	5 Years (5) X=10
Component Examination	4.11		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Non-Operating and Operating Environment Tests	4.13.1 4.14.1		
Thermal Cycling (2)	4.14.2	X	X
High Temperature Storage	4.13.3	-	X
Component Examination	4.11.1	-	-
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.31.9		
High Temperature	4.31.9c(1)	2	5
Low Temperature	4.31.9c(2)	3	5

Notes for Table 4.31-5:

(1) This table applies to any rotor lead or booster charge that is used by an ordnance interrupter device. In order to extend the service-life of a rotor lead or booster charge, the rotor lead or charge shall undergo each test required by the one-year column or the five-year column. Service life extension samples shall be stored with the flight ordnance component or in an environment that duplicates the storage conditions of the flight ordnance component.

(2) This test shall subject each ordnance sample to the qualification environmental test level. For ordnance that is internal to an ordnance interrupter device, the test level shall be no less than the actual environment that the ordnance experiences when installed and the ordnance interrupter device is subjected to its qualification environment.

(3) For each column, the quantity of sample components required at the top of the column shall be from the same production lot and shall undergo each test designated with an X. For a test designated with a lesser quantity, each component tested shall be one of the original samples for that column.

(4) Five ordnance samples from the same lot shall undergo the tests required by this column to extend the service-life of the remaining ordnance from the same lot for one year.

(5) Ten ordnance samples from the same lot shall undergo the tests required by this column to extend the service-life of the remaining ordnance from the same lot for five years.

4.31.1 General. Any ordnance interrupter, rotor lead, or booster charge shall satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

4.31.2 Functional Tests. An ordnance interrupter shall be tested to demonstrate it meets its performance requirements and shall include the following:

a. Insulation Resistance. An insulation resistance test shall measure mutually insulated pin-to-pin and pin-to-case points using maximum operating voltage plus a margin. The test shall demonstrate that the internal wiring and other insulation material are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 500 VDC between the mutually-insulated points or between insulated points and ground immediately after a one-minute period of uninterrupted test voltage application. The voltage used for this test shall not damage or degrade the component.
2. The measurement error at the required insulation resistance value shall not exceed 10 percent.
3. The insulation resistance between all insulated parts shall be greater than 2 MΩ.

b. Ordnance interrupter transition time from Safe/Arm and Arm/Safe through multiple S&A transition cycles.
c. The test shall demonstrate that the monitors accurately determine S&A transition and whether the ordnance interrupter device is in the proper configuration.

1. The presence of the arm indication when the ordnance interrupter is armed.
2. The presence of the safe indication when the ordnance interrupter is safed.

d. Continuity and Isolation. The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all its performance specifications.

1. Isolation resistance shall be 2 MΩ.
2. The test shall measure the continuity of the internal circuits to demonstrate that the continuity resistances satisfy their performance specifications.

4.31.3 Cycle Life. This test shall demonstrate that the S&A transition, such as rotational or sliding operation, satisfies all its performance specifications. The test shall demonstrate the ability of an ordnance interrupter device to satisfy all its performance specifications when subjected to five times the maximum predicted number of safe-to-arm and arm-to-safe cycles.

4.31.4 Stall. A stall test shall demonstrate that an ordnance interrupter device satisfies all its performance specifications after being locked in its safe position and subjected to an operating arming voltage for the greater of 5 minutes or the maximum time that could occur inadvertently and the device still be used for flight.

4.31.5 Safety Tests. The following safety tests shall demonstrate that an ordnance interrupter device can be handled safely:

a. Containment. A containment test shall demonstrate that an ordnance interrupter device will not fragment when all interfacing and internal ordnance components are initiated.
b. Barrier Functionality. A barrier functionality test shall demonstrate that, when in the safe position, if an ordnance interrupter device's internal low voltage initiator is fired, the ordnance output will not propagate to an ETS. This demonstration shall include all of the following:
   (1) The test shall consist of firings at high and low temperature extremes, the ETS shall be configured for flight.
   (2) The high temperature firing shall be initiated at the maximum predicted high temperature or a 71 °C workmanship screening level, whichever is higher
   (3) The low temperature firing shall be initiated at the maximum predicted low temperature or a -54 °C workmanship screening level, whichever is lower.
c. Extended Stall. An extended stall test shall demonstrate that an ordnance interrupter device does not initiate when locked in its safe position and is subjected to a continuous operating arming voltage for the maximum predicted time that could occur accidentally or one hour, whichever is greater.

This test is required for ordnance interrupters with rotor lead charges.

d. Manual Safing. A manual safing test shall demonstrate that an ordnance interrupter device can be manually safed in accordance with all its performance specifications.

When the safing interlock is inserted and rotated, it shall manually safe the device.

e. Safing-Interlock. A safing-interlock test shall demonstrate that an ordnance interrupter device's safing-interlock prevents arming in accordance with all the performance specifications when operational arming current is applied.

Removal of the safing interlock shall not be possible if the arming circuit is energized. The retention mechanism of the safing pin shall be capable of withstanding an applied force of at least 100-pounds tension or a torque of 100 in-pounds without failure.

f. Safing Verification. A safing verification test shall demonstrate that, while an ordnance interrupter device is in the safe position, any internal LVI will not initiate if the ordnance interrupter device input circuit is accidentally subjected to a firing voltage.

4.31.6 Thermal Performance. A thermal performance test shall demonstrate that an ordnance interrupter device satisfies all its performance specifications when subjected to operating and

workmanship thermal environments including thermal cycle, thermal vacuum, humidity and salt-fog. The test shall include all of the following:

a. The test shall measure the ordnance interrupter ARM/SAFE monitor resistances for the first and last thermal cycle during the high and low temperature dwell times to demonstrate that the firing circuit resistance satisfies its performance specification.
b. The test shall subject the ordnance interrupter device to multiple Safe/Arm cycles and measure the SAFE/ARM continuity during each cycle to demonstrate that the continuity is consistent.

For electrically armed ordnance interrupters, the transition and firing circuit tests shall be performed using 25 Arm/Safe cycles with measurements taken every 5 cycles.

c. The test shall measure the ordnance interrupter Safe/Arm and Arm/Safe cycle time to demonstrate that it satisfies the manufacturer specification.

4.31.7 Dynamic Performance. A dynamic performance test shall demonstrate that an ordnance interrupter device satisfies all its performance specifications when subjected to the dynamic operational environments, including random vibration, sinusoidal vibration, acoustic and shock. This demonstration shall include all of the following:

a. The ordnance interrupter device shall undergo the test while subjected to each required dynamic operational environmental tests.
b. The test shall continuously monitor the ordnance interrupter device monitor circuit for continuity.
c. The test shall continuously monitor the ordnance interrupter device to demonstrate that it remains in the fully armed position throughout all dynamic environment testing. Any rotation beyond the specification limit constitutes a test failure.

4.31.8 Barrier Alignment. A barrier alignment test shall consist of a statistical test firing series that demonstrate that the device's safe to arm transition motion provides for ordnance initiation with a reliability of 0.999 at a 95 percent confidence level. The test shall also demonstrate that the device's arm to safe transition motion provides for no ordnance initiation with a reliability of 0.999 at a 95 percent confidence level. This test may employ a reusable ordnance interrupter subassembly that simulates the flight configuration.

4.31.9 Firing Tests.

a. General. Each firing test of an ordnance interrupter, rotor lead, or booster charge shall satisfy all of the following:
   (1) The test shall demonstrate the initiation and transfer of all ordnance charges. For an interrupter that has more than one ordnance initiation path, each firing test shall also demonstrate that the initiation of one initiation path does not adversely affect the performance of any other.
   (2) Before initiation, each component sample shall experience the required temperature for enough time to achieve thermal equilibrium.
   (3) The output test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all its performance specifications.

For ordnance interrupters using an ETS output, the ETS output shall demonstrate it produces the required output.

   (4) The ordnance interrupter shall use a flight-representative configured interface to verify the output meets its performance requirements.

Ordnance interrupters shall be tested using input and output ETS interfaces that duplicate the flight configuration.

   (5) Each test of a rotor lead or booster charge shall subject the component to an energy source that simulates the flight energy source. The test shall measure ordnance output using a measuring device, such as a dent block, to demonstrate that the output satisfies all its performance specifications.
b. Ambient Temperature. Each sample shall be fired at ambient temperature.
c. Firing Temperature. Each sample shall be fired at the required temperature.
   (1) High Temperature. Each sample shall be fired at the qualification high temperature level or at +71 °C, whichever is higher.
   (2) Low Temperature. Each sample shall be fired at the qualification low temperature level or at -54 °C, whichever is lower.

4.32 Percussion Activated Device (PAD)

This section applies to any PAD that is part of an FTS, including any primer charge it uses.

TABLE 4.32-1. PAD LOT ACCEPTANCE TEST REQUIREMENTS[1]

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification	4.10.4	
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1	Lot Sample [4]
Thermal Cycling [2]	4.14.2	Lot Sample
High Temperature Storage [3]	4.13.2	Lot Sample
Shock [2], [5]	4.14.8	Lot Sample
Sinusoidal Vibration [2], [5]	4.14.10	Lot Sample
Random Vibration [2], [5]	4.14.11	Lot Sample
Safety Tests	4.32.2	Lot Sample
Component Examination	4.11.1	
Visual Examination	4.11.2	Lot Sample
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
PAD Firing Tests	4.32.3a	
Ambient Temperature	4.32.3b	1/3 of Lot Sample
High Temperature	4.32.3c	1/3 of Lot Sample
Low Temperature	4.32.3d	1/3 of Lot Sample

Notes for Table 4.32-1:

(1) The tests required by this table apply to a fully assembled PAD including all internal ordnance.
(2) This test shall subject each PAD sample to the qualification environmental test level.
(3) A high temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.
(4) The lot sample quantity shall be no less than the greater of 10 percent of the lot or nine sample units.
(5) These tests shall be performed without the safing interlock installed.

TABLE 4.32-2. PAD QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [2] X=5	X=21
Component Examination	4.11.1		
Visual Inspection	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Identification Check	4.11.5	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Performance Verification	4.10.4		
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1		
Storage Temperature	4.13.2	-	X
Transportation Shock	4.13.4	-	X
Bench Handling	4.13.5	-	X
Transportation Vibration	4.13.6	-	X
Fungus Resistance	4.13.7	-	X
Fine Sand	4.13.8	-	X
Handling Drop	4.13.10	-	X
Thermal Cycling	4.14.2	-	X
High Temperature Storage [1]	4.13.3	-	X
Humidity	4.14.4	-	X
Salt Fog	4.14.5	-	X
Temperature/Humidity/Altitude	4.14.6		X
Acceleration [5]	4.14.7	-	X
Shock [5]	4.14.8	-	X
Acoustic [5]	4.14.9	-	X
Sinusoidal Vibration [5]	4.14.10	-	X
Random Vibration [5]	4.14.11	-	X
Safety Tests	4.32.2	X	X
Abnormal Drop	4.13.11	1	-
Auto-Ignition [4]	4.32.6	X	-
Component Examination	4.11.1		
Visual Inspection	4.11.2	X	X
Leakage	4.11.8	-	X
X-ray and N-ray	4.11.6	-	X
Internal Inspection	4.11.7	-	3 [3]
PAD Firing Tests	4.32.3a		
Ambient Temperature	4.32.3b	-	6
High Temperature	4.32.3c	-	6
Low Temperature	4.32.3d	-	6

Notes for Table 4.32-2:

(1) A high temperature storage test is optional. A lot will have an initial service-life of three years if it passes this test and all the required tests. A lot will have an initial service-life of one year if it passes all the required tests, but does not undergo this test.

(2) For each column, the required quantity of sample components from the same lot shall undergo each test designated with an X. For a test designated with a lesser quantity, each component tested shall be one of the original samples for that column.

(3) One of the three disassembled sample components shall be a sample that was subjected to all non-operating environment tests required by this table except for the abnormal drop test.

(4) An auto-ignition test applies to any ordnance internal to a PAD. The ordnance may undergo the test in a subassembly.

(5) These tests shall be performed without the safing interlock installed. These tests shall be performed in the flight configuration using ETS lines to the flight first tie-down location.

TABLE 4.32-3. PAD PRIMER CHARGE LOT ACCEPTANCE TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested	
Component Examination	4.11.1		
Visual Examination	4.11.2	100%	
Dimension Measurement	4.11.3	100%	
Leakage	4.11.8	100%	
X-ray and N-ray	4.11.6	100%	
Operating Environment Tests	4.14.1		
Thermal Cycle	4.14.2	Lot Sample (4)	-
Component Examination	4.11.1		
Visual Examination	4.11.2	Lot Sample	-
Leakage	4.11.8	Lot Sample	-
X-ray and N-ray	4.11.6	Lot Sample	-
Primer Charge Firing Tests	4.32.5		
All-Fire Impact (2)			-
Ambient Temperature	4.32.5b	1/3 Lot Sample	
High Temperature	4.32.5c	1/3 Lot Sample	-
Low Temperature	4.32.5d	1/3 Lot Sample	-
All-Fire Energy Level (3)	4.32.4	-	SS

Notes for Table 4.32-3:

(1) Each test required by this table applies to a primer charge before its installation in a PAD.
(2) This test shall subject each sample primer charge to the all-fire impact determined by the statistical all-fire impact series required during qualification testing.
(3) This test shall demonstrate that the production lot is a representative sample of the all-fire baseline established during qualification testing.
(4) The lot sample quantity shall be no less than the greater of 10 percent of the lot or 30 sample units.

TABLE 4.32-4. PAD PRIMER CHARGE QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested X= Statistical Sample (4)	105
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Statistical All-Fire Energy Level (3)	4.32.4	X	-
Operating Environment Tests	4.14.1		
Thermal Cycling	4.14.2	-	X
Component Examination	4.11.1		
Visual Examination	4.11.2	-	X
Leakage	4.11.8	-	X
X-ray and N-ray	4.11.6	-	X
Primer Charge Firing Tests	4.32.5		
Ambient Temperature	4.32.5b		
All-Fire Impact (1)	4.32.5a	-	15
Operational Impact (2)	4.32.5a	-	15
200% Operational Impact	4.32.5a	-	5
High Temperature	4.32.5c		
All-Fire Impact (1)	4.32.5a	-	15
Operational Impact (2)	4.32.5a	-	15
200% Operational Impact	4.32.5a	-	5
Low Temperature	4.32.5d		
All-Fire Impact (1)	4.32.5a	-	15
Operational Impact (2)	4.32.5a	-	15
200% Operational Impact	4.32.5a	-	5

Notes for Table 4.32-4:

(1) This test shall subject each sample primer charge to the all-fire impact determined by the statistical all-fire impact series required by this table.

(2) This test shall subject each sample primer charge to no less than the operational impact that it would receive from the PAD assembly according to the device's performance specifications.

(3) This test shall demonstrate that the production lot is a representative sample of the all-fire baseline established during qualification testing.

(4) The lot sample quantity shall be no less than the greater of 10 percent of the lot, or 30 sample units.

TABLE 4.32-5. PAD SERVICE-LIFE EXTENSION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested (3)	
		1 Year (4) X=5	3 Years (5) X=10
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1		
Thermal Cycling (2)	4.14.2	X	X
High Temperature Storage (1)	4.13.3	-	X
Shock (2), (6)	4.14.8	X	X
Random Vibration (2), (6)	4.14.11	X	X
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
PAD Firing Tests	4.32.3a		
High Temperature	4.32.3c	2	5
Low Temperature	4.32.3d	3	5

Notes for Table 4.32-5:

(1) A high temperature storage test is optional. In order to extend a PAD's service-life, the component shall undergo the tests required by the one-year column or the three-year column to extend its service-life. Each test required by this table applies to a fully assembled PAD including all internal ordnance.

(2) This test shall subject each sample PAD to the qualification environmental level.

(3) For each column, the quantity of sample components required at the top of the column shall be from the same production lot and shall undergo each test designated with an X. For a test designated with a lesser quantity, each sample component tested shall be one of the original samples for that column.

(4) Five sample PADs from the same lot shall undergo each test required by this column to extend the service-life of remaining PADs from the same lot for one year.

(5) Ten sample PADs from the same lot shall undergo each test required by this column to extend the service-life of remaining PADs from the same lot for three years.

(6) These tests shall be performed with the firing pin removed.

4.32.1 General. Any PAD or primer charge shall satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

These devices are also known as “lanyard pull initiators” and “separation plane initiators.”

4.32.2 Safety Tests.

a. General. Each safety test shall demonstrate that a PAD is safe to handle and use on the launch vehicle.
b. No-Fire Pull Test. A no-fire pull test shall demonstrate that a PAD, when pulled with the guaranteed no-fire pull force:
   (1) Will not fire
   (2) The device’s primer initiation assembly will not disengage.
   (3) The device will continue to satisfy all its performance specifications including pull force versus distance.
c. Safing-Interlock Locking. A safing-interlock test shall demonstrate that, a PAD, with its safing-interlock in place, will continue to satisfy all its performance specifications and the device’s firing assembly movement will be less than the no-fire pull distance plus a margin when subjected to the greater of:
   (1) The device’s all-fire pull-force.
   (2) Twice the worst-case pull force that the device can experience after it is installed on the vehicle.

The safing interlock shall remain engaged when subjected to a minimum 200-pound pull force The device’s firing assembly movement will be less than one half the no-fire pull distance

d. Safing-Interlock Retention Test. A safing-interlock retention test shall demonstrate that a PAD’s safing-interlock cannot be removed when a no-fire pull or greater force is applied to the PAD lanyard. The test shall also demonstrate that the force needed to remove the safing-interlock with the lanyard in flight configuration satisfies its performance specification.

The force required for safing pin removal shall be a minimum of 100 pounds when the lanyard is pulled with the no-fire pull force or greater.

4.32.3 Percussion-Activated-Device Firing Tests.

a. General. Each firing test of a PAD shall satisfy all of the following:
   (1) The test shall demonstrate that the device satisfies all its performance specifications when subjected to all qualification stress conditions.
   (2) The number of samples that the test shall fire and the test conditions, including temperature, shall satisfy each table of this section.

(3) Before initiation, each component sample shall experience the required temperature for enough time to achieve thermal equilibrium.
(4) The test shall subject the device to the manufacturer specified pull-force.
(5) The test shall simulate the flight configuration, including the ETS lines on the output.
(6) The test shall measure each ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all its performance specifications.
(7) The test shall demonstrate that the pull distance and spring constant meet performance requirements.

b. Ambient Temperature. This test shall initiate each ordnance sample while it is subjected to ambient temperature.

c. High Temperature. A high temperature test shall initiate each ordnance sample while it is subjected to no lower than the qualification high temperature level or a +71 °C, whichever is higher.

d. Low Temperature. A low temperature test shall initiate each ordnance sample while it is subjected to no higher than the qualification low temperature level or a -54 °C, whichever is lower.

4.32.4 All-Fire Energy Level. An all-fire energy level test shall consist of a statistical firing series of primer charge lot samples to determine the lowest energy impact at which the primer will fire with a reliability of 0.999 at a 95 percent confidence level. The test shall use a firing pin and configuration that is representative of the flight configuration.

4.32.5 Primer Charge Firing Tests.

a. General. Each firing test of a primer charge shall satisfy all of the following:
(1) The test shall demonstrate that the primer charge, including any booster charge or ordnance delay as an integral unit, satisfies all its performance specifications when subjected to all qualification stress conditions.

PADs that use ordnance delays shall verify that the function time meets performance requirements.

(2) The number of samples that the test shall fire and the test conditions, including impact energy and temperature, shall satisfy each table of this section.
(3) Before initiation, each component sample shall experience the required temperature for enough time to achieve thermal equilibrium.
(4) The test shall use a firing pin and configuration that is representative of the flight configuration.
(5) The test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications.

b. Ambient Temperature. This test shall initiate each ordnance sample while it is subjected to ambient temperature.

c. High Temperature. A high temperature test shall initiate each ordnance sample while it is subjected to no lower than the qualification high temperature level or +71 °C, whichever is higher.
d. Low Temperature. A low temperature test shall initiate each ordnance sample while it is subjected to no higher than the qualification low temperature level or -54 °C, whichever is lower.

4.32.6 Auto-Ignition. This test shall demonstrate that any ordnance internal to a PAD does not experience auto-ignition, sublimation, or melting when subjected to any high temperature environment during handling, testing, storage, transportation, installation, or flight. The test shall include all of the following:

a. The test environment shall be no less than 30° C higher than the highest non-operating or operating temperature that the device could experience.
b. The test duration shall be the maximum predicted high temperature duration or one hour, whichever is greater.
c. After exposure to the test environment, each ordnance component shall undergo external and internal examination, including any dissection needed to identify any auto-ignition, sublimation, or melting.

4.33 Explosive Transfer System (ETS), Ordnance Manifolds, and Destruct Charges

This section applies to any ETS, ordnance manifold, or destruct charge that is part of an FTS.

TABLE 4.33-1. ETS, ORDNANCE MANIFOLD AND DESTRUCT CHARGE LOT ACCEPTANCE TEST REQUIREMENTS

Test	Paragraph	Quantity Tested		
		Ordnance Manifolds (3), (4)	ETS (5)	Destruct Charges
Component Examination	4.11.1			
Visual Examination	4.11.2	100%	100%	100%
Dimension Measurement	4.11.3	100%	100%	100%
Leakage	4.11.8	100%	100%	100%
X-ray and N-ray	4.11.6	100%	100%	100%
Non-Operating and Operating Environments	4.13.1 4.14.1	Lot Sample (6)	Lot Sample (6)	Lot Sample (6)
Thermal Cycling (1)	4.14.2	Lot Sample	Lot Sample	Lot Sample
High Temperature Storage(2)	4.13.3	Lot Sample	Lot Sample	Lot Sample
Shock (1)	4.14.8	Lot Sample	Lot Sample	Lot Sample
Sinusoidal Vibration (1)	4.14.10	Lot Sample	Lot Sample	Lot Sample
Random Vibration (1)	4.14.11	Lot Sample	Lot Sample	Lot Sample
Tensile Load	4.13.9	-	Lot Sample	Lot Sample
Component Examination	4.11.1			
Visual Examination	4.11.2	Lot Sample	Lot Sample	Lot Sample
Leakage	4.11.8	Lot Sample	Lot Sample	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample	Lot Sample	Lot Sample
Firing Tests	4.33.2			
Ambient Temperature	4.33.2b	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample
High Temperature	4.33.2c	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample
Low Temperature	4.33.2d	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample

Notes for Table 4.33-1:

(1) This test shall subject each sample component to the qualification environment.
(2) A high temperature storage test is optional. A lot will have an initial service-life of three, five or ten years as required in paragraph 4.13.3.
(3) Any inert manifold need only undergo visual examination and dimension measurement.
(4) The tests required by this column apply to any manifold that contains explosive charges. A fully assembled manifold, including any internal ordnance shall undergo each test.
(5) The required quantity applies to each configuration of explosive transfer line end-tip.
(6) The lot sample quantity shall be no less than 10 percent of the lot or nine sample units, whichever is greater.

TABLE 4.33-2. DESTRUCT CHARGE QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested			
		X=5	X=2	X=1	X=21
Component Examination	4.11.1				
Visual Examination	4.11.2	-	-	X	X
Dimension Measurement	4.11.3	-	-	X	X
Leakage	4.11.8	-	-	X	X
X-ray and N-ray	4.11.6	-	-	X	X
Non-Operating Environment Tests and Operating Environment Tests	4.13.1 4.14.1				
Storage Temperature	4.13.2	-	-	-	X
Transportation Shock	4.13.4	-	-	-	X
Bench Handling	4.13.5	-	-	-	X
Transportation Vibration	4.13.6	-	-	-	X
Fungus Resistance	4.13.7	-	-	-	X
Fine Sand	4.13.8	-	-	-	X
Thermal Cycling	4.14.2	-	-	-	X
High Temperature Storage (1)	4.13.3	-	-	-	10
Humidity	4.14.4	-	-	-	X
Salt Fog	4.14.5	-	-	-	X
Shock	4.14.8	-	-	-	X
Acceleration	4.14.7	-	-	-	X
Sinusoidal Vibration	4.14.10	-	-	-	X
Random Vibration	4.14.11	-	-	-	X
Handling Drop	4.13.10	-	-	-	X
Abnormal Drop	4.13.11	-	-	X	-
Tensile Load	4.13.9	-	-	-	X
Component Examination	4.11.1				
Visual Examination	4.11.2	-	-	-	X
Leakage	4.11.8	-	-	-	X
X-ray and N-ray	4.11.6	-	-	-	X
Penetration Margin Test (2)	4.33.3				
High Temperature	4.33.2c	3	-	-	-
Low Temperature	4.33.2d	3	-	-	-
Propellant Detonation	4.33.4	-	X	-	-
Firing Tests	4.33.2				
Ambient Temperature	4.33.2b	-	-	-	7
High Temperature	4.33.2c	-	-	-	7
Low Temperature	4.33.2d	-	-	-	7

Notes for Table 4.33-2:

(1) A high temperature storage test is optional. A high temperature storage test is optional. A lot will have an initial service-life of three, five or ten years as required in paragraph 4.13.3.

(2) One-third of sample shall be functioned at minimum standoff and two-thirds of the sample at maximum standoff.

TABLE 4.33-3. ETS AND ORDNANCE MANIFOLD QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested [3], [4]	
		X=1	X=21
Component Examination	4.11.1		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Non-Operating Environment Test and Operating Environment Tests	4.13.1 4.14.1		
Storage Temperature	4.13.2	-	X
Transportation Shock	4.13.4	-	X
Bench Handling	4.13.5	-	X
Transportation Vibration	4.13.6	-	X
Fungus Resistance	4.13.7	-	X
Fine Sand	4.13.8	-	X
Thermal Cycling	4.14.2	-	X
High Temperature Storage [1]	4.13.3	-	10
Humidity	4.14.4	-	X
Salt Fog	4.14.5	-	X
Shock [2], [5]	4.14.8	-	X
Acceleration [5]	4.14.7	-	X
Sinusoidal Vibration [2], [5]	4.14.10	-	X
Random Vibration [2], [5]	4.14.11	-	X
Handling Drop	4.13.10	-	X
Abnormal Drop	4.13.11	X	-
Tensile Load	4.13.9	-	X
Component Examination	4.11.1		
Visual Examination	4.11.2	-	X
Leakage	4.11.8	-	X
X-ray and N-ray	4.11.6	-	X
Firing Tests	4.33.2		
Ambient Temperature	4.33.2b	-	7
High Temperature	4.33.2c	-	7
Low Temperature	4.33.2d	-	7

Notes for Table 4.33-3:

(1) A high temperature storage test is optional. A lot will have an initial service-life of three, five or ten years as required in paragraph 4.13.3.

(2) Any ETS shall undergo this test attached to a dynamically equivalent test fixture that simulates each flight configured interface.

(3) The quantity of test samples required by the column applies to explosive transfer lines and explosive manifolds with internal ordnance.

(4) The required quantity applies for each configuration of explosive transfer line end-tip.

(5) Any ETS manifold and destruct charge shall undergo this test with its ETS assembly attached.

TABLE 4.33-4. ETS, EXPLOSIVE MANIFOLD, AND DESTRUCT CHARGE SERVICE-LIFE EXTENSION TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested (3)		
		1 Year (4) X=5	3 Years (6) X =10	5 Years (5) X=10
Component Examination	4.11			
Visual Examination	4.11.2	X	X	X
Dimension Measurement	4.11.3	X	X	X
Leakage	4.11.8	X	X	X
X-ray and N-ray	4.11.6	X	X	X
Non-Operating Environment Test and Operating Environment Tests	4.13.1 4.14.1			
Thermal Cycling (2)	4.14.2	X	X	X
High Temperature Storage	4.13.3	-	X	X
Shock (2)	4.14.8	X	X	X
Random Vibration (2)	4.14.11	X	X	X
Tensile Load	4.13.9	X	X	X
Component Examination	4.11			
Visual Examination	4.11.2	X	X	X
Leakage	4.11.8	X	X	X
X-ray and N-ray	4.11.6	X	X	X
Firing Tests	4.33.2			
High Temperature	4.33.2c	2	5	5
Low Temperature	4.33.2d	3	5	5

Notes for Table 4.33-4:

(1) A high temperature storage test is optional. The component shall undergo the tests required by the one-year column or the five-year column to extend its service-life. For any explosive manifold with internal ordnance, the ordnance may undergo each test installed in the manifold or separately.
(2) This test shall subject each sample component to the qualification environmental level.
(3) The quantity required by each column applies for each configuration of explosive transfer line end-tip. For each column, the quantity of sample components required at the top of the column shall be from the same production lot and shall undergo each test designated with an X. For a test designated with a lesser quantity, each sample component tested shall be one of the original samples for that column.
(4) Five sample ordnance components from the same lot shall undergo each test required by this column to extend the service-life of the remaining components from the same lot for one year.
(5) Ten sample ordnance components from the same lot shall undergo each test required by this column to extend the service-life of the remaining components from the same lot for five years.
(6) Devices that use deflagration to detonation interfaces or use a small ordnance load such as shock tube, may only be extended 3 years.

4.33.1 General. Any ETS, ordnance manifold, or destruct charge shall satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all its performance specifications when subjected to each non-operating and operating environment.

4.33.2 Firing Tests.

a. General. A firing test of an ETS, explosive manifold, or destruct charge shall satisfy all of the following:
   (1) The test shall demonstrate that each ordnance sample satisfies all its performance specifications when subjected to all qualification stress conditions.
   (2) The number of samples that the test shall fire and the test conditions, including temperature, shall satisfy each table of this section.
   (3) Before initiation, each ordnance sample shall experience the required temperature for enough time to achieve thermal equilibrium.
   (4) For any destruct charge, the test shall initiate the charge against a witness plate to demonstrate that the charge satisfies all its performance specifications and is in-family.
   (5) For any ETS component, the test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the ordnance output satisfies all its performance specifications.
   (6) For any explosive manifold that contains ordnance, the test shall initiate the ordnance using an ETS in a flight representative configuration.
b. Ambient Temperature. This test shall initiate each ordnance sample while it is subjected to ambient temperature.
c. High Temperature. A high temperature test shall initiate each ordnance sample while it is subjected to no lower than the qualification high temperature level or +71 °C, whichever is higher.
d. Low Temperature. A low temperature test shall initiate each ordnance sample while it is subjected to no higher than the qualification low temperature level or -54 °C, whichever is lower.

4.33.3 Penetration Margin. A penetration margin test shall demonstrate a destruct charge's ability to accomplish its intended flight termination function, such as to destroy the pressure integrity of any solid propellant stage or motor or rupture any propellant tank. This shall include penetrating no less than 150 percent of the thickness of the target material.

1. Witness plates shall be thick enough to measure the depth of the cut without cutting all the way through the plate.
2. Witness plates shall be consistent throughout qualification and subsequent lot acceptance and age surveillance tests.
3. Linear shaped charges may be correlated to witness plates by placing the target material under one part of the charge and a witness plate under the other part of the charge.

4.33.4 Propellant Detonation. A propellant detonation test or analysis shall demonstrate that a destruct charge will not detonate the propellant of its intended target.

4.34 Ordnance Interfaces and Manifold Qualification

4.34.1 General. This section applies to any ordnance interface or manifold that is part of an FTS. Each ordnance interface or manifold shall undergo a qualification test that demonstrates that the interface or manifold satisfies its performance specifications with a reliability of 0.999 at a 95 percent confidence level.

This requirement includes any internal gaps in an ordnance component.

4.34.2 Interfaces. A qualification test of an ordnance interface shall demonstrate the interface's reliability. This shall include all of the following:

a. The test shall use a simulated flight configured interface and test hardware that duplicates the geometry and volume of the firing system used on the vehicle.
b. The test shall account for performance variability due to manufacturing and workmanship tolerances such as minimum gap, maximum gap, and axial and angular offset.

Gaps greater than 0.30 inches shall not be used.

c. The test shall account for performance variability due to qualification temperature extremes.

4.34.3 Detonation Flier Plate Ordnance Transfer Systems. A qualification test of a detonation flier plate ordnance transfer system shall demonstrate the reliability of the system.

1. Detonation flier plate ordnance transfer systems include LVIs, EBWs, ordnance delays, ETSs and PADs.
2. The .999@ 95 percent requirement shall be verified using one of the following methods.
   a. A statistical firing series that varies critical performance parameters, including gap and axial and angular alignment, to ensure that ordnance initiation occurs across each flight configured interface with a reliability of 0.999 at a 95 percent confidence level. Any statistical method acceptable to safety may be used including Neyer, Bruceton or Langley.
   b. Firing 2994 flight units in a flight representative configuration to demonstrate that ordnance initiation occurs across each flight configured interface.
   c. Firing all of the following units to demonstrate a gap margin that ensures ordnance initiation.
      (1) Five units at four times the combined maximum system gap
      (2) Five units at four times the combined maximum system axial misalignment
      (3) Five units at four times the combined maximum system angular misalignment
      (4) Five units at 50 percent of the combined minimum system gap
3. Testing shall be performed at qualification low temperature

4.34.4 Deflagration and Pressure Sensitive Ordnance Transfer Systems. A qualification test of a deflagration or pressure sensitive ordnance transfer system shall demonstrate the required system reliability.

1. Deflagration and pressure sensitive systems include cartridge actuated devices, primers, ordnance delays and shock tubes.
2. The .999@ 95 percent requirement shall be verified using one of the following methods.
   a. A statistical firing series that varies critical performance parameters, including gap interface, to ensure that ordnance initiation occurs across each flight configured interface with a reliability of 0.999 at a 95 percent confidence level.
   b. Firing 2994 flight units in a flight representative configuration to demonstrate that ordnance initiation occurs across each flight configured interface with a reliability of 0.999 at a 95 percent confidence level;
   c. Firing all of the following units to demonstrate a significant gap margin:
      (1) Five units using a 80 percent of a nominal donor charge load across the maximum gap at qualification cold temperature.
      (2) Five units using a 120 percent of a nominal donor charge load across the minimum gap at qualification hot temperature.
3. Testing shall be performed at the worst-case qualification temperature.

4.35 Shock and Vibration Isolators

TABLE 4.35-1. SHOCK AND VIBRATION ISOLATOR ACCEPTANCE TEST REQUIREMENTS(1)

Test	Paragraph	Quantity Tested
Component Examination	4.11.1	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Performance Verification Tests	4.10.4	
Load Deflection	4.35.2	100%
Dynamic Response	4.35.3	100%

Note for Table 4.35-1:

(1) Each isolator shall undergo the tests required by this table in a configuration that demonstrates whether isolator satisfies all its performance specifications. The test configuration need not be the flight configuration.

TABLE 4.35-2. SHOCK AND VIBRATION ISOLATOR QUALIFICATION TEST REQUIREMENTS

Test	Paragraph	Quantity Tested (2)
Component Examination	4.11	
Visual Examination	4.11.2	3
Dimension Measurement	4.11.3	3
Performance Verification Tests	4.10.4	
Load Deflection (3)	4.35.2	3
Dynamic Response (3)	4.35.3	3
Characterization Tests (1)	4.35.4	
Thermal Performance	4.35.4a	3
Compression	4.35.4b	3

Notes for Table 4.35-2:

(1) The test configuration must be in a flight-like configuration. Characterization tests shall be performed in three perpendicular axes.
(2) Quantity tested indicates the number of system tests for each flight isolator configuration. The FTS component used for this test may be a mass simulator.
(3) The test configuration need not be the flight configuration and only requires testing in one vibration axis.

4.35.1 General. Any isolator shall satisfy each test or analysis identified by Table 4.35-1 to demonstrate that it has repeatable performance and is free of any workmanship defects.

4.35.2 Load Deflection. A load deflection test shall demonstrate the ability of a shock or vibration isolator to withstand the full-scale deflection expected during flight while satisfying all its performance specifications. This shall include subjecting each isolator to varying deflection increments from the null position to the full-scale flight deflection and measuring the isolator's compression at each deflection increment.

4.35.3 Dynamic Response. The isolator's performance characteristics shall be demonstrated while being subjected to vibration testing using a mass representative of the flight configuration.

a. The test shall measure the isolator's natural frequency while the isolator is subjected to a random vibration or sinusoidal sweep vibration with amplitudes that are representative of the maximum predicted operating environment.
b. The test shall measure the dynamic amplification value while subjected to a random vibration or sinusoidal sweep vibration with amplitudes that are representative of the maximum predicted operating environment
c. The pass/fail criteria shall ensure that a flight isolator amplification and natural frequency have been enveloped by the qualification test levels.

1. Typically, an additional ±1.5 dB margin is added to the 6 dB qualification margin (7.5 dB total) to account for isolator variability. This allows isolators within a lot to perform with a ±1.5 dB variability when compared to the amplification used for qualification Isolators that perform outside the qualification test regime shall not be used for flight.
2. Isolators natural frequency pass/fail criteria shall be ±10 percent of the natural frequency used for qualification testing.

4.35.4 Characterization Tests. Characterization testing shall be performed on simulated flight hardware using a flight isolator mounting configuration. These tests account for in-flight environments that affect performance. Any variation in performance shall be added to the qualification test margin to ensure differences between flight and qualification isolators do not result in overstressed FTS components during flight. The variations factored into the qualification test margin will become the tolerance used for the 100 percent screen test in 4.35.3. The following tests shall be performed:

a. Thermal Response. Isolators shall be subjected to the dynamic response tests of 4.35.3 at ambient and qualification temperature extremes.
b. Acceleration Response. Isolators shall be subjected to the dynamic response tests of 4.35.3 at ambient temperature to characterize the effect of compression loads that occur during qualification acceleration loads.

Combined thermal and acceleration response variations shall be factored into hardmount qualification.

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CHAPTER 5

FTS COMPONENT, SUBSYSTEM, AND SYSTEM PRELAUNCH TEST AND LAUNCH REQUIREMENTS

5.1 General

An FTS, its subsystems, and components shall undergo the preflight tests required in this chapter to demonstrate that the system satisfies all its performance specifications during prelaunch, countdown and vehicle flight. After successful completion of any preflight test, if the integrity of the system, subsystem, or component is compromised due to a configuration change or other event, such as a lightning strike or connector demate, the system, subsystem, or component shall repeat some or all of the preflight test.

Testing may need to be performed again if the launch is delayed by extended holds or recycles for a period that exceeds the range-approved time limit. The time limit is range specific.

5.1.1 Installation, Test and Countdown Procedures.

a. Each test of a subsystem or system shall follow a written procedure that specifies the test parameters, including pass/fail criteria, test resolution, and a testing sequence that satisfies the requirements.

b. The ranges shall review and approve all procedures. The Range User shall not deviate from or change an approved procedure unless specifically approved by the ranges. Test procedures shall be submitted to the range with sufficient time to review the procedure and address comments. Testing shall not begin until the test plan and/or procedure has been approved. This includes software for automated checkout, test equipment, pass/fail criteria, etc.

1. Plans and procedures shall be submitted for review and approval 45 days prior to the start of the procedure.
2. Components whose test data reflect the unit is out-of-family when compared to other units shall be considered out of specifications.
3. Range Safety personnel may be required to be present any time the FTS is powered and/or tested.
4. Stray Energy Test. The system shall have “no-volt/no-current” or "stray energy" tests before ordnance connection.
5. All ordnance connections shall be validated through an approved Range Safety inspection procedure.
6. Close-out photos shall be taken of all FTS components and connections after installation in the final flight configuration.

5.1.2 Test Notification. The Range User shall notify the range with sufficient time before the start of testing to allow Range Safety support at the test location.

The Range User shall notify the range 2 weeks before the start of testing, at which time the range will determine if a representative will be sent to witness the test. The range shall have the prerogative of witnessing any test.

5.1.3 Test Anomalies and Failures. Each of the following constitutes a condition that requires resolution with Range Safety approval:

a. Any test that does not satisfy a performance specification or pass/fail criteria.
b. Any failure to accomplish a test objective.
c. Any test result that indicates an out-of-family condition when compared to other tests even if it satisfies other test criteria.
d. Any unexpected change in the performance occurring at any time during testing.
e. Examination showing any defect or other incidental finding that could adversely affect the performance.
f. Any discontinuity or dropout in a measured performance parameter.
g. Any inadvertent output.
h. Any unexpected loss of solid, liquid, or gaseous material from the component, subsystem, or system.

5.1.4 Failure Analysis. In the event of a test failure or anomaly, the test item, procedures, and equipment shall undergo a written failure analysis. The failure analysis shall identify the cause and mechanism of the failure and isolate the failure to the smallest replaceable item or items and ensure that there are no design, workmanship, or process problems with other flight components of similar configuration. Corrective actions shall also be identified when appropriate.

a. Unless emergency action is needed to safe the system to protect personnel, in the event of a test anomaly or failure, the test configuration shall be frozen until a Range Safety representative can be contacted. The range shall have the prerogative of participating in any failure analysis and corrective action. Invasive troubleshooting or corrective action shall not begin without Range Safety approval.

A failure investigation plan shall be submitted that describes the detailed approach to resolve the anomaly or failure.

b. The failure or anomaly of an FTS test shall be reported verbally or electronically to the Range Safety representative within 24 hours. Data shall be provided in a timely manner that allows Range Safety sufficient time to review documentation, which supports program schedule.

Detailed description with any supporting data shall be provided in writing within 14 calendar days of the date the failure is noted.

c. This requirement for failure reporting and documentation includes failure of tests conducted at the supplier plant, contractor plant, or at the range.

d. Flight approval will not be granted until Range Safety approves the failure analysis and corrective action.

5.1.5 Test Failure Reports.

a. This requirement includes failure of tests conducted at the supplier plant, contractor plant, or at the range.

b. A formal report containing a description and analysis of the failure, and planned corrective actions, shall be submitted to Range Safety so that Range Safety has sufficient time to review documentation, which supports program schedule.

Failure analyses shall be submitted to Range Safety for approval within 30 days of the failure. In the event a failure investigation requires more than 30 days for the contractor to resolve, status reports on the failure investigation shall be submitted to Range Safety every 30 days until the investigation is completed.

5.1.6 Test Tolerances. Each test shall use the criteria specified in Chapter 4. The tolerance of any ground or airborne equipment used during a functional test shall provide the accuracy needed to detect any out-of-family or out-of-specification condition.

1. Vehicle monitoring system (e.g. telemetry) tolerances, instrumentation/sensor error, and calibration error shall be included in the launch go/no-go criteria to ensure that qualification margins are maintained. 2. Preflight component test equipment tolerances, instrumentation/sensor error, and calibration error shall be quantified and factored into pass/fail criteria.

5.1.7 FTS Monitoring.

a. The Range User shall ensure that FTS components are not exposed to electrical overstress and environments that exceed qualification limits. Range Safety shall be notified of any FTS component exposed to overstressing or anomalous conditions.

b. Monitoring systems shall be continuously available to safety personnel or representatives during prelaunch tests, launch or whenever the FTS is powered-up.

1. FTS components that have been potentially overstressed shall not be used for flight until an analysis and corrective action have been approved by Range Safety. 2. Monitoring systems shall demonstrate proper functioning of destruct initiator simulators.

c. Range Safety shall determine the required telemetered FTS parameters for each launch.

The Range User shall provide a list of all vehicle telemetry measurements.

d. FTS Parameter Channel Identification/Calibration. The Range User shall provide synthesized FTS parameter channel identification/calibration telemetry playback data that is compatible with range instrumentation. The Range User shall contact each affected range for specific requirements for media and format.

1. Telemetry playback is used to facilitate the setup of real-time recorders, certify de-commutation capability and verify displays.
2. FTS measurements shall be varied during playback to reflect expected prelaunch and launch performance. Analog values shall be exercised at minimum, mid-scale and full-scale. The playback data shall include a script that describes when the measurements are expected to change.
3. Data shall be provided no later than 60 days prior to launch.

5.2 Preflight Component Tests

5.2.1 A component shall undergo one or more preflight tests at the launch site to detect any change in performance due to any shipping, storage, or other environments that may have affected performance after the component passed the acceptance tests.

5.2.2 Each test shall measure performance parameters of the component and compare the measurements to the acceptance test performance baseline to identify any performance variations, including any out-of-family results that may indicate potential defects that could result in an in-flight failure.

Component Certification Testing.

a. Component certification tests are conducted on FTS components before installation in a higher assembly or vehicle to certify them for flight.
b. Tests are usually performed in a laboratory-type environment and include electrical and functional tests.
c. These tests may be required to be conducted at ambient and workmanship high and low temperatures.
d. Certification tests are designed to detect changes in performance since the manufacturer acceptance test or the last range certification test was carried out.
e. Tests shall be performed as close to launch day as possible. Certification time limits shall depend on the type of component and the overall vehicle configuration.
f. Certification test data shall correlate with the ATP baseline data and any previous certification test data. Differences in test results that may indicate a degradation in performance may result in rejection of the particular component for FTS purposes.

5.2.3 Batteries.

a. Silver-Zinc Batteries. A battery shall undergo preflight processing and testing that satisfies all of the following:

(1) Batteries shall be conditioned and processed to ensure they meet critical performance parameters. Preflight processing shall be equivalent to that used during qualification testing.

Activation, top charge and load test methodology and equipment for processing the flight units shall be equivalent to that used for the qualification units.

(2) Capacity Verification Test. Coupons cells associated with the flight batteries shall be tested IAW Table 4.22.1.

1. Coupon cell testing shall be completed prior to start of flight battery processing/testing. 2. For multi-cycle, secondary batteries, coupon cell testing shall validate every cycle for the full duration of each cycle's charge stand.

(3) Each battery shall undergo the required tests at ambient temperature within the specified wet-stand life IAW Table 4.22-1-note 2.

(4) The test results from the coupon and battery tests of paragraph 5.2.3.a(2) and paragraph 5.2.3.a(3) shall be compared to data from the qualification tests. The flight battery test data shall be evaluated to identify any out-of-family performance.

(5) For manually activated batteries, a visual inspection shall be performed on the tops of the cells and battery compartment for electrolyte spewing, debris, and excess materials prior to final battery cover installation.

(6) Battery voltage and individual cell voltages shall be monitored after the final FTS end-to-end testing at a sufficient frequency to detect a loss in voltage.

Daily monitoring of open circuit voltage of each cell or a demonstration of battery voltage under a current load is required for batteries installed in the peroxide state to verify that on-vehicle voltage losses in open circuit voltage are due to self discharge and not a cell short.

b. Remotely Activated Silver-Zinc and Thermal Batteries. Certification testing shall be conducted on all FTS batteries before installation on the vehicle.

(1) Each battery shall undergo all of the following tests at ambient temperature as close to launch as possible.

1. Testing shall be performed within 90 days prior to launch. 2. Testing shall be performed at the launch site. 3. When a battery is activated after launch/drop, the Activation Circuit LVI Resistance shall be performed within 30 days prior to launch.

(2) Each battery shall undergo the required tests at ambient temperature IAW Table 4.23.1 (note 13) for Remotely Activated Silver-Zinc batteries and Table 4.24.1 (note 13) for thermal batteries.

c. Nickel-Cadmium Batteries. A battery shall undergo preflight processing and testing that satisfies all of the following:

(1) Batteries shall be conditioned and processed to ensure they meet all performance parameters. Preflight processing shall be equivalent to that used during qualification testing.

Charging/discharging methodology and equipment used to process flight units shall be equivalent to that used for the qualification units.

(2) Each battery shall undergo the required tests at ambient temperature IAW Table 4.25.2 (note 8).

1. Testing shall be performed within 4 weeks prior to launch. 2. Testing shall be performed at the launch site.

(3) The test results from the battery acceptance tests of Table 4.25.2 shall be compared to data from the preflight tests. The flight battery test data shall be evaluated to identify any out-of-family performance.

d. Lithium-ion Batteries. A battery shall undergo preflight processing and testing that satisfies all of the following:

(1) Batteries shall be conditioned and processed to ensure they meet all performance parameters. Preflight processing shall be equivalent to that used during qualification testing.

Charging/discharging methodology and equipment used to process flight units shall be equivalent to that used for the qualification units.

(2) Each battery shall undergo the required tests at ambient temperature IAW Table 4.26.2 (note 8).

1. Testing shall be performed within 4 weeks prior to launch. 2. Testing shall be performed at the launch site.

(3) The test results from the battery acceptance tests of Table 4.26.2 shall be compared to data from the preflight tests. The flight battery test data shall be evaluated to identify any out-of-family performance.

(4) Battery voltage and individual cell voltages shall be monitored after the end-to-end testing at a sufficient frequency to detect a loss in voltage.

Daily monitoring of open circuit testing or a demonstration of voltage under a significant current load is required for batteries installed to verify that on-vehicle voltage losses in open circuit voltage are only due to a self discharge.

e. Lead Acid Batteries. A battery shall undergo preflight processing and testing that satisfies all of the following:

(1) Batteries shall be conditioned and processed to ensure they meet all performance parameters. Preflight processing shall be equivalent to that used during qualification testing.

Charging/discharging methodology and equipment used to process flight units shall be equivalent to that used for the qualification units.

(2) Each battery shall undergo the required tests at ambient temperature IAW Table 4.27.2 (note 8).

1. Testing shall be performed within 4 weeks prior to launch.
2. Testing shall be performed at the launch site.

(3) The test results from the battery acceptance tests of Table 4.27.2 shall be compared to data from the preflight tests. The flight battery test data shall be evaluated to identify any out-of-family performance.

5.2.4 Preflight Testing of an S&A Device With an Internal LVI. An internal LVI in an S&A device shall undergo a preflight test that satisfies all of the following:

a. The S&A shall be tested as close to launch as possible.

1. The test shall take place no earlier than 10 calendar days before the first flight attempt.
2. If the flight is delayed more than 14 calendar days or the FTS configuration is broken or modified for any reason, such as to replace batteries, the device shall undergo the test again no earlier than 10 calendar days before the next flight attempt.
3. Note: Most low voltage initiators (LVI) in S&A devices incorporate Electro-explosive Devices (EEDs).

b. Each S&A device shall undergo the required tests at ambient temperature IAW Table 4.28.1 (note 1).

5.2.5 Acceleration Armed S&As.

a. Certification testing shall be conducted on all acceleration armed S&As before installation on the launch vehicle.

b. The following tests shall be conducted as close to launch as possible.

The test shall take place no earlier than 10 calendar days before the first flight attempt.

(1) Visual checks for physical defects.
(2) Continuity tests.

c. The following tests shall be conducted as close to launch as possible.

The test shall take place within 180 calendar days before the first flight attempt.

(1) Visual checks for physical defects.
(2) Acceleration arming tests (axial and lateral acceleration).
(3) Continuity of bridgewire in the armed state.

5.2.6 Preflight Testing of an External LVI. An external LVI that is part of an S&A device shall undergo a preflight test that satisfies all of the following:

a. The LVI shall be tested as close to launch as possible.

1. The test shall take place no earlier than 10 calendar days before the first flight attempt. 2. If the flight is delayed more than 14 calendar days or the FTS configuration is broken or modified for any reason, such as to replace batteries, the device shall undergo the test again no earlier than 10 calendar days before the next flight attempt. 3. Note: Most low voltage initiators (LVI) in S&A devices incorporate Electro-explosive Devices (EEDs).

b. The test shall include visual checks for signs of any physical defect or corrosion and a resistance check of the LVI.

c. Each LVI device shall undergo the required tests at ambient temperature IAW Table 4.28.3 (note 5).

5.2.7 Preflight Testing of an EBW/EFI. An EBW/EFI shall undergo a preflight test that satisfies all of the following:

a. The EBW/EFI shall be tested as close to launch as possible.

1. The test shall take place no earlier than 10 calendar days before the first flight attempt. 2. If the flight is delayed more than 14 calendar days or the FTS configuration is broken or modified for any reason, such as to replace batteries, the device shall undergo the test again no earlier than 10 calendar days before the next flight attempt.

b. Each EBW/EFI device shall undergo the required tests at ambient temperature IAW Table 4.29.3 (note 1).

5.2.8 Preflight Testing of a Laser Initiated Device (LID).

a. The LID shall be tested as close to launch as possible.

1. The test shall take place no earlier than 10 calendar days before the first flight attempt.
2. If the flight is delayed more than 14 calendar days or the FTS configuration is broken or modified for any reason, such as to replace batteries, the device shall undergo the test again no earlier than 10 calendar days before the next flight attempt.

b. Each LID shall undergo the required tests at ambient temperature IAW Table 4.30.3 (note 9).

5.2.9 Preflight Testing for FTRs and Other Electronic Components.

This section includes any component that contains piece-part circuitry, such as a command receiver decoder, autonomous flight termination units (AFTUs), automatic destruct systems (ADSs), and relay boxes.

a. The electronic component shall be tested as close to launch as possible.

1. The test shall take place no earlier than 180 calendar days before flight.
2. If the 180-day period expires before flight, the Range User shall replace the component with one that meets the 180-day requirement or test the component in place on the launch vehicle.
3. Alternate procedures for testing the component on the launch vehicle may be performed.
4. An acceptance test for a preflight test may be substituted for the preflight test if the acceptance test is performed no earlier than 180 calendar days before flight.

b. The test shall repeat the annotated performance tests conducted during acceptance testing in the applicable component table of Chapter 4.

Bench testing at temperature extremes shall be performed when the receiver functions in a non-ambient temperature environment, such as long-duration captive carry. The requirement for bench testing at temperature extremes shall be determined by the specific range.

5.2.10 Preflight Testing for High Energy Electronic Ordnance Firing Units. High energy electronic ordnance firing units include FTS, EAFDs, ESADs, and EBW firing units.

a. The Electronic component shall be tested as close to launch as possible.

1. The test shall take place no earlier than 180 calendar days before flight.
2. If the 180-day period expires before flight, the Range User shall replace the component with one that meets the 180-day requirement or test the component in place on the launch vehicle.
3. Alternate procedures for testing the component on the launch vehicle may be performed.
4. An acceptance test for a preflight test may be substituted for the preflight test if the acceptance test is performed no earlier than 180 calendar days before flight.

b. Each component shall undergo the required tests at ambient temperature IAW Table 4.29.1 (note 3).

c. Certification tests shall be performed within 180 days of launch.

d. If the FTS firing units have been electrically connected and the launch subsequently scrubbed, removal and retest may be required by Range Safety.

5.2.11 Preflight Testing for FTS Fuel Shutoff/Cutoff Valves.

a. The valve shall be tested as close to launch as possible.

1. The test shall take place within 180 calendar days before flight.
2. Testing shall be conducted on all FTS fuel shutoff/cutoff valves within 30 days prior to installation on the vehicle.
3. If the 180-day period expires before flight, the Range User shall replace the component with one that meets the 180-day requirement or test the component in place on the launch vehicle.
4. Alternate procedures for testing the component on the launch vehicle may be performed.
5. An acceptance test may be substituted for the preflight test if the acceptance test is performed within the required timelines.

b. Each component shall undergo the required tests at ambient temperature IAW Table 4.19.1 (note 6), Table 4.19.3 (note 6) or Table 4.19.5 (note 5), as applicable.

c. Pressurized lines that control FTS valves shall not leak when proof tested in their final flight configuration at the maximum expected operating pressure plus a margin.

1. Proof pressure leak testing shall be performed to at least 1.5 times MEOP.
2. Proof pressure leak testing shall not violate design qualification margins.

5.3 Prelaunch Subsystem and System Level Tests

It is important to note that an FTS shall undergo preflight subsystem and system level testing after the components are installed on a launch vehicle.

5.3.1 Test Data. Data obtained from the this test shall be compared to data from the preflight component tests and acceptance tests to demonstrate that there are no discrepancies indicating a flight reliability concern.

5.3.2 Instrumentation tolerances. Instrumentation tolerances shall have sufficient resolution to ensure that an anomalous component is not masked.

1. System Testing.
   a. System level tests are the final checkouts of an FTS.
   b. Subsystem tests may be performed during or after system assembly.
2. Monitoring may be accomplished either through telemetry or a hard line to the GSE.

5.3.3 RF System Preflight Test. All RF systems shall undergo a preflight test that satisfies all of the following:

a. The test shall demonstrate that the FTS antennas and associated RF systems satisfy all their performance specifications once installed in their final flight configuration.

1. VSWR testing shall be performed to ensure all FTS RF components and component connections are correct.
2. Insertion loss of the entire FTS RF system shall be determined.

(1) The test shall measure the VSWR of the system and demonstrate that any insertion losses are within the design limits.
(2) The VSWR/insertion loss shall be tested as close to launch as possible.

The test shall take place within 90 days of launch.

b. The test shall demonstrate the functions of each FTR. At a minimum, the following performance parameters shall be performed.
   (1) SSTO curves
   (2) Threshold sensitivity for each command
   (3) Operational bandwidth.

1. Covers and hats are mandatory for all in-vehicle closed-loop testing required in this chapter.
2. Calibrated antenna terminations (covers) and couplers (hats) shall be provided for all FTS antennae.
3. The antenna termination and coupler calibration data shall be used in the in-vehicle system pass/fail criteria analysis.
4. If FTS antenna heat shields are used, they shall be installed during all in-vehicle system testing.
5. The test shall take place within 90 days of launch.

5.3.4 Non-Secure FTR System, automatic destruct and Fail-Safe.

a. After installation of the FTS up to, but not including the electrical and/or optical connection of the flight termination initiators, an end-to-end verification test of the entire command, automatic, and fail-safe FTS shall be performed.
   (1) The FTS end-to end test shall be performed as close to launch as possible and after all vehicle processing has occurred in the FTS component locations.

1. The test shall take place within 72 hours before flight.
2. End-to end testing shall be performed again if:
   a. At any time after the test, the integrity of the system is suspect or compromised by a configuration change, demating of any connector or wiring harness, lightning strikes, mate/demate of any connectors, or other event.
   b. If the flight is delayed and the FTS configuration is not broken or modified, the 72 hour requirement may be extended on a case-by-case basis.

   (2) The entire airborne FTS, except for FTS initiators, shall undergo the test in its final flight configuration.

1. Unless otherwise approved, the end to end test shall use Range equipment and transmitters.
2. Where shutdown valves are used as the primary termination method, valve position and functionality shall be verified. Note: This may be performed using gas pressurized propellant tanks and verifying valve position through pressure detection.
3. Where control surfaces or pin-pullers are used as the primary termination method, their functionality shall be verified.
4. The FTS shall undergo the test while powered by FTS flight batteries.

   (3) The test shall use a FTS ordnance simulator in place of each flight ordnance initiator to demonstrate that the command terminate, automatic or fail-safe terminate systems deliver the required energy to initiate the FTS ordnance. For non-ordnance FTS actions, the flight hardware shall be used to validate FTS functionality.

For multiple terminate cases, only one end-to-end test is required into a high current load.

Other test cases may output into a high impedance/open circuit load.

(4) The end-to-end test shall exercise all FTR, automatic and fail-safe functions critical to FTS operation during flight.
(5) The test shall verify that each string of the FTS system meets all performance requirements.

b. Open-Loop Test of a Non-Secure Command Terminate System. A non-secure FTS shall undergo an open-loop RF test as late in the launch countdown as possible. The test shall satisfy all of the following:

An open-loop RF test shall be performed within 60 minutes before launch to validate the entire RF command terminate link.

(1) The system shall undergo the test with all FTS initiation devices in a safe condition.
(2) FTRs shall be powered by flight batteries.
(3) The test shall demonstrate that each FTR is operational and is compatible with the command control transmitter system. The test shall exercise the FTR, including check channel, using a command control transmitter in its flight configuration.

This test shall include an ARM or optional command.

(4) Following successful completion of the open-loop test, if any FTR is turned off or the transmitter system fails to continuously transmit the check channel, the FTS shall undergo the open-loop test again before flight.

The open-loop test does not need to be re-performed if the FTR is switched from internal power to external (or vice-versa) as long as there is no interruption in power (make before break power switching).

5.3.5 Secure High-Alphabet Command Terminate System.

a. Initial Open-Loop Test of a Secure High-Alphabet Command Terminate System. Any FTS that uses a secure high-alphabet command receiver decoder shall undergo an open-loop RF test to demonstrate the integrity of the system between the command control transmitter system and launch vehicle RF system from the antenna to the FTRs. The test shall satisfy all of the following:
(1) The test shall occur before loading the secure flight code on to the command transmitting system and the command receiver decoders.
(2) The test shall use a non-secure code, also known as a maintenance code, loaded on to the command control transmitting system and the FTRs.
(3) Each command receiver decoder shall be powered by either the ground or launch vehicle power sources.

(4) The command control transmitter system shall transmit, open-loop, all receiver decoder commands required for the FTS functions, including pilot or check tone to the vehicle.
(5) The test shall demonstrate that each FTR receives, decodes, and outputs each command sent by the command control system.
(6) The testing shall demonstrate that all primary and redundant FTS components, FTS circuits, and command control system transmitting equipment are operational.

b. End-To-End Test of a Secure High-Alphabet Command Terminate System. Any FTS that uses a secure high-alphabet command receiver decoder shall undergo an end-to-end test of all FTS subsystems, including command terminate systems and inadvertent separation destruct systems. The test shall satisfy all of the following:
(1) The system shall undergo the test no earlier than 72 hours before the first flight attempt. After the test, if the flight is delayed more than 14 calendar days or the FTS configuration is broken or modified for any reason, such as to replace batteries, the system shall undergo the end-to-end tests again no earlier than 72 hours before the next flight attempt.
(2) The system shall undergo the test in a closed-loop configuration using the secure flight code.
(3) The FTS, except for the ordnance initiation devices, shall undergo the test in its final onboard launch vehicle configuration.

Where shutdown valves are used as the primary termination method, valve position and functionality shall be verified. Note: This may be performed using gas pressurized propellant tanks and verifying valve position through pressure detection.

(4) The test shall use a destruct initiator simulator in place of each flight initiator to demonstrate that the command terminate and inadvertent separation destruct systems deliver the energy required to initiate the FTS ordnance.
(5) The FTS shall undergo the test while powered by the batteries that the launch vehicle uses for flight.
(6) The test shall exercise all command receiver decoder functions critical to FTS operation during flight, including the pilot or check tone, in a closed-loop test configuration using ground support testing equipment hardwired to the launch vehicle RF receiving system.
(7) The test shall demonstrate that all primary and redundant launch vehicle FTS components and circuits are operational.
(8) The test shall exercise the triggering mechanism of all electrically initiated inadvertent separation destruct systems to demonstrate that they are operational.

c. Abbreviated Closed-Loop Test of a Secure High-Alphabet Command Terminate System. Any FTS that uses a secure high-alphabet command receiver decoder shall undergo an abbreviated closed-loop test if, due to a launch scrub or delay, more than 72 hours pass since the end-to-end test of 5.3.5b. The test shall satisfy all of the following:
   (1) The FTS shall undergo the test in its final flight configuration with all flight destruct initiators connected and in a safe condition.
   (2) The test shall occur just before launch support tower rollback or other similar final countdown event that suspends access to the launch vehicle.
   (3) Each command receiver decoder shall undergo the test powered by the flight batteries.
   (4) The test shall exercise all command receiver decoder functions critical to FTS operation during flight except the destruct function, including the pilot or check tone, in a closed-loop test configuration using ground support testing equipment hardwired to the launch vehicle RF receiving system.
   (5) The test shall demonstrate that the launch vehicle command terminate system, including each command receiver decoder and all batteries, are functioning properly.

d. Final Open-Loop Test of a Secure High-Alphabet Command Terminate System. Any FTS that uses a secure high-alphabet command receiver decoder shall undergo a final open-loop RF test no earlier than 60 minutes before flight, to validate the entire RF command terminate link from the command control transmitting system to launch vehicle antenna. The test shall satisfy all of the following:
   (1) The FTS shall undergo the test in its final flight configuration with all flight destruct initiators connected and in a safe condition.
   (2) Flight batteries shall power all receiver decoders and other electronic components. The test shall account for any warm-up time needed for reliable operation of the electronic components.
   (3) The test shall exercise the self-test function of each command receiver decoder, including pilot or check tone using the command control system transmitters in their flight configuration.
   (4) The test shall demonstrate that each receiver decoder is operational and compatible with the command control transmitter system.
   (5) Following successful completion of the open-loop test, if any command receiver decoder is turned off or the transmitter system fails to continuously transmit the pilot or check tone the FTS shall undergo the final open-loop test again before flight.

5.3.6 Autonomous FTS end-to-end testing. An autonomous FTS end-to end test shall be performed as close to launch as possible and after all vehicle processing has occurred in the FTS component locations.

1. The test shall take place within 72 hours before flight.
2. End-to end testing shall be reperformed if:
   a. At any time after the test, the integrity of the system is suspect or compromised by a configuration change, demating of any connector or wiring harness, lightning strikes, mate/demate of any connectors, or other event.
   b. If the flight is delayed and the FTS configuration is not broken or modified, the 72 hour requirement may be extended on a case-by-case basis.

a. The entire airborne FTS, except for FTS initiators, shall undergo the test in its final flight configuration.

1. Unless otherwise approved, the end to end test shall use range equipment and transmitters.
2. Where shutdown valves are used as the primary termination method, valve position and functionality shall be verified. Note: This may be performed using gas pressurized propellant tanks and verifying valve position through pressure detection.
3. Where control surfaces or pin-pullers are used as the primary termination method, their functionality shall be verified.
4. The FTS shall undergo the test while powered by FTS flight batteries.

b. The test shall use an FTS ordnance simulator in place of each flight ordnance initiator to demonstrate that the command terminate, automatic or fail-safe terminate systems deliver the required energy to initiate the FTS ordnance. For non-ordnance FTS actions, the flight hardware shall be used to validate FTS functionality.

For multiple mission rule test cases required in this section, only one end-to-end test is required into a high current load. Other test cases may output into a high impedance/open circuit load.

c. The test shall verify that each FTS system string meets all performance requirements.

d. The AFTU shall be tested to demonstrate that the unit will initiate a terminate output when any mission rule is violated and will not initiate a terminate output under other conditions.
   (1) Mission simulations shall be performed IAW 4.18.2 test scenarios and actual mission scenarios. All terminate/non-terminate decision criteria shall be tested.

1. The same software scenarios used for qualification and acceptance test software shall be used for the test scenarios to detect performance variations that may screen for potential system anomalies.
2. The mission scenarios shall use all mission rules and flight trajectories. The AFTU shall demonstrate that it meets its performance requirements while updating real-time variables such as wind data.
3. The AFTU shall meet its performance requirements when subjected to a series of potential flight trajectories (including dispersions) and tracking data input scenarios.

(2) Testing shall be performed using ground support equipment that injects simulated trajectory scenario signals into the AFTU.

1. A GPS based AFTS shall have antenna hats that can receive simulated trajectory data from a ground satellite simulator.
2. An INS based AFTS shall have inputs that can receive simulated trajectory data from a ground simulator. Note: only the INS electrical outputs need to be simulated to allow validation of software and termination sequences.

e. FTS Software Verification.
   (1) The AFTS shall output all software and firmware contents in memory to ground support equipment to perform a bit-by-bit comparison against the mission specific software/firmware.
   (2) The AFTU may not be reloaded or reconfigured without re-accomplishing system end-to-end tests other than real-time data updates, such as winds
   (3) Any real-time data updates for mission constants shall be validated after loading and prior to launch.

5.4 Range and Vehicle Compatibility

An electromagnetic compatibility test of the airborne system, range equipment and any other electromagnetic source shall be conducted in the flight configuration. All critical FTS circuits shall be monitored to determine the amount of electromagnetic noise coupled into the system. The FTS shall meet all performance requirements when subjected to this added noise. At a minimum, this test shall include the following:

a. All range transmitter sources including command, communications and radar.
b. All vehicle transmitter sources including telemetry, transponder and payload.
c. All support equipment transmitter sources such as repeaters, support aircraft, support ships, and communications.
d. This may include unintentional radiating sources produced by electronic components that are not intended to be transmitters.

The compatibility test may be broken up into prelaunch operations, captive carry and flight.

5.5 Special Tests

Special tests are those deemed by the ranges as necessary to prove a unique performance specification. The need for special tests will be determined by Range Safety on a case-by-case basis.

5.6 Post Mission Data Analysis

The requirements in this section are for post-mission data submittals and analysis.

5.6.1 The Range User shall review all in-flight telemetry to validate all FTS parameters met their performance requirements.

1. Analysis shall be submitted to Range Safety within 60 days of the end of the mission.
2. Data includes FTS health, FTR commands and environmental data.

5.6.2 Any in-flight failure/anomaly occurring in an FTS or any identical component shall be reported immediately to Range Safety. FTS approvals for any subsequent flights are automatically revoked until a detailed written report containing a description and analysis of the anomaly and corrective action taken is submitted to and approved by the Range Safety Office. Each of the following constitutes a failure:

a. Any FTS component, subsystem, or system not satisfying performance specifications.
b. Any result indicating an out-of-family condition as compared to prelaunch test data.
c. Any unexpected change in the performance occurring at any time.
d. Any discontinuity or dropout in a measured performance parameter.
e. Any inadvertent output.
f. Environmental data that shows that predicted environment has been exceeded.

1. Any loss or gain in temperature that exceeds the assumptions used to derive pre-flight red lines for battery temperature.
2. Vibration and shock data shall be analyzed to ensure the measured environment is enveloped by the predicted MPE.

5.6.3 <u>Mission failure necessitating FTS action</u>.

a. Range Safety representatives shall be given all required data to determine if the FTS functioned as required. Flight approval for future flights will not be granted until it has been determined that the FTS functioned correctly.

b. In the event of an FTS anomaly or failure, the FTS failure analysis shall identify the cause of the failure, the mechanism of the failure, and isolate the failure to the smallest replaceable item or items and ensure that there are no generic design, workmanship, or process problems with other flight components of similar configuration. Flight approval for future flights will not be granted until corrective actions have been implemented and approved by Range Safety.

c. The final safety investigation report shall be provided to Range Safety.

The final safety investigation report shall be provided to Range Safety within 30 days of its completion.

CHAPTER 6

FTS GROUND SUPPORT AND MONITORING EQUIPMENT DESIGN REQUIREMENTS

6.1 General

Ground support equipment (GSE) referenced in this section includes, but is not limited to, the FTS console, other blockhouse consoles, antenna couplers (hats), and RF sensitivity and insertion loss test equipment.

6.1.1 Design.

a. Design requirements for ground support and test equipment used to perform mandatory range prelaunch tests shall be reviewed and approved by Range Safety.

b. All FTS ground support and test equipment shall be designed to meet industry safety requirements such as those defined in American National Standards Institute (ANSI), Occupational Safety and Health Act Administration (OSHA), National Fire Protection Association (NFPA), and other applicable standards.

6.1.2 GSE Maintenance.

a. All GSE used for checkout and monitoring of the FTS shall be verified on a periodic basis.

b. The verification pass/fail criteria and frequency of verification shall be documented in a formal procedure.

6.1.3 Test Equipment Calibration.

a. All test equipment used for testing and monitoring of the FTS shall be periodically calibrated by a laboratory whose standards are traceable to the National Institute of Standards and Technology.

b. All test equipment shall bear evidence of current calibration when in use.

6.2 Ordnance Initiator Simulator

6.2.1 An ordnance initiator simulator shall be provided for all command, fail-safe and automatic destruct system tests, dress rehearsals, countdown demonstration tests, or similar tests including range prelaunch tests. The ordnance initiator simulator shall:

a. Have electrical and/or optical operational characteristics matching those of the actual ordnance initiator.

b. Monitor the firing circuit output current, voltage, or energy, and indicate whether the operating current, voltage, or energy for the initiating device is outputted from the firing circuit.

The indication that the output occurred shall remain after the output is removed.

c. Have the ability to remain connected throughout ground processing until the electrical connection of the actual initiators is accomplished.

d. Include a capability that permits the issuance of termination commands by test equipment only if the simulator is installed and connected to the firing lines.

e. For any low voltage initiator, provide a stray current monitoring device in the firing line. The stray current monitoring device, such as a fuse or automatic recording system, shall be capable of indicating a minimum of 1/10 of the maximum no-fire current.

This stray current monitoring device shall be installed in the firing line.

6.2.2 An analysis shall be provided to demonstrate compliance.

6.3 Laser Test Equipment

6.3.1 All laser test equipment that has the capability to fire the LID directly or indirectly shall be assessed and approved by Range Safety.

6.3.2 Laser test equipment shall be designed to meet the following criteria:

a. The energy level shall be 20 dB below the no-fire level of the LID. A single point failure shall not preclude this requirement from being met.
b. The energy level shall be 10 dB below the no-fire level of the LID for a dual piece part failure.
c. The test source shall emit a different wavelength than the firing unit laser.

6.4 Range Safety Console (RSC)

Key points regarding the RCC are:

a. The RSC is located in the launch control center (blockhouse).
b. The RSC displays the status of the FTS and vehicle-peculiar functions critical to flight safety during prelaunch and up to lift-off.
c. The RSC provides control capability to operate the FTS.
d. Combining multiple measurements into a single measurement requires specific Range Safety approval.

6.4.1 The RSC design shall be developed and submitted to Range Safety for review and approval.

6.4.2 There shall be no single point failure components in the GSE or firing room systems that could cause the loss of a safety critical system monitor (as determined by Range Safety) at the RSC.

6.4.3 The RSC design shall take human factors engineering into consideration.

The RSC shall comply with the requirements in MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, or equivalent.

6.4.4 When applicable, the following vehicle FTS status shall be provided continuously to the RSC during prelaunch and up to lift-off:

Range Safety may require FTS status during flight.

a. Signal strength telemetry output voltage for each FTR.
b. Monitors for all command outputs for each electronic component.

All FTR command and tones shall be monitored.

c. Status of all arming devices and all inhibits.
   (1) Optical Interrupter Devices. Barrier position (safe/arm), barrier locked/unlocked, and electrical power status of the main laser.
   (2) Ordnance Interrupter Devices. Safe and Arm.
   (3) Electromechanical S&A Devices. Safe and Arm.
   (4) High Energy Firing Unit. Trigger capacitor voltage, high-voltage capacitor voltage, arm and fire input, inhibit input and power.
   (5) Laser Firing Unit.

The exact circuits to be monitored shall be determined by Range Safety.

   (6) Other electronic arming devices or inhibits.

The exact circuits to be monitored shall be determined by Range Safety.

d. Battery status.
   (1) Voltages of each FTS airborne battery and ground power supplies.
   (2) Battery temperature of each FTS airborne battery.
   (3) Current of each FTS airborne battery and ground power supplies.
   (4) Provisions for monitoring battery life, operating time, or other means of monitoring energy remaining for flight.
e. Proper functioning of ordnance initiator simulators.

f. FTS power source status (on/off and airborne/ground).
g. Monitors for vehicle-peculiar functions critical to flight safety and other vehicle peculiar functions critical to FTS as identified by Range Safety.
h. Status of the range command transmitter carrier (on/off).

6.4.5 The RSC shall provide FTS control capability of critical FTS functions. These functions will be determined during the tailoring process.

At a minimum, the following controls shall be provided:
a. Power source selection
b. Safing and Arming the FTS
c. Squib-activated battery activation
d. Battery charging
e. BIT testing

6.4.6 Electronic displays shall provide an indicator that the screen is receiving new data updates and has not "locked up".

6.4.7 The RSC will be under the control of Range Safety personnel. The RSC controls may include a key (if applicable) or safety interlocks.

6.5 Ground Support Equipment (GSE) Provided by the Range User

6.5.1 FTRs. The Range User may be required to provide flight-configured FTRs for compatibility testing and troubleshooting. The requirement to provide an FTR and the number of units shall be determined during the tailoring process.

The FTR may be a fully functioning qualification unit.

6.5.2 Test Sets. The Range User shall provide test sets or provide the range with funding to develop certification test equipment for any FTS component. Specific requirements for test sets will be developed during the tailoring process.

Range Safety will determine on a case-by-case basis whether test sets will be delivered to the Range.

CHAPTER 7

FLIGHT TERMINATION SYSTEM ANALYSIS

7.1 General

A summary of all analyses shall be included in the FTSR. Detailed analyses shall be submitted separately. (See Chapter 8 of this volume.)

7.2 System Reliability

The FTS shall undergo an analysis that demonstrates the predicted reliability of the system. The predicted design reliability shall be a minimum of 0.999 at the 95 percent confidence level.

1. The mission time used in the reliability predictions includes a minimum of 150 percent of the predicted flight time verified by analysis in accordance with the Parts Stress Analysis of MIL-HDBK-217E, Reliability Prediction of Electronic Equipment, using the applicable environmental factor.
2. A reliability analysis shall be performed in accordance with the requirements in MIL-STD-785, Reliability Program for System and Equipment Development and Production, to demonstrate the reliability goal was used in the concept and detailed design of the components and/or system.
3. The FTS reliability shall include effects of storage, transportation, handling, and maintenance.

7.3 Single Point Failure

An FTS shall undergo an analysis that demonstrates that the system satisfies the fault tolerance requirement. Each analysis shall:

a. Follow a standard industry methodology such as a fault tree analysis or a failure modes effects and criticality analysis.
b. Identify all possible failure modes and undesired events, their probability of occurrence, and their effects on system performance.
c. Identify single point failure modes.
d. Identify functions, including redundancy, that are not or cannot be tested.
e. Account for any potential system failures due to hardware, software, test equipment, or procedural or human errors.
f. Account for any single point failure on another system that could disable an FTS.

7.4 Fratricide

An FTS shall undergo an analysis that demonstrates that the flight termination of any stage, at any time during flight, does not sever interconnecting FTS circuitry or ordnance to other stages until flight termination on all the other stages has been initiated.

7.5 Bent Pin

Each FTS component shall undergo an analysis that demonstrates that any single short circuit occurring as a result of a bent electrical connection pin does not result in inadvertent system activation or inhibiting the proper operation of the system.

Bent pin analysis shall include pin-to-pin and pin-to-case.

7.6 Radio Frequency (RF) Link

7.6.1 RF link analyses shall be performed to demonstrate:

a. A 12 dB margin over 95 percent of the antenna radiation pattern using a nominal trajectory.
b. A 12 dB margin using actual antenna patterns for a nominal trajectory.

7.6.2 When demonstrating the 12 dB margin, each link analysis shall account for the following nominal system performance and attenuation factors:

a. Path losses due to plume or flame attenuation.

Plume attenuation for solid rocket motors shall be a minimum of 20 dB within a 20 degree aspect angle when referenced from the back of the vehicle

b. Free space loss throughout the vehicle trajectory.
c. Ground system and airborne system RF characteristics.
d. Polarization losses.

7.7 Sneak Circuit

With all components functioning nominally, the analysis shall demonstrate that there are no latent paths that could cause an undesired event or inhibited function.

7.8 Software and Firmware

Any computing system, software, or firmware that performs a software safety critical function shall undergo the analysis needed to ensure reliable operation in accordance with the requirement in Attachment 1 of this document.

7.9 Battery Capacity

An analysis shall be performed to demonstrate that each FTS battery meets the performance requirements of Chapter 3.

7.10 Component Maximum Predicted Environment (MPE)

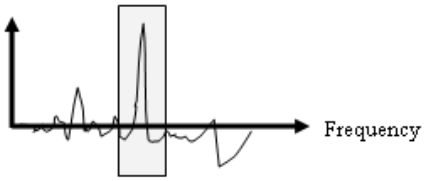
An analysis shall be performed to determine FTS component MPE such as shock, thermal, and vibration. The assumptions, derivation technique, supporting data and final environment shall be submitted to Range Safety for review and approval.

The analytical approach may use flight data from previous missions, flight data from similar vehicles, analysis, computer modeling, and subsystem testing such as bracket and truss vibration testing.

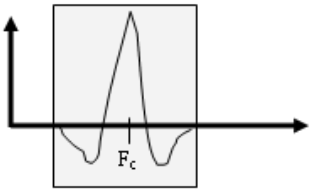
Measured vibration data may contain narrow-band levels. These narrow-band peaks can be reduced using the following technique.

Narrow-Band Vibration Peak Clipping Procedures

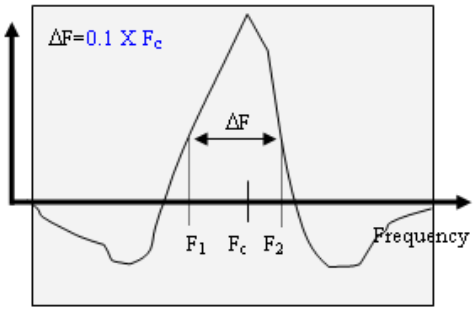
STEP 1: Identify peak to be clipped



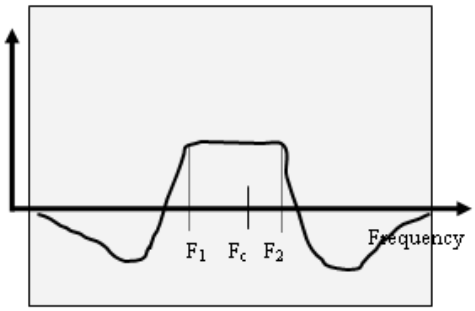
STEP 2: Locate center frequency of the peak and multiply it by 10% (0.10X F_c)



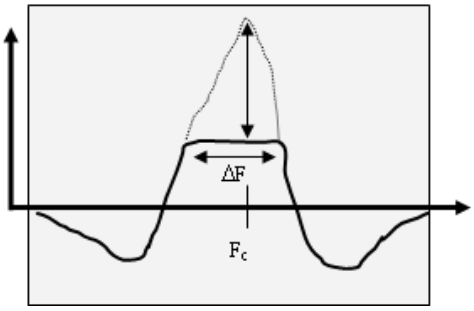
STEP 3: Determine the value on the curve where the width (bandwidth) is equal to 0.10 X F_c



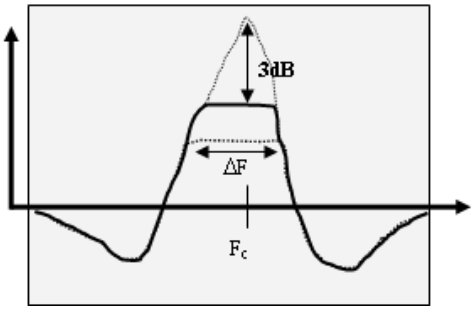
STEP 4: Clip the curve at the 0.10 X F_c bandwidth level



STEP 5: Determine the amount of the peak clipping by measuring the amplitude to the clipped level. If it is greater than 3 dB proceed to Step 6. If not, this becomes the final value.



STEP 6: The final reduction of the peak is the lesser of the peak clipped curve in Step 4 or a 3 dB reduction from the peak. **Note:** A curve can be clipped no more 3 dB.



7.11 Failure Analysis

Any failure/anomaly occurring in an FTS or any identical component shall be submitted to Range Safety for review and approval. A summary of all failure analyses during qualification testing shall be included in the FTSR with all detailed reports submitted separately.

7.12 Qualification by Similarity Analysis

A qualification by similarity analysis shall be submitted to Range Safety for review and approval. A summary of all qualification by similarity analyses shall be included in the FTSR with all detailed reports submitted separately.

7.13 Vehicle Power Analysis

If vehicle-generated power is used to supply any part of the FTS, a vehicle power analysis shall be performed to include:

a. A detailed description of the power-generation system.
b. Generator ratings, rectification, and regulation circuits.
c. Failure modes that could result in overvoltage, undervoltage, or loss of rectification.

7.14 RF Radiation Analysis

An RF radiation analysis shall demonstrate that the system and components meet all performance requirements when subjected to emitting sources on the vehicle and from surrounding environments. A summary of the radiation analysis shall be included with the detailed report submitted separately.

1. This analysis shall be performed by comparing the component level MIL-STD-461 EMI/EMC with the energy delivered by any emitting source to ensure that component were tested to correct levels.
2. Emitting sources include radiated emissions from FTS and other vehicle components.

7.15 FTS Breakup Analysis

A breakup analysis shall be performed to determine the design and location of the FTS components and subsystems to ensure that the FTS functions reliably during a vehicle failure. The breakup analysis shall account for:

a. Aerodynamic loading effects at high angle of attack trajectories during early stages of flight.
b. A hard-over engine nozzle induced tumble during various phases of flight for each stage.
c. Out-of-sequence timing of launch vehicle staging and other events that could damage FTS hardware or inhibit the functionality of FTS components or subsystems.

1. Breakup due to aerodynamic loading effects at high angle of attack trajectories during early stages of flight shall be analyzed at a minimum of 5-second increments.
2. The purpose of the breakup analysis is to determine where and when a vehicle is most likely to break up under the credible failure scenarios. This data is used to ensure FTS components and separation detection systems are properly designed and located to maximize FTS survivability in the analyzed failure scenarios.

7.16 Tip-Off Analysis

For standoff autodestruct systems crossing staging or breakup interfaces, a tip-off analysis shall demonstrate that the destruct charge will hit the target before the stages become misaligned. A summary of the tip-off analysis shall be included with the detailed report submitted separately.

7.17 Automatic Destruct System Timing Analysis

The automatic destruct system (ADS) timing analysis shall calculate the worst case time between ADS triggering and final destruct action. The analysis shall demonstrate that the FTS will function prior to becoming disabled by vehicle breakup. A summary of the ADS timing analysis shall be included in the FTSR with the detailed report submitted separately.

7.18 Ordnance Initiator Simulator Analysis

The analysis shall demonstrate that the simulator input current, impedance, voltage, optical power or energy simulates the flight ordnance characteristics. A summary of the analysis shall be included in the FTSR with the detailed report submitted separately.

7.19 In-Flight FTS Analysis

An analysis shall be performed to demonstrate that the FTS met all applicable performance requirements during flight. An analysis shall be provided for review and approval for any in-flight anomaly or when termination action is taken. Range Safety representatives shall participate in the investigation and be given sufficient notice to support all activities.

7.20 FTS LID Heat Dissipation Analysis

An analysis shall be performed to demonstrate that the LIDs dissipate heat faster than single failure conditions can input into the device without initiating or dudding.

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CHAPTER 8

DOCUMENTATION

8.1 General

This chapter defines the documentation requirements for Range Users requesting FTS approval. This documentation and data allow an independent technical review of the FTS design by the appropriate Range Safety personnel.

8.1.1 FTS Component Test History.

a. A test history shall be maintained for each FTS component.

b. The test history shall be made available to Range Safety upon request.

c. The history for each component shall include the following information:
   (1) Component part, serial and lot number.
   (2) Date of initial manufacture.
   (3) Date of acceptance or lot acceptance test.
   (4) Date of modification with brief description of the modification.
   (5) Reuse or captive carry time log.
   (6) Bench test or other prelaunch test data.
   (7) Shelf life expiration and any subsequent age surveillance extension data.
   (8) Storage conditions for thermally sensitive components
   (9) Retest data and reason for retest.
   (10) Any failures and corrective action.
   (11) Additional items shall be added on a case-by-case basis during the tailoring process.

8.1.2 Failure Reports. Failure reports shall be submitted for review and approval in accordance with the required timelines. A summary of qualification test failures shall be included in the FTS Report (FTSR).

8.2 Flight Termination System Report (FTSR)

An FTSR shall be developed by the Range User and submitted to the ranges for review and approval. The FTSR is the medium through which FTS approval is obtained from the ranges. The FTSR contains a detailed description of the FTS, tailoring summary, system analysis results, design data, reliability data, component design data, ground support systems data, test data, and the FTS telemetry data.

8.3 FTSR Submittal Process

One hard copy and an electronic copy of the FTSR shall be submitted to each applicable Range Safety Office.

1. Copies of the initial or updated FTSR shall be submitted to the ranges for review 45 days before each of the design reviews specified in the following paragraphs.
2. The Range User may be required to provide software to Range Safety if the FTSR or supporting data uses a non-standard software package.

8.3.1 Initial and Updates. A draft FTSR may be submitted to facilitate an expedited review. As the design progresses, the FTSR shall be updated to contain the latest information on the FTS.

a. Preliminary Design Review (PDR). A detailed presentation to the ranges of the FTS design details, identifying major components and operational concepts, shall be held before the beginning of engineering fabrication.

The initial FTSR should be provided at least 45 days before the start of the PDR.

b. Critical Design Review (CDR). A review of the design, design drawings, and documentation as delivered. The FTS shall be under configuration control following approval of the CDR design. Any changes thereafter require Range Safety approval.

The updated FTSR shall be provided at least 45 days before the start of the CDR.

c. Final Submittal. The final submittal must be early enough to allow Range Safety to review and approve all data to support the launch schedule.

The final FTSR shall be submitted to the ranges for review and approval no later than 4 months before the first scheduled launch.

8.4 Final Approval

Formal acceptance of the FTS by the Range Safety Office shall be transmitted by letter after approval of the final FTSR and appendices. Unauthorized changes to the design shall result in automatic revocation of the approval. Changes shall be reviewed for approval on a case-by-case basis by the appropriate Range Safety Office.

8.5 FTSR Format

Any Range User format is acceptable provided that all required data is included. Data submittals (e.g. procedures, specifications, manuals, and computer storage media) that cannot be included in the FTSR because of their size or configuration shall be referenced in the applicable section and submitted as attachments. All data submittals, including schematics, functional diagrams, and operational manuals, shall use industry standard terminology. These standards include Institute of Electrical and Electronics Engineers (IEEE) and Military Specification terminology and symbols. This data package shall contain (as a minimum) the following information:

The Range User shall provide detailed drawings, schematics, and wiring diagrams of the FTS as a system. These shall fully describe all plug and jack designations, all pin assignments and all FTS-to-telemetry or other vehicle component interfaces. Additionally, all components shall be identified by component number and value such that a circuit analysis can be performed.

a. Table of Contents and Glossary. The FTSR shall have a table of contents and a glossary.
b. Introduction. The introduction shall address the scope and purpose of the FTSR.
c. FTS General System Description. The general system description section shall present a brief description of the launch vehicle and the FTS. The following items shall be included in this section:
   (1) Vehicle Description. A brief and general description of the launch vehicle.
   (2) FTS Description. A brief and general description of the FTS, including a block diagram showing the location of all FTS components on the vehicle and the interfaces with other systems.
   (3) FTS Cable Diagram. A cable diagram of the FTS from the antennas to the termination device.
   (4) Overall FTS Schematic. A complete line schematic of the entire FTS from antenna to the destruct charge, including telemetry pick-off points and ground (umbilical) interfaces.

Schematics shall be legible and use font size of at least 8 point.

8.5.1 FTS Detailed Component and System Descriptions. The detailed system description section includes a complete and detailed narrative description of all of the major components of the FTS. The Narrative Description shall include the following items:

a. A complete and detailed description of the FTS operation including all possible scenarios and discussion of how FTS components function at the system and piece-part level.
b. A complete and detailed description of each FTS component and how it functions, including specifications and schematics, mechanical and piece-part specifications, and operating parameters.

c. Detailed schematics and drawings to include:
   (1) Detailed schematics of the complete FTS showing component values such as resistance, capacitance, and wattage, tolerance, shields, grounds, connectors and pin numbers, and telemetry pick-off points.

The entire FTS shall be depicted in not more than three sheets: size C, D, or E. All schematics, functional diagrams, and operational manuals shall have well defined, standard, IEEE, or Mil-Spec terminology and symbols.

   (2) The schematics shall include all vehicle components and elements that interface with or share common use with the FTS.
   (3) All pin assignments shall be accounted for.

d. Drawings showing the location of all FTS system and subsystem components on the vehicle, shall include the following descriptions:
   (1) Descriptions of component locations, mounting (attach points), orientation and cable routing.
   (2) Descriptions of electrical connectors and connections, and the electrical isolation of the FTS.
   (3) An illustrated parts breakdown of all mechanically operated FTS components.

8.5.2 FTS Analysis Results. A summary of the applicable results of the analyses required in Chapter 7 shall be included. The detailed analyses shall be submitted separately.

8.5.3 FTS Ordnance Classification. The ordnance classifications for each ordnance device in accordance with the DOT, DoD, or UN. Supporting documentation shall be included in this section.

8.5.4 FTS Development, Qualification, Acceptance, Age Surveillance, and Reuse Test Plans, Procedures, and Reports. The following data shall be included in the body of the FTSR:

a. A list of test plans, procedures, and reports by title, number, and revision date.
b. The maximum predicted flight loads for all anticipated environmental forces such as shock, vibration, and thermal for each FTS component, subsystem, and system.
c. A matrix of the actual qualification and acceptance test levels used for each component, subsystem, and system in each test versus the predicted flight levels for each environment. The test tolerance allowed for each operational qualification test shall be included.
d. A clear identification of those components qualified by similarity analysis or a combination of analysis and test.
e. A summary of each applicable test report: The actual test report shall be submitted as a stand-alone document.

8.5.5 Software and Firmware Independent Verifications and Validations. A summary of software and firmware independent verification and validation shall be included.

8.5.6 FTS Modifications. All modifications to an approved FTS, its associated equipment, component identification, test procedures, or any changes affecting the configuration and integrity of the FTS shall be included.

8.5.7 FTS Ground Support and Monitoring Equipment. The ground support and monitoring equipment section shall include a complete description of the ground test equipment used to checkout the FTS including contractor-peculiar tests. This section shall also include specifications, system schematics, and component schematics for program unique test equipment for the following:

a. Ordnance initiator simulator.
b. RF ground support system.
c. RF repeater system.
d. Safety console layout, display arrangement, and function of each monitor.
e. Safety console terminations including the following:
   (1) Schematics of all FTS monitor circuits from the FTS component pick-off points to the console termination.
   (2) Calibration data for all monitor circuit terminations provided to the console.
f. Any other ground support and monitoring equipment as required by Range Safety.

8.5.8 FTS Installation and Checkout. The installation and checkout section shall include the following information:

a. A list of procedures for checkout, calibration, and installation of all components, systems, and subsystems of the FTS and its associated ground checkout equipment, including launch-day countdown.
b. A summary of each task, objective, test configuration, test equipment and a time sequence flow chart.

8.5.9 Exception to Requirements. The section shall include all waivers and conditionally compliant requirements.

8.5.10 Changes to the FTSR. The change section shall include a summary of all changes to the last version of the FTSR. All changes shall be highlighted using change bars or similar means of identification.

8.6 Telemetry Measurement

This section provides a list of all FTS telemetry measurements. For each measurement, this section includes the following minimum information:

a. Description of each parameter.
b. Telemetry measurement ID.
c. Sample rate.
d. Minimum and full-scale level.
e. Resolution.
f. Engineering units and scaling factors.
g. Analog or digital.

8.7 FTSR Appendixes

FTS development, qualification, and age surveillance test reports shall be included as stand-alone appendixes.

REFERENCES

a. National Security Decision Directive (NSDD) No. 298, National Operations Security Program.

b. Joint Publication (JP) 3-54, Joint Doctrine for Operations Security.

c. Air Force Instruction (AFI) 33-129 (AFI 33-129), Web Management and Internet Use

d. Air Force Instruction (AFI) 33-219, Telecommunications Monitoring and Assessment Program (TMAP)

e. DoD Instruction (DoDI) 2000.16 Red Teaming Requirement.

f. Air Force Instruction (AFI) 10-701, Operations Security (OPSEC) http://www.dtic.mil/mctl/MCTL.html), The Militarily Critical Technologies List (MCTL).

g. DoD Directive (DODD) 5205.2, DoD Operations Security (OPSEC) Program.

h. DoD Directive (DODD) 5100.20, The National Security Agency and the Central Security Service

i. DoD Directive (DODD) 5200.39, Security, Intelligence, and Counterintelligence Support to Acquisition Program Protection.

j. CJCSI 3213.01B, Joint Operations Security.

k. DoD Directive (DODD) 3600.1, Information Operations.

l. DoD 5230.9, Clearance of DoD Information for Public Release.

m. DoD Directive (DODD) 8500.1, Information Assurance.

n. DoD Instruction (DODI) 5000.2, Operation of the Defense Acquisition System.

o. DoD Directive (DODD) 5200.1-R, DoD Information Security Program.

p. DoD Directive (DODD) 5200.39, Security, Intelligence, and Counterintelligence Support to Acquisition Program Protection.

q. DoD Directive (DODD) 5205.2, DoD Operations Security (OPSEC) Program.

r. Air Force Doctrine Document (AFDD) 2-5, Information Operations.

s. Air Force Policy Directive (AFPD) 10-7, Information Warfare.

t. Air Force Policy Directive (AFPD) 90-2, Inspector General -- The Inspection System.

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APPENDIX A

SOFTWARE/FIRMWARE INDEPENDENT VERIFICATION AND VALIDATION

1.1 Independent Verification and Validation Analysis Support

The independent verification and validation (IV&V) effort shall be performed by an independent department not reporting to the same first-level supervisor. The IV&V process is applied to ensure an extremely high level of confidence. This work shall consist of the following steps:

1.1.1 Requirements. The IV&V process starts during the definition phase by using an independent group to verify requirements, evaluate specifications for completeness, accuracy, traceability, and testability.

1.1.2 Design and Development. Once the requirements have been defined, support design and development activities to ensure the system meets all performance requirements.

1.1.3 Operational Evaluation and Test. After the system development is complete, review program testing for completeness. Develop and conduct IV&V to identify any special tests required to verify any potential failure modes identified in the design and coding failure analysis.

1.2 Requirements

1.2.1 During the definition phase, an independent group shall verify requirements, evaluate specifications for completeness, accuracy, traceability, and testability.

1.2.2 Systems include all software, firmware and hardware interfaces necessary to ensure public and property safety during operational missions.

1.2.3 Ensure that compliance to requirements can be validated through Test and Evaluation.

1.2.4 IV&V may also include special studies or analyses of operational launch anomalies or failures attributed to operational and range systems.

1.3 Design and Development

1.3.1 Analyze the detailed hardware/software design in the systems design documentation to determine if it meets system performance requirements including reliability, single fault tolerance, timing and sizing.

1.3.2 Evaluate the equations and algorithms of the systems design documents to ensure that they are correct and satisfy the requirements of the Range User. Code testing for nominal and non-nominal conditions is required during the development phase.

1.3.3 Analyze the detailed design specified in the system design documents for correlation to the software and hardware requirements of the system requirements' documents.

1.3.4 Analyze selected source code to verify that the validated software design is correctly implemented in the code, during the development process. Equations shall be generated and their structuring determined. Equations and code structuring shall be compared to those in the system design documents and analyzed to determine if code meets or exceeds system requirements.

1.3.5 Validate software-to-software interfaces between critical software configuration items (CSCIs), software-to-hardware interfaces between CSCIs and hardware configuration items (HWCIs), and hardware-to-hardware interfaces between HWCIs have been correctly implemented.

1.3.6 Monitor the detailed hardware/software development to determine if it meets system performance requirements including reliability, single fault tolerance, timing and sizing.

1.3.7 Monitor the detailed development for correlation to the software and hardware requirements of the system requirements documents.

1.4 Operational Evaluation and Test

1.4.1 Review and analyze development contractor test programs to validate that they demonstrate that the system complies with all requirements. Support the test team by reviewing the developing contractor test plans and procedures and assessing applicability for meeting requirements. The IV&V contractor shall recommend testing to cover areas where additional testing is needed.

1.4.2 Develop a program to evaluate selected system Configuration Items (HWCI/CSCIs). Firmware and software shall be checked to confirm that the algorithms and logic are correctly implemented. Stress evaluation shall be conducted to ensure that the system functions as specified and that no undesirable characteristics exist or have the potential to develop, that will lead to delaying test programs for weapon systems, or that will result in the destruction of life or property.

1.4.3 Evaluate the accuracy of the algorithms using independently coded versions when numerical accuracy or rate of convergence is in question.

1.4.4 Conduct stress evaluation to ensure that the system functions as specified and that no undesirable characteristics exist or have the potential to develop, that will lead to delaying test programs for weapon systems, or that will result in the destruction of life or property.

1.4.5 Model and simulate selected hardware, software, firmware and interfaces to demonstrate compliance to system requirements.

1.4.6 Evaluate the testing for each system, subsystem component, and interfaces for performance of those functions necessary to satisfy requirements. Compare the performance of the new system to the performance of the existing system being replaced and identify any

differences. Verify that tests at the system level are conducted so as to require the use of every subsystem, as well as evaluation of any abnormal characteristics noted in subsystem component testing or identified in the analysis as a possible source of failure or substandard performance.

1.4.7 Verify that the system demonstrates operability and reliability associated with man-machine interfaces. Identify functions, physical conditions and inadvertent human actions that could render a system inoperable or result in undesirable outcomes.

1.4.8 Witness testing and identify any deviation from the test procedure documents.

1.5 Reporting Anomalies

Report all anomalies throughout the development and operational implementation process as follows:

a. Report hardware/software single points of failures that inhibit the system to function as designed.
b. Report configuration item anomalies assessed during test and evaluation of test articles that are not representative of the final delivered configuration.
c. Identify and track open, close, and unverifiable anomalies.
d. Open items shall include pending resolutions, date opened and expected closure dates.
e. Verify that all closed issues are documented with supporting rationale, including mitigating factors for anomalies the Government has accepted the risk.
f. Archive and maintain all closed or unverifiable anomalies within the database.
g. Anomaly Classification. Anomalies shall be categorized by severity and probability. Tables A-1 and A-2 shall be used when categorizing new and reevaluating anomalies.
h. Design/Development Anomalies: Report all anomalies found during IV&V supported design and evaluation activities, and report on the status of anomalies pending resolution. The IV&V contractor shall report configuration item anomalies assessed during test and evaluation of test articles that are not representative of the final delivered configuration. To complete the IV&V process, verify that all anomalies have been resolved. The contractor shall archive and maintain all generated anomaly reports in a configuration-controlled database.
i. Anomaly Resolution: Anomaly closure shall be approved through Range Safety. The rationale for closing an anomaly is analysis, investigation, validation, demonstration, or inspection and shall be presented to Range Safety within 30 working days of need date. Unverifiable failures that cannot be tracked to a specific piece of hardware or software shall be documented as such. Unverifiable failures shall document any analysis done, special testing performed, configuration of the system at the time of the failure, or any other applicable information for the future.

1.6 Reviews

Conduct design reviews and test readiness reviews for IV&V processes, criteria and tools. The IV&V contractor shall participate in technical interchange and program management meetings as required with the development contractor/organizations. This shall include, but not limited to, the weekly design reviews, Technical Interchange Meetings, and test readiness reviews. The contractor shall provide briefings and written reports as required to support the certification process.

TABLE A-1. PROBLEM SEVERITY CATEGORIES

Category	Safety and Health Results Criteria
Cat I – Catastrophic	• Loss of mission. • Loss of life. • Failure to send ordered critical command(s) from command and control systems. • An inadvertent Command Terminate Signal sent from the range command and control systems. • Prevents detection of a violation of flight termination criteria. • Failure to detect equipment malfunctions or status of any above Cat I item.
Cat II – Critical	• Major degradation of mission capability. • Severe injury, major property damage, or major system damage. • Erroneous real-time inputs to Range Safety and launch software from telemetry, metrics, command & control, and meteorology sources. • Erroneous real-time processing or display error(s) to Range Safety and launch software from telemetry, metrics, command & control, and meteorology sources. • Negates the ability to determine vehicle performance. • Failure to detect equipment malfunctions or status of any of the above Cat II items.
Cat III – Marginal	• Minor injury, minor property damage, or minor system damage. • Failure degrades Next Higher Assembly from performing its function, but no loss in mission due to equipment redundancy. • Delay requiring launch rescheduling and cost impacts. • Costly processing inefficiency or performance degradation. • Improper equipment startup, operation, or shutdown. • Long responses to timeshare inputs or late delivery of data to Range Users. • Failure to detect equipment malfunctions or status of any of the above Cat III items.
Cat IV - Negligible	• No injury. • No property, system, or equipment damage. • Data-recording format errors requiring operator attention to correct. • Operator developed work-around. • Administrative inconvenience.

TABLE A-2: PROBLEM PROBABILITY CATEGORIES	
Description	**Life of Program**
Level A - Frequent	Likely to occur often in the life of the System, with a probability of occurrence greater that 10^{-1} (Will occur continuously).
Level B - Probable	Will occur several times in the life of the System, with a probability of occurrence less than 10^{-1} but greater that 10^{-2} (Will occur frequently).
Level C - Occasional	Likely to occur a few times in the life of the System, with a probability of occurrence less than 10^{-2} but greater that 10^{-3} (Will occur several time in the life of the program).
Level D – Remote	Unlikely to occur in the life of the System, with a probability of occurrence less than 10^{-3} but greater that 10^{-6}. (Not expected, but still possible)
Level E - Improbable	So unlikely, it can be assumed occurrence may not be experienced with a probability of occurrence less than 10^{-6} in the life of the system.

1.7 Configuration Audit

The IV&V contractor shall assess configuration control of test and evaluation configuration items to assure test articles are representative of the final delivered configuration. The contractor shall also participate in the evaluation of Engineering Change Proposals for the Change Control Board. Conduct and/or participate in Functional Configuration Audits and Physical Configuration Audits.

1.8 Reliability Analysis

Analyze selected design reliability and verify that the design meets or exceeds the requirements of the system requirements documents and Range User needs when operated in an environment representative of the actual operating conditions. Analyze the reliability assessments and predictions of the developer for accuracy and completeness. Evaluate Failure Mode, Effects, and Criticality Analysis (FMECA) and single point of failures analyses for the resulting impact on mission success, performance, staff safety, and maintainability.

1.9 Human Factors Analysis

Analyze selected design as determined by the government to verify that the design is user friendly and can be easily operated without ambiguity in controls or operation. Identify and report design human factor deficiencies and recommended improvements.

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APPENDIX B

ELECTRONIC PIECE-PART UPSCREENING REQUIREMENTS

1.1 Piece-Part Program Plan

A Range User shall describe its compliance in its FTS piece-parts program plan. All electronic piece-parts used in an FTS shall successfully undergo derating, qualification, screening, lot acceptance testing, and lot destructive physical analysis in accordance with the Range User piece-parts program plan. Any failure or out of family test results and a description of any corrective actions shall be submitted for review and approval before the part, including any part from the same production lot, is installed in an FTS component. A Range User piece-parts program shall include a monthly review of information disseminated by the Government Industry Data Exchange Program (GIDEP) and shall account for any GIDEP alerts related to the quality and reliability of piece-parts used in an FTS component. GIDEP alert information is available at the GIDEP Internet Web page http://www.gidep.org/.

1.2 U.S. Military-Quality Piece Parts

1.2.1 U.S. military quality piece-parts used in an FTS shall meet the performance, quality, and reliability levels required by the Department of Defense product qualification program as they apply to the following parts and classifications:

a. JANTX, JANTXV, or JANS classes for diodes and transistors.
b. Class B or Class S for microcircuits.
c. Class H or Class K for hybrids.
d. Established reliability level R or S level for passive parts.
e. Established reliability level R for relays.
f. Class B for crystal oscillators or filters.
g. Electronic and RF cables to MIL-C Standard

1.2.2 All internal cavity piece-parts shall undergo PIND testing.

1.2.3 The Defense Supply Center, Columbus (DSCC) Sourcing and Qualification Unit (DSCC-VQ) maintains lists of suppliers of U.S. military-quality parts with the classifications required by paragraph 1.2.1 above. When using U.S. military-quality parts, a Range User shall select parts from a Qualified Manufacturers List (QML) or Qualified Product List (QPL), available at the DSCC-VQ Web page http://www.dscc.dla.mil/offices/sourcing%5Fand%5Fqualification/.

1.3 Custom or Non-Military Piece Parts

1.3.1 All custom or non-military parts used in an FTS shall be subjected to screening tests, lot acceptance testing, qualification testing, and destructive physical analysis to demonstrate equivalence to the military-quality parts. Each piece-part shall successfully undergo testing in accordance with the following:

a. All parts (100 percent) shall be subjected to screening tests to detect any electrical or mechanical workmanship defects and infant mortality failure modes.
b. The mechanical and electrical design of each part shall be qualified through sample qualification testing to confirm the ability of the part to operate without mechanical or electrical degradation. The quality of the manufacturing processes for each part shall be demonstrated through lot acceptance testing of production lot samples to confirm that the manufacturing process produces parts consistent with the qualified design of the part. For qualification and lot acceptance testing, each sample piece-part shall be subjected to mechanical, electrical, and environmental stress tests that demonstrate the part meets its performance specifications. Where applicable, a 1,000-hour life test meets these requirements.
c. As part of the lot acceptance testing, lot samples of each piece-part shall undergo a destructive physical analysis after those samples have been subjected to the environmental stress tests. The destructive physical analysis shall demonstrate that the design, materials, and processes of the part are consistent with its specification and shall detect any internal anomalies and defects that may occur during environmental testing that cannot be detected by other tests. The number of samples from each piece-part production subjected to destructive physical analysis is dependent on the type of component and may vary from two to five samples. A description of any anomaly or defect and any corrective actions shall be submitted for review and approval of the test and before any part from the same production lot is installed in an FTS.

1.3.2 All internal cavity piece-parts shall undergo PIND testing, unless they have external and internal pressure contacts (die to electrical contacts), optical coupled isolators, and double plug diodes. PIND testing shall insure that applicable electronic parts are free of workmanship induced internal debris that could degrade the performance of the part. If a production lot experiences a failure rate greater than 1 percent during PIND testing, additional PIND test runs shall be performed or the entire lot shall be rejected and not used in any FTS. If subsequent PIND test runs are made, the failure rates for each subsequent run shall not increase from any previous run or the entire production lot shall be rejected. If the 1-percent failure criterion is not met within five PIND test runs, the entire production lot shall be rejected. Any device from a production lot that failed PIND testing is not acceptable for use in an FTS and shall be marked accordingly.

1.3.3 Each part shall be derated according to the Range User piece-part program plan approved during the licensing process. The derating criteria of a Range User shall ensure that the variability in electronic parts within a part production lot and the relationship between that variability and the variability of other parts used in the same FTS component shall not result in a

degradation of functional performance of the FTS. The stresses applied to a piece-part during operation in its component circuit shall be below the manufacturer-specified ratings for that piece-part. The specifications that shall be derated for each piece-part include, but need not be limited to voltage, current, power, operating temperature range, and voltage or current over temperature as applicable.

Derating of electionic parts shall be performed in accordance with Appendix C.

1.2.4 All piece-parts shall be separately packaged and identified, including identification of the testing to which they have been subjected. Piece parts to be used for flight shall be subjected to life testing only. Piece parts that have been subjected to destructive testing shall not be used for flight.

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APPENDIX C

ELECTRONIC PIECE-PART DERATING REQUIREMENTS

1.1 Capacitors

1.1.1 Military Specification Capacitor Types.

TABLE C1-1. CAPACITORS, MIL-SPEC LISTING (FOR REFERENCE)

Dielectric Material	Mil-Spec	Style
Ceramic	MIL-C-39014	CKR
Ceramic	MIL-C-20	CCR
Ceramic	MIL-C-123	CKS
Ceramic, High Voltage	MIL-C-20	---
Ceramic Chip	MIL-C-55681	CDR
Mica	MIL-C-87164	CMS
Glass, Porcelain	MIL-C-23269	CYR
Supermetallized Film	MIL-C-83421	CRH
Supermetallized Film (Low Energy Application)	MIL-C-87217	CHS
Plastic Film; Metallized and Nonmetallized	MIL-C-19978	CQR
Tantalum Foil	MIL-C-39006	CLR
Solid Tantalum	MIL-C-39003	CSR
Solid Tantalum, Low Impedance Applications	MIL-C-39003/10	CSS
Solid Tantalum Chip	MIL-C-55365	CWR
Variable, Air, Piston, Type	MIL-C-14409 (1)	P
Variable, Glass or Ceramic	MIL-C-14409 (1)	---
Wet Tantalum-Tantalum	MIL-C-39006/22 (2)	CLR 79

Notes for Table C1-1:

(1) Variable capacitors should only be used where absolutely necessary. Their design is such that they are non-hermetic, easily damaged by excessive installation soldering and have a limited adjustment life.
(2) Only tantalum-tantalum construction (style CLR79) manufactured by a QPL/QML source with a double seal is approved for wet tantalum construction in expendable launch vehicle applications.

1.1.2 General Requirements. The normal maximum operating temperature for all capacitors shall not be greater than shown in the derating curves for the applied stress or 10 °C less than maximum rated temperature, whichever is less. The longevity and reliability of capacitors are increased by operation below their rated temperature limits and below their rated voltage, both AC and DC.

1.1.3 Capacitor Reliability Application Derating Guidelines.

TABLE C1-2. CAPACITOR DERATING (9)

Type	Parameter	Maximum Stress Ratio	Comments
Ceramic	Voltage	0.50 (4)	0.70 WC (5)
Ceramic Chip	Voltage	0.50 (4)	0.70 WC (5)
Feed Through Capacitor	See EMI Filters		
Glass	Voltage	Figure C1-1	
Supermetallized Film CRH	Voltage	0.50 to 85 °C max.	0.65 WC to 85 °C max.
Supermetallized Film, & Nonmetallized Film, CHS, CQR	Voltage	0.50 to 85 °C max.	0.65 WC to 85 °C max. (6)
Mica Voltage	Voltage	Figure C1-2	
Porcelain	Voltage	Figure C1-1	
Tantalum Foil	Voltage	Figure C1-3	(2)
Tantalum Solid	Voltage	Figure C1-4	(1), (7)
Solid Tantalum Chip	Voltage	Figure C1-4 (8)	(1)
Wet Tantalum-Tantalum	Voltage	Figure C1-5	(2)
Variable	Voltage	0.5	0.70 WC (3)

Notes for Table C1-2:

(1) At least 0.1 ohms/volt series resistance or equivalent current limit of 10 amps shall be provided for solid tantalum and tantalum chip capacitors. Parallel tantalum capacitors do not require separate series resistors for each capacitor.
(2) Temperature rise due to ripple current shall not result in an operating temperature exceeding 85 °C.
(3) Use only after PMPCB review and approval.
(4) 0.5 to 85 °C, decreasing to 0.30 at +125 °C.
(5) 0.7 to 85 °C, decreasing to 0.50 at +125 °C.
(6) Linearly decrease voltage to zero at 100 °C.
(7) Special assembly and test procedures are required to ensure that tantalum capacitors are installed in accordance with the correct polarity.
(8) The maximum surge voltage shall not exceed the steady state rated voltage.
(9) Reserved.

1.1.4 Use of Derating Curves (Figure C1-1 through Figure C1-5). To determine the maximum permitted operating voltage from the following figures:

a. Determine the maximum part temperature at the location where the capacitor will be mounted. The maximum temperature is the sum of the part ambient temperature, which is the acceptance test temperature plus the temperature rise from the component baseplate to the part location, and the part operational temperature, which is a function of the applied voltage.
b. Find the maximum temperature on the X-axis, and read the Voltage Stress Ratio upper limit from the Region I curve. The voltage stress ratio is determined by dividing the maximum voltage across the capacitor in its intended circuit application by the manufacturer's maximum voltage rating.
c. Any combination of part temperature and voltage stress ratio that lies in Region I shall be considered approved for that application. Any combination that lies in Region III shall be considered disapproved for the intended application. Combinations falling in Region II shall be identified, analyzed to assure that the part application meets mission requirements, and presented to the PMPCB for approval. Combinations falling 20 percent or less above the Region I curve shall be documented on a PMPCB Action Form and forwarded to the Government PMPCB representatives for approval. Combinations greater than 20 percent above the Region I curve shall require acquisition activity approval.

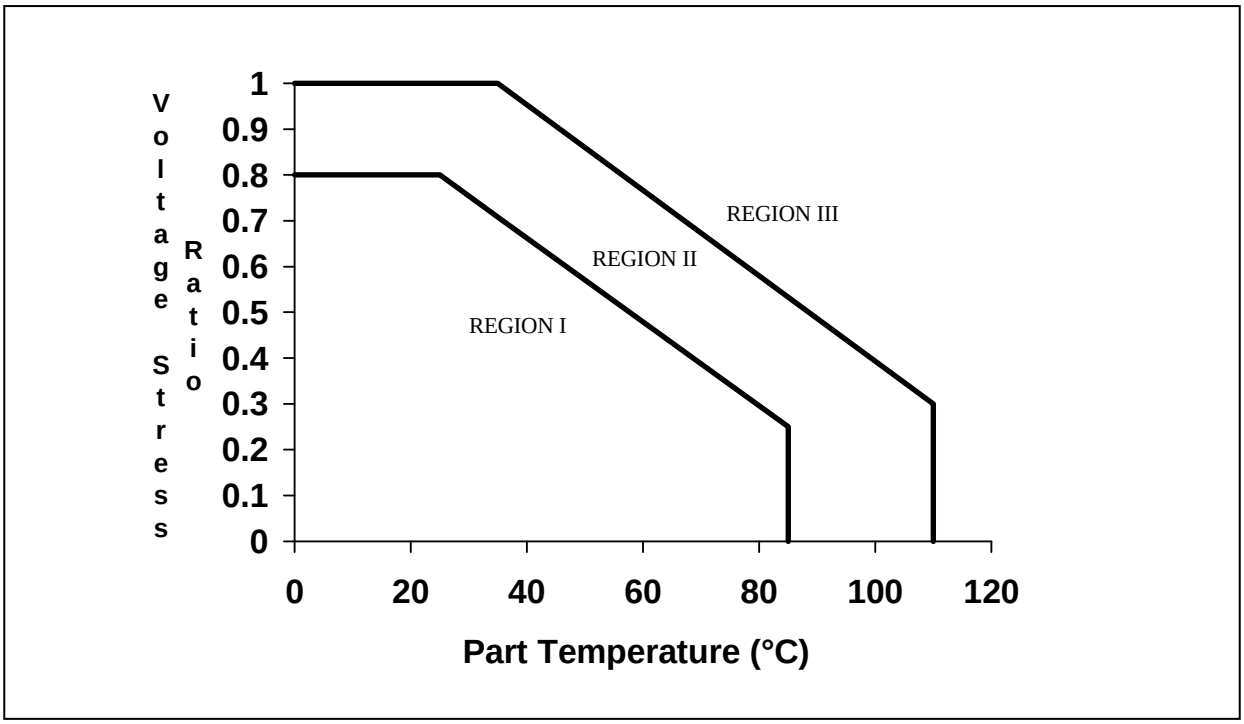

Figure C1-1. Glass, porcelain (CYR)

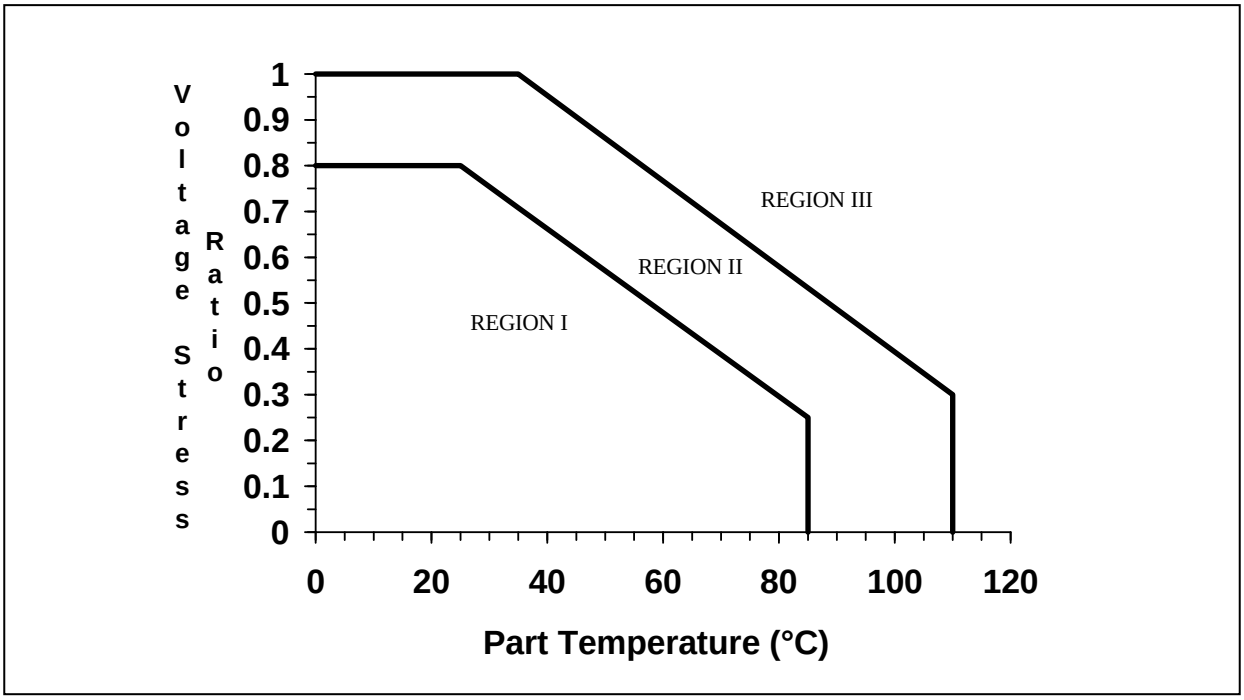

Figure C1-2. Mica (CMS).

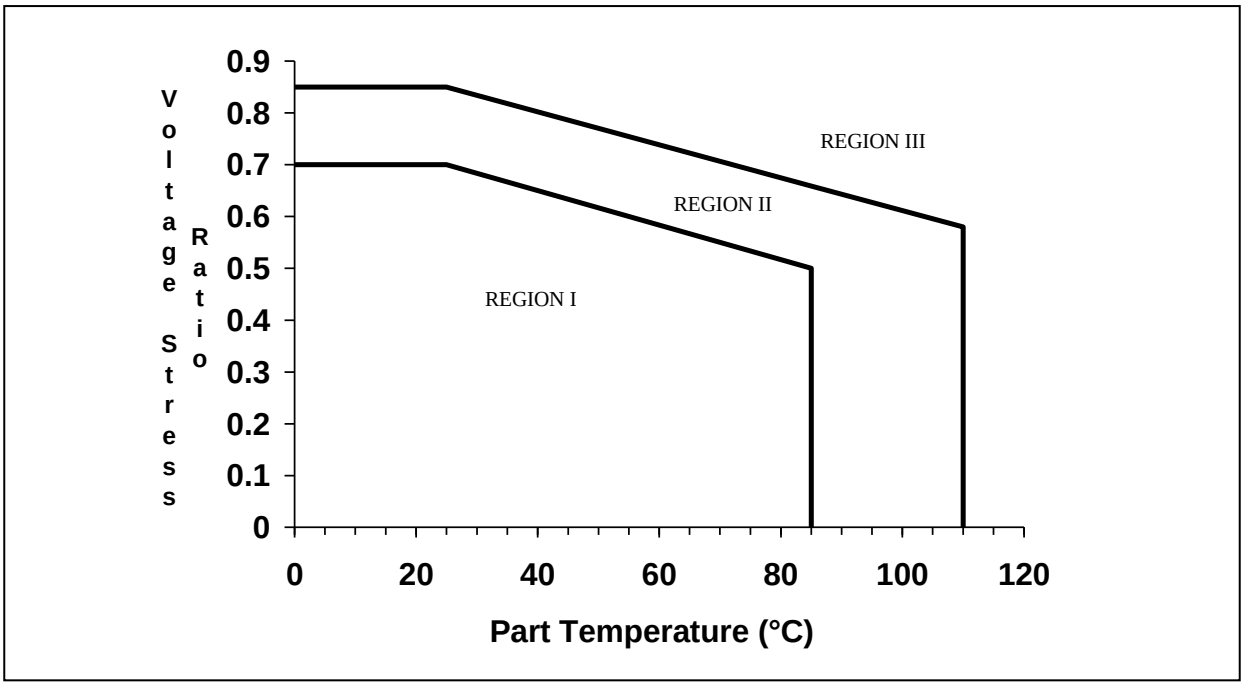

Figure C1-3. Tantalum foil (CLR 25,27,35,37).

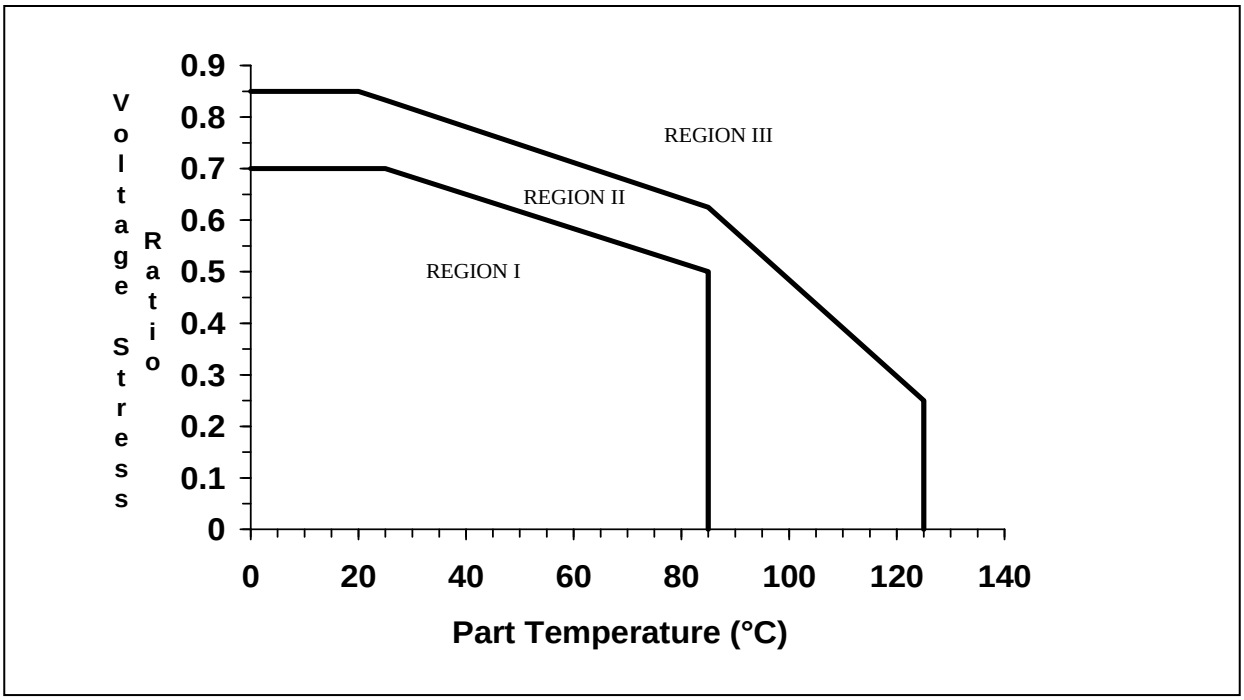

Figure C1-4. Solid Tantalum (CSR, CSS).

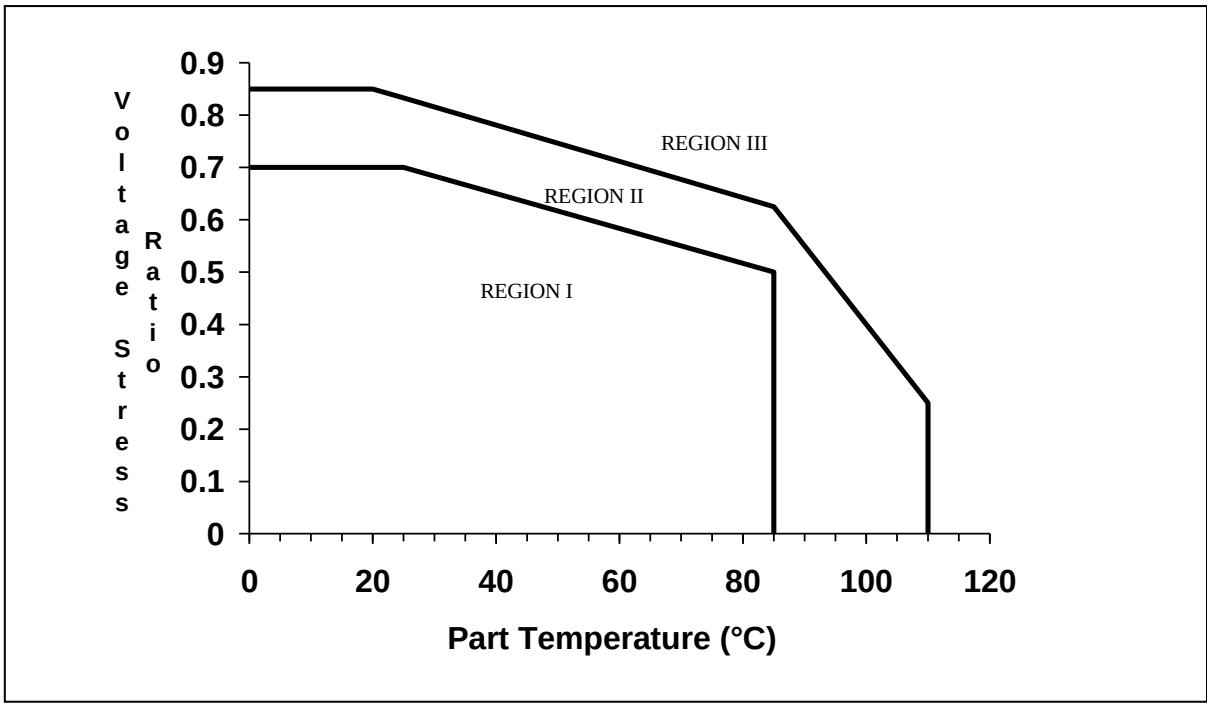

Figure C1-5. Wet Tantalum-Tantulum (CLR 79).

1.2 Connectors

1.2.1 Connectors Reliability Application Derating Guidelines.

TABLE C2-1. CONNECTORS

Type	Parameter	Maximum Stress Ratio	Comments (1), (2), (3)
ALL	Current	0.50 of rating	When pins are connected in parallel to increase current capacity, each pin shall have the capability of conducting (within the derating criteria) 25 percent more current than the calculated equally divided current to compensate for "current hogging".
	Voltage	0.50 of rating	The maximum voltage stress ratio derating should be multiplied by the sea level rated working voltage to obtain the maximum voltage to be applied between the pin and the case. This provides a safe working voltage for high altitude or space applications.
	Temperature	Not to exceed: T(max-dielectric) - 50 °C	The maximum hot spot temperature shall be at least 50 °C below the maximum rated temperature of the connector dielectric material.

Notes for Table C2-1:

(1) Within the constraints of this table, use Table C2-2 as a guide for contact and wire sizes.
(2) For block connectors and crimp connections, the current derating is the same as Table C17-1 for the single wire.
(3) Power connector failure risks should be minimized by requiring that power and return lines be separated by at least one unassigned connector pin to reduce short circuit risk.

TABLE C2-2. CONNECTOR DERATING

Number Of Contacts Used In The Connector	Contact Size	Maximum Derated Current (Amps) For Contact Wire Size (Awg) (1)							Maximum Voltage
		16	18	20	22	24	26	28	
1 to 4	16	13.0	9.2	6.5					50 percent of the rated sea level Dielectric Withstanding Voltage (DWV) between the pin and case for all contact sizes.
1 to 4	20			6.0	4.5	3.3			
1 to 4	22				4.5	3.3	2.5	1.8	
5 to 14	16	9.0	7.0	5.0					
5 to 14	20			5.0	3.5	2.7			
5 to 14	22				3.5	2.7	1.9	1.4	
15 or more	16	6.5	5.0	3.7					
15 or more	20			3.7	2.5	2.0			
15 or more	22				2.5	2.0	1.4	1.0	

Note for Table C2-2:

(1) Connector derating must also comply with the "per pin" derating of Table C2-1.

1.3 Crystals

1.3.1 Crystal Reliability Application Derating Guidelines.

TABLE C3-1. CRYSTALS			
Type	**Parameter**	**Maximum Stress Ratio**	**Comments**
ALL	Current (Drive Level)	0.50	50% drive current equals 25% drive power.

1.4 Diodes

1.4.1 Diode Reliability Application Derating Guidelines.

TABLE C4-1. DIODE (SWITCHING, SMALL SIGNAL, RECTIFIER, AND TRANSIENT SUPPRESSORS)			
Parameter	**Maximum Stress Ratio**		
	Switching, Small Signal	**Rectifier**	**Transient Suppressor**
Power	0.50 (0.70 WC) (2)	0.65 (0.70 WC) (2)	0.75
Voltage, DC or repetitive pulse	0.75 (2)	0.75 (2)	----
Voltage Transients (1)	0.85 (2)	0.85 (2)	0.75
Forward Current	0.50 (2)	0.75 (0.85 WC) (2)	
Surge Current	0.50 (2)	0.75 (0.85 WC) (3)	
Junction temperature	125 °C, or 20 °C less than the manufacturer's rating (4)	125 °C. or 20 °C less than the manufacturer's rating (4)	125 °C, or 20 °C less than the manufacturer's rating (4)

Notes for Table C4-1:

(1) Worst case turn-on or repetitive transient.
(2) Of maximum rating.
(3) Of surge rating.
(4) Whichever is lower.

TABLE C4-2. DIODE (STEP RECOVERY, VARACTOR, AND VARICAP)	
Parameter	**Maximum Stress Ratio**
Power	0.50 (0.70 WC)
Voltage, DC or Repetitive pulse	0.75 (2)
Voltage Transients (1)	0.80 (2)
Forward Current	0.75 (2)
Junction temperature	125 °C, or 20 °C less than the manufacturer's rating (4)

TABLE C4-3. ZENER DIODE (REFERENCE AND REGULATOR)		
Parameter		**Maximum Stress Ratio**
Reference Zener		
	Power	0.50 (0.85 WC) (2)
	Junction Temperature	125 °C, or 20 °C less than the manufacturer's rating (4), (5), (6)
Regulator Zener		
	Power	0.50 (0.75 WC) (2), (6)
	Junction Temperature	125 °C, or 20 °C less than the manufacturer's rating (4), (6)

Notes for Table C4-2 and C4-3:

(1) Worst case turn-on or repetitive transient.
(2) Of maximum rating.
(4) Whichever is lower.
(5) Note that temperature compensated reference diodes must be operated at the manufacturer's specified current to optimize temperature compensation.
(6) The Zener Current shall be limited to no more than IZ = IZ nominal + .05 (IZ maximum - IZ nominal) but do not derate to the point where the device is operating at the knee.

TABLE C4-4. DIODE, SHOTTKY BARRIER	
Parameter	**Maximum Stress Ratio**
Power	0.75 (0.85 WC)
Voltage, DC or repetitive pulse	0.75 (2)
Voltage transients (1)	0.80 (2)
Junction temperature	125 °C, or 20 °C less than the manufacturer's rating (3)

Notes for Table C4-4:

(1) Worst case turn-on or repetitive transient.
(2) Of maximum rating.
(3) Whichever is lower.

TABLE C4-5. DIODE (TUNNEL, GERMANIUM) (1)	
Parameter	**Maximum Stress Ratio**
Power	0.50 (0.70 WC)
Voltage, DC or repetitive pulse	0.70 (2)
Voltage transients	0.80 (2)
Junction temperature	125 °C, or 20 °C less than the manufacturer's rating (3)

Notes for Tables C4-5:

(1) Germanium diodes are not recommended for new or modified designs.
(2) Of maximum rating.
(3) Whichever is lower.

TABLE C4-6. DIODE (PHOTO, LED)	
Parameter	**Maximum Stress Ratio**
Current	0.50 (0.70 WC)
Junction temperature	125 °C, or 20 °C less than the manufacturer's rating (1)

Note for Table C4-6:

(1) Whichever is lower.

1.5 EMI Filters

1.5.1 EMI Filter Reliability Application Derating Guidelines.

TABLE C5-1. EMI FILTERS		
Type	**Parameter**	**Maximum Stress Ratio**
ALL	Voltage	0.50 of rating
	Current	0.75 of rating
	Temperature	Case 85 °C maximum

1.6 Fuses

1.6.1 Fuse Reliability Application Derating Guidelines.

TABLE C6-1. FUSE DERATING

Type	Parameter	Maximum Stress Ratio	Comments (1), (2)
Solid Body	Current	0.75 of rating	Multiply 0.75 by the additional derating of Figure 6-1 to compensate for temperature.
Glass Fuses (1) 1/8 amp (2) 1/4 amp (2) 3/8 amp (2) 1/2 amp (2) 1 amp 2 amp or greater	 Current Current Current Current Current Current	 0.25 of rating 0.30 of rating 0.35 or rating 0.40 of rating 0.45 of rating 0.50 of rating	Manufacturer's current ratings are temperature dependent. Derating factors are based on data from fuses mounted on printed circuit boards and conformally coated. The derating criteria allows for possible loss of pressure that lowers the blow current rating and allows for a decrease of current capability with time.
Fusible resistors	Current	Consult Reliability Engineering	Above 25 °C, the derating factor decreases an additional 0.5 percent for each degree C above 25 °C. In the event a non-standard fuse size is required, use the next highest rated fuse size.

Notes for Table C6-1:

(1) Glass fuses are derated for reliability and to allow for air loss in vacuum.
(2) Shall not be used on new or modified designs without PMPCB approval.

1.7 Inductors and Transformers

1.7.1 Inductor and Transformer Reliability Application Derating Guidelines.

TABLE C7-1. INDUCTORS AND TRANSFORMERS

Type	Parameter	Maximum Stress Ratio	Comments (1), (2), (3)
All	Current	0.50 of rating	(note 2)
	Voltage	0.50 of rating	Inductors: As established , per MIL-C-39010, MIL-T-27, or MIL-T-21038 (as applicable) for Dielectric Withstanding Voltage (DWV), induced voltage and corona voltage. Transformers: As established per MIL-T-27 or MIL-T-21038 for DWV, induced voltage, and corona voltage.
	Temperature (Inductors)	(1), (4)	Classes per MIL-C-39010 or MIL-T-27 as appropriate. (3)
	Temperature (Transformers)	(1), (5)	Classes per MIL-T-27 or MIL-T-21038 as appropriate. (3)

Notes for Table C7-1:

(1) Insulation rated at less than 150 °C shall not be used. The maximum operating temperature of the device shall be at least 30 °C lower than the maximum temperature of the item with the lowest maximum temperature. This may be the core material, the insulation of the magnet, etc.

(2) Current rating for each winding shall be less than or equal to the rating for a bundle of wires of the same AWG size as the wire used for the winding (see Table C17-1 Wire Derating).

(3) The permitted maximum temperature stress is defined as the worst case temperature resulting from the combined effects of hot spot temperature, the ambient and/or base plate temperature, and the temperature rise resulting from joule heating.

(4) Maximum operating temperature equals ambient temperature plus temperature rise +10 °C (allowance for hot spot). Compute temperature rise as follows:

Inductor temperature rise (°C) = ((R-r)/r)(T+234.5*).

Where:

R = Winding resistance under load.**
r = No-load winding resistance at ambient temperature T (°C).
T = Maximum ambient temperature (°C) at time of power shutoff.

* This factor is for copper wire, but varies for different wire materials.
** For accurate results, this measurement must be made in a vacuum to simulate actual operating conditions.

(5) Maximum operating temperature equals ambient temperature plus temperature rise + 10 °C (allowance for hot spot). Compute temperature rise as follows:

Transformer temperature rise (°C) = ((R-r)/r)(t+234.5*)-(T-t).

Where:

R = Winding resistance under load. **
r = No-load winding resistance at ambient temperature T (°C).
t = Specified initial ambient temperature (°C).
T = Maximum ambient temperature (°C) at time of power shutoff. (T) shall not differ from (t) by more than +5 °C.

* This factor is for copper wire, but varies for different wire materials.
** For accurate results, this measurement must be made in a vacuum to simulate actual operating conditions.

1.8 Integrated Circuits

1.8.1 Derating Criteria for Digital Integrated Circuits.

TABLE C8-1. INTEGRATED CIRCUIT, CMOS, TTL		
Parameter	**Maximum Stress Ratio**	**Comments**
Voltage, Input	May not exceed supply voltage applied to IC	(1)
Voltage, Supply DIGITAL Turn on Operational	 Transient peaks shall not exceed the absolute maximum value. Per manufacturer's recommended operational voltages	
Fanout	Derate by one load or to 80% (90% WC) of maximum rating, whichever is greater.	Not applicable to single fanout devices.
Current, Load	0.80 (0.90 WC) (2)	Not applicable to single fanout devices.
Propagation delay	1.1	Worst case only
Power	0.80 (0.90 WC)	
Junction or Hot Spot Temperature	125 °C or 20 °C less than the manufacturer's rating	Whichever is lower

Notes for Table C8-1:

(1) For parts that are designed to accept an input voltage that is greater that the IC supply voltage, the maximum stress shall be 10 percent or more below the part manufacturer's maximum specified rating.

(2) The derating for all outputs of digital devices must be calculated for both high and low output states.

1.8.2 Derating Criteria for Linear, Op Amp, Comparator Devices.

TABLE C8-2. INTEGRATED CIRCUIT, LINEAR, OP AMP, COMPARATOR (1)		
Parameter	**Maximum Stress Ratio**	**Comments**
Power	0.75 (0.85 WC)	
Voltage, Input	0.70 (0.80 WC) of max. rating	(2)
Operating Frequency (Applications)	0.75 (0.85 WC) of max. rating	
Transients	Transient peaks shall not exceed the absolute maximum value	
Gain (Applications)	0.75 (0.85 WC) of max. rating	
Voltage, Supply	0.90 of maximum rating	Not to exceed the manufacturer's recommended operating voltage in WC.
Current, Output	0.75 (0.85WC) of max. rating	Of rated value, or 0.75 of the current limited value.
Junction or Hot Spot Temperature	125 °C or 20 °C less than the manufacturer's rating	Whichever is lower.

Notes for Table C8-2:

(1) In general, the 10 percent minimum/maximum margin applies to operational characteristics for the device, such as usable gain bandwidth, propagation delay, etc.

(2) Of the maximum rated supply voltage applied to the IC and/or of the rated differential input voltage. The input voltage shall not exceed the applied supply voltage.

1.8.3 Derating Criteria for Linear Voltage Regulator ICs.

TABLE C8-3. INTEGRATED CIRCUIT, LINEAR VOLTAGE REGULATOR		
Parameter	**Maximum Stress Ratio**	**Comments**
Power	0.80 (0.85 WC)	The controlling factor for voltage regulators is the input-output voltage differential which shall be limited to 80 percent of the max. rated (V_{in}-V_{out}).
Voltage, Input	0.80 (0.85 WC)	
Current, Input	0.80 (0.90 WC)	
Current, Output	0.75 (0.85 WC)	
Transients	Transient peaks shall not exceed absolute maximum values	
Junction or Hot Spot Temperature	125 °C or 20 °C less than manufacturer's rating	Whichever is lower.

1.8.4 Hybrids Chip and Wire.

a. Derating Criteria for Hybrids Chip and Wire Devices. Integrated circuit hybrids shall be designed so that discrete piece parts and deposited resistors meet the derating requirements of this document.
b. Internal Wire. Maximum design current for any given internal wire or ribbon used in a Hybrid Microcircuit is dependent upon the conductor material and the wire diameter and is equal to 50 percent of the value determined by the equation $I=Kd^{3/2}$. The constant (K) is dependent upon the composition of the wire or ribbon as shown.

TABLE C8-4. VALUES FOR K		
	K Values For Conductor Length, L	
Conductor Material	**L ≤ 0.040"**	**L > 0.040"**
Aluminum	22,000	15,200
Gold	30,000	20,500
Copper	30,000	20,500
Silver	15,000	10,500
All others	9,000	6,300

1.8.5 Derating Criteria (Integrated Circuits, Other). For large scale integrated circuits, microcircuit chips for hybrids, and integrated circuit part types not specifically addressed in the preceding material, apply appropriate linear and/or digital criteria from the appropriate derating tables. For devices that are part digital and part linear, the digital device derating factors shall apply to the digital portion of the device and the linear device derating factors shall apply to the linear portion.

1.9 Motors

1.9.1 Derating Criteria.

TABLE C9-1. MOTOR DERATING

TEMPERATURE:

Motor parts and materials shall be subject to the same temperature restrictions as inductors. Specifically:

1. Maximum temperature (hot spot, ambient + temperature rise) Class A, 105 °C, and Class B, 125 °C; classes per MIL-C-15305.

2. insulation rated at less than 105 °C shall not be used.

In general, no part or material shall operate at a temperature greater than 30 °C below the manufacturer's rated temperature for the part or material.

BEARING LOAD: 75 percent maximum of rated value.

Note that motor loading directly affects electrical stress and lifetime. Motor loading at operating speed shall be sufficiently derated from maximum rated torque so as to comply with the above temperature guidelines.

WIRE:

Restrictions on wire size shall apply to motor windings and leads. (See Table C17-1).

LIFETIME DERATING:

Motor lifetime in space applications will be determined by such factors as bearing lubrication, motor loading, and electrical stress. These factors shall be derated to 25 percent or less of their predicted capability under the application conditions.

1.10 Printed Wiring Boards

1.10.1 Derating Criteria. The minimum conductor width for both single and multi-layer copper foil printed wiring boards (PWBs) is a function of required circuit current.

Two sets of plots are provided. The first set (Figure 10-1 and Figure 10-2) plot the current carrying capability of the etched foil versus the cross sectional area required for a 10 °C temperature rise in the trace. This rise ensures minimal component heating. The second set (Figure 10-3 and Figure 10-4) plot the copper trace width versus the cross sectional area for four thicknesses of foil. The curves provided appear in FULL and EXPANDED scales to improve accuracy. The FULL scale covers the current range up to 7 amperes and a trace cross section up to 700 square mils. The EXPANDED scale covers the current range up to 1.8 amperes and a cross section up to 100 square mils.

1.10.2 Use of Derating Curves.

a. Enter the Current versus Area plot at the current required by the circuit and determine the cross sectional area.
b. Enter the Width versus Area plot of the same horizontal scale for the weight of copper foil used and determine the minimum trace width required.

1.10.3 Additional Factors.

a. Reliability review or approval is required for higher current densities than shown herein.
b. This information does not take into account the voltage drop between points on the PWB. The circuit designer must determine what is acceptable.
c. These curves are based upon MIL-STD-275E, Type 3, multilayer PWBs with inside traces, but also apply to all PWBs used in space-launched applications.
d. The curves include an industry standard 10 percent margin on the allowed current per trace to allow for variations in etching copper thickness and conductor width.
e. Where under etching becomes significant, the trace cross sectional area will be reduced as will its current carrying capability. A wider trace should be used in this case.
f. The effect of components on the trace temperature rise has not been included.
g. These charts are for single conductors. For groups of similar, closely spaced, parallel conductors, the temperature rise may be found by summing the currents and summing the cross sectional areas as though the group were only one wire.
h. These curves apply to copper traces without overplating.

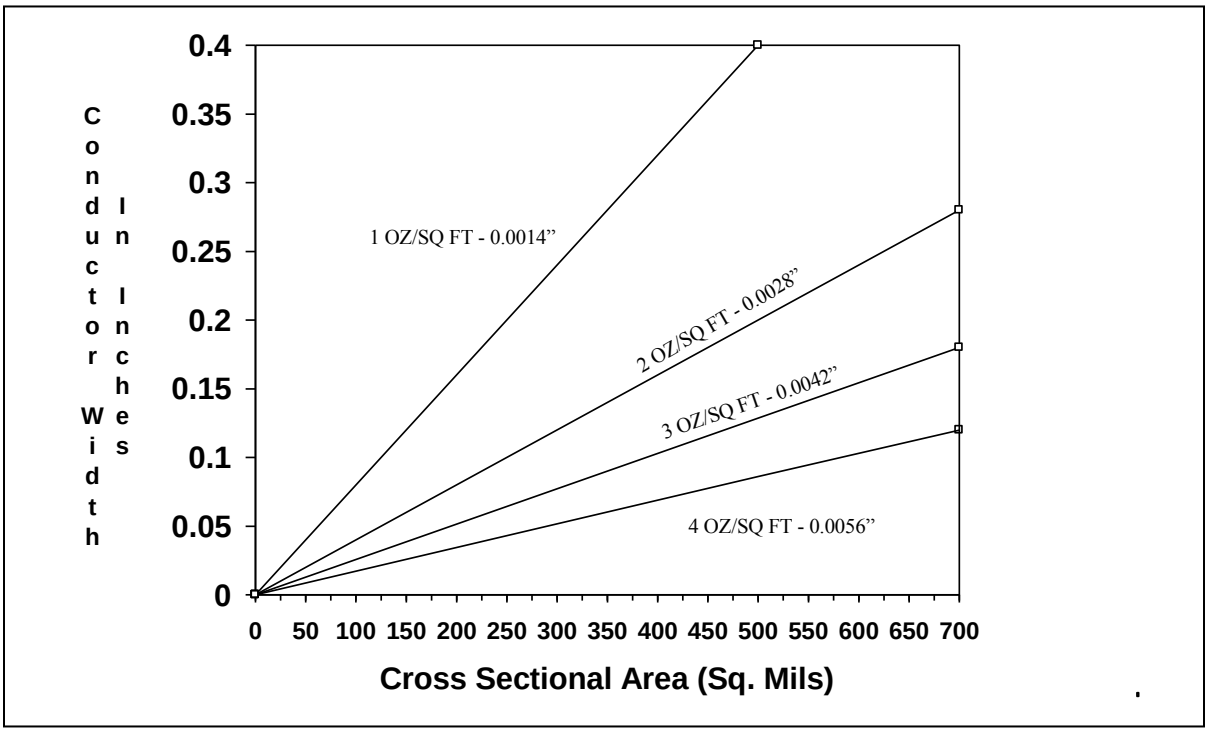

Figure C10-2. Conductor width vs. cross sectional area.

1.11 Relays

1.11.1 Derating Criteria.

TABLE C11-1. RELAY DERATING (SEE NOTES 1 THROUGH 8)

Relay Load Type	Contact Current Maximum Stress	Coil Voltage	
		Minimum Allowable	Maximum Allowable
Resistive	0.75 of resistive load rating	1.1 of must-operate voltage at +125° C rating	0.9 of maximum rated voltage
Inductive	0.50 of inductive load rating, or 0.40 of resistive load rating if inductive load rating is not specified	1.1 of must-operate voltage at +125° C rating	0.9 of maximum rated voltage
Motor	0.5 of motor load rating, or 0.20 of resistive load rating if motor load rating is not specified	1.1 of must-operate voltage at +125° C rating	0.9 of maximum rated voltage
Filament	0.10 of resistive load rating	1.1 of must-operate voltage at +125° C	0.9 of maximum rated voltage
Capacitive or in-rush type load	Series resistance shall be used with any capacitive load to insure that currents do not exceed derated levels for resistive loads.	1.1 of must-operate voltage at +125° C rating	0.9 of maximum rated voltage

Notes for Table C11-1:

(1) Maximum number of operations shall be 50 percent of rated life when relay is used with resistive loads, and 25 percent of rated life when used with inductive loads. Relay actuations performed during pre-flight testing shall be included as a portion of the permitted maximum number of relay operations.

(2) Suppression of induced transient voltage spikes is typically recommended to minimize effects on circuits/devices used to drive relay coils. Back-to-back Zener diodes, or a Zener diode with a blocking diode, across the coil are effective techniques. These techniques minimize degradation to contact life that can occur because of longer drop-out times for the suppressed coil. Bifilar wound coils are another option. If used, they should not require additional external suppression.

(3) For loads other than those specified in the above table, the stress on the relay contacts shall be no greater than 75 percent of the manufacturer's rating for the type of load specified.

(4) Contacts can be paralleled for redundancy. However, paralleled contacts should not be used as a means to increase contact current rating over the value specified for a single current. This restriction is necessary because there is no guarantee that parallel contacts will open and close simultaneously. Therefore, a single contact must be capable or carrying the entire load.

(5) Relays used to switch resistive loads at an appreciable distance from the relay contacts (such as in a spacecraft harness) may, in fact, be switching a load with significant inductance (the harness) in series with the load resistance. Each case shall be examined separately to determine the amount of inductance. If the amount of inductance as defined by the equation L`.0001RL in MIL-R-6106 is exceeded, the relay contact load shall be considered to be inductive. In these cases, the contacts shall be derated using the inductive derating rather than the resistive derating.

(6) Arc suppression techniques for the relay contacts are not recommended for use in spacecraft designs to provide higher than the derated current value in Table C11-1, since failure of the arc suppression circuit increases the risk of relay contact failure. Instead, relay contacts of a higher rating that can withstand the surge current during switching should be used.

(7) Relay contacts can safely carry more current than they can switch. For purposes of derating, the "carry-only" load shall not exceed 90 percent of the rated "carry-only" load.

(8) Relay coil voltages should not be derated. Relay coils should be operated at their specified nominal voltage level. Since operation exactly at the specified nominal voltage is not always possible. There are some upper and lower tolerance limits for coil voltage. Table C11-1 defines the limits that will ensure proper relay operation. The minimum actuation voltage supplied to the relay coil should never be less then 110 percent of the smallest voltage which will operate the relay at its maximum related temperature. The voltage supplied to the coil should never be greater than 90 percent of the specified maximum voltage rating for the coil over the specified temperature range.

1.12 Resistors

TABLE C12-1. MIL-SPEC LISTING (FOR REFERENCE)		
Resistor Type	**Mil-Spec**	**Style**
Fixed, Carbon (Insulated) Composition	MIL-R-39008	RCR
Fixed Film (Insulated)	MIL-R-39017	RLR
Fixed Film Resistor Chips	MIL-R-55342	RM, RMO
Fixed Film	MIL-R-55182	RNC
Fixed Film, Precision	MIL-R-55182	RNR (1)
Fixed Film, High Voltage	MIL-R-55182	
Fixed, Wire Wound (Accurate)	MIL-R-39005	RBR
Fixed, Wire Wound (PWR Type)	MIL-R-39007	RWR
Fixed, Wire Wound Power Type Chassis Mounted	MIL-R-39009	RER
Pill Resistor (Stripline)	MIL-R-10509	
Resistance Network	MIL-R-83401	RZ, RZO
Thermistor	MIL-T-23648	RTH
Variable, Nonwire Wound (2) (Adjustment Type)	MIL-R-39035	RJR
Variable, Nonwire Wound (Lead Screw Actuated) (2)	MIL-R-39015	RTR

Notes for Table C12-1:

(1) For solder only applications, not for welding.
(2) Not recommended for space usage.

1.12.1 Derating Criteria.

TABLE C12-2. RESISTOR DERATING		
Type	**Parameter**	**Maximum Stress Ratio** [11]
Carbon Composition	Power	Figure C12-1 [1]
Metal Film RLR RNC	 Power Power	 Figure C12-2 [1] Figure C12-3 [1]
Film, Chip - RMO	Power	0.50 (0.75 WC) [2], [9]
Film Resistance Network	Power	0.50 (0.75 WC) [2], [9]
Wire Wound Accurate - RBR	Power	Figure C12-4 [1], [8], [10]
Wire Wound Power - RWR	Power	Figure C12-5 [1], [4]
Wire Wound Power - RER Chassis Mounted	Power	Figure C12-5 [1], [4]
Deposited (Thick Film as Part of a Hybrid Substrate)	Power	0.50 [3]
Inconel Foil Heaters or Deposited Heaters on Kapton	Power	0.50 [6]
Thermistors Positive Temperature Compensating	Power	0.50
Thermistors Negative Temperature Compensating	Power	0.50 [5]
Microwave Loads, Isolators, Circulators (Pill Resistors)	Power	0.50 [7]

Notes for Table C12-2:

(1) For discrete resistors, the voltage shall not exceed 50 percent of rated voltage. Where a specific voltage rating has not been stated, the nominal rated voltage shall be determined from E = Square Root of (PR). When the voltage is applied in short pulses so that the average power of the resistor is less than 50 percent of the manufacturer's rating, this voltage derating may be the controlling derating factor.

Average pulse power is defined by:

$$P_{average} = P(t/T)$$

Where:

P = pulse power, calculated from E2/R.
E = amplitude of the pulses.
R = impedance across which the pulses appear.
t = pulse width or duration in seconds.
T = cycle width or duration in seconds.

Note: For non-repetitive pulse applications, the resistor's thermal time constant shall be determined and the temperature rise at the resistor surface shall not exceed the temperature that results from a derated power DC input.

(2) Power rating shall be determined from the maximum hot spot temperature and a calculation of the thermal resistance from the element to the equipment-mounting surface. Above 70 °C, linearly reduce the power derating factor from 0.50 at +70 °C to zero at +125 °C.

(3) Deposited resistors: Dimensions are determined by required resistance value and the resistivity of the ink used. Power rating for DuPont Birox 1400 series inks is 100 watts per square inch. The total power dissipated on a substrate, however, shall not exceed 4 watts per square inch and the voltage shall not exceed 1500 volts per inch of length. Consult the appropriate specification for other inks.

(4) For chassis-mounted applications, resistor body temperature (hot spot) shall not exceed 140 °C.

(5) Current limiting resistors or other methods shall be used to prevent thermal runaway. The 50 percent power stress ratio applies to +25 °C. Derate linearly to zero milliwatts at +125 °C (or the appropriate zero power temperature for the thermistor used.)

(6) 50 percent derating applies only if low thermal resistance exists between the heater and the heatsink. Higher derating (dissipating less power) is required if there is no heat sink, or if the thermal resistance to the heat sink is not low.

(7) This is 50 percent of the manufacturer's maximum power rating for the component (such as an isolator or circulator) at maximum acceptance temperature with the maximum power reflected into load that will still permit the circuit to function.

(8) These resistors are susceptible to absorption of water vapor and can exhibit a positive or negative (usually positive) shift of resistance of 30 to 70 parts per million.

(9) Under relatively low humidity conditions, film chip resistors (particularly those of smaller base size with high sheet resistance films) are subject to electrostatic discharge (ESD) and sudden shifts in resistance and in the temperature coefficient of resistance. Precautions against ESD are necessary in packaging and handling.

(10) The RBR resistors are designed as precision resistors. They are physically larger than RWR resistors for the same wattage rating which enables them to be used at higher power stress ratios than RWR resistors while maintaining their accuracy.

(11) The resistor derating guidelines account for the vacuum environment of space and are based on the maximum allowable resistor body hot spot temperature for lead mounted resistors in vacuum, except for RER and Inconel foil heater resistors, which are based on chassis mounting.

1.12.2 Use of Derating Curves (Figure C12-1 through Figure C12-5). To determine the maximum permitted operating power from the following figures:

a. Determine the maximum temperature at the location where the resistor will be mounted. The maximum temperature is the sum of the part ambient temperature, which is the acceptance test temperature plus the temperature rise from the component baseplate to the part location, and the part operational temperature, which is a function of the power applied.
b. Find that maximum temperature on the X axis, and read the Power Stress Ratio upper limit from the Region I curve. The power stress ratio is determined by dividing the maximum power across the resistor in its intended circuit application by the manufacturer's maximum power rating.
c. Any combination of part temperature and power stress ratio that lies in Region I shall be considered approved for that application. Any combination that lies in Region III shall be considered disapproved for the intended application. Combinations falling in Region II shall be identified, analyzed to assure that the part application meets mission requirements, and presented to the PMPCB for approval. Combinations falling 20 percent or less above the Region I curve shall be documented on a PMPCB Action Form and forwarded to the Government PMPCB representatives for approval. Combinations greater than 20 percent above the Region I curve shall require acquisition activity approval.

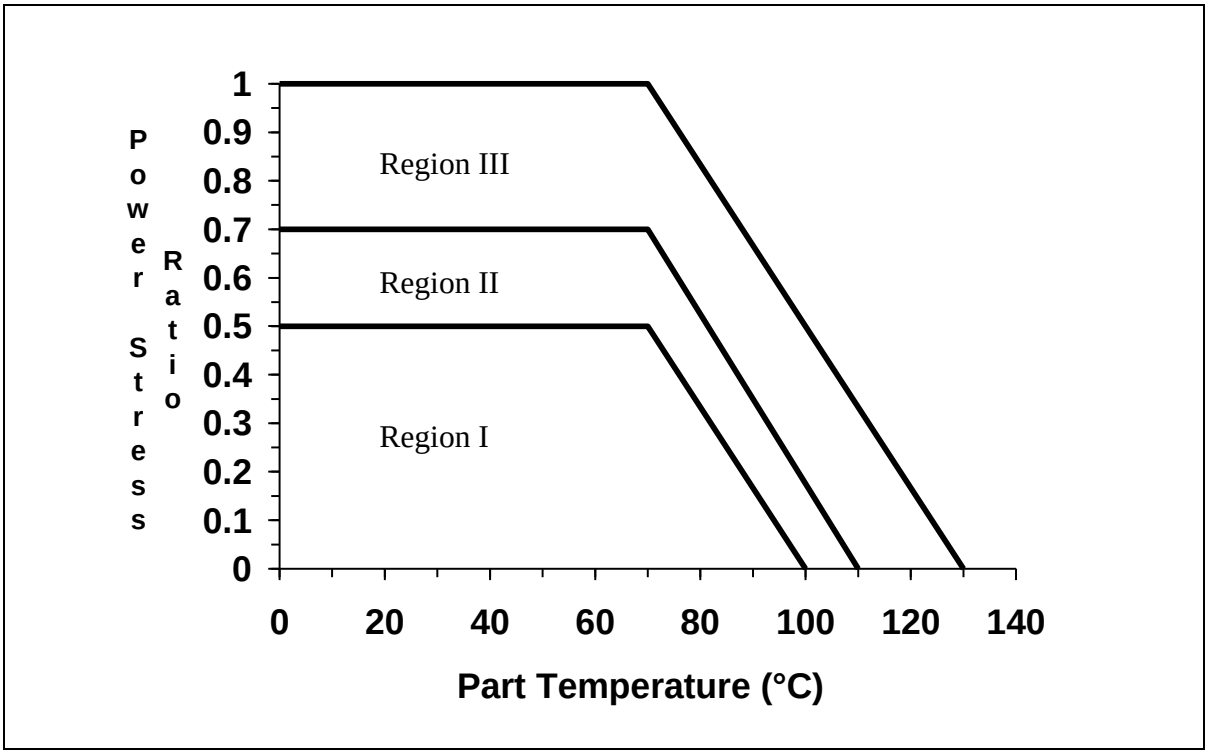

Figure C12-1. Carbon Composition Resistor (RCR).

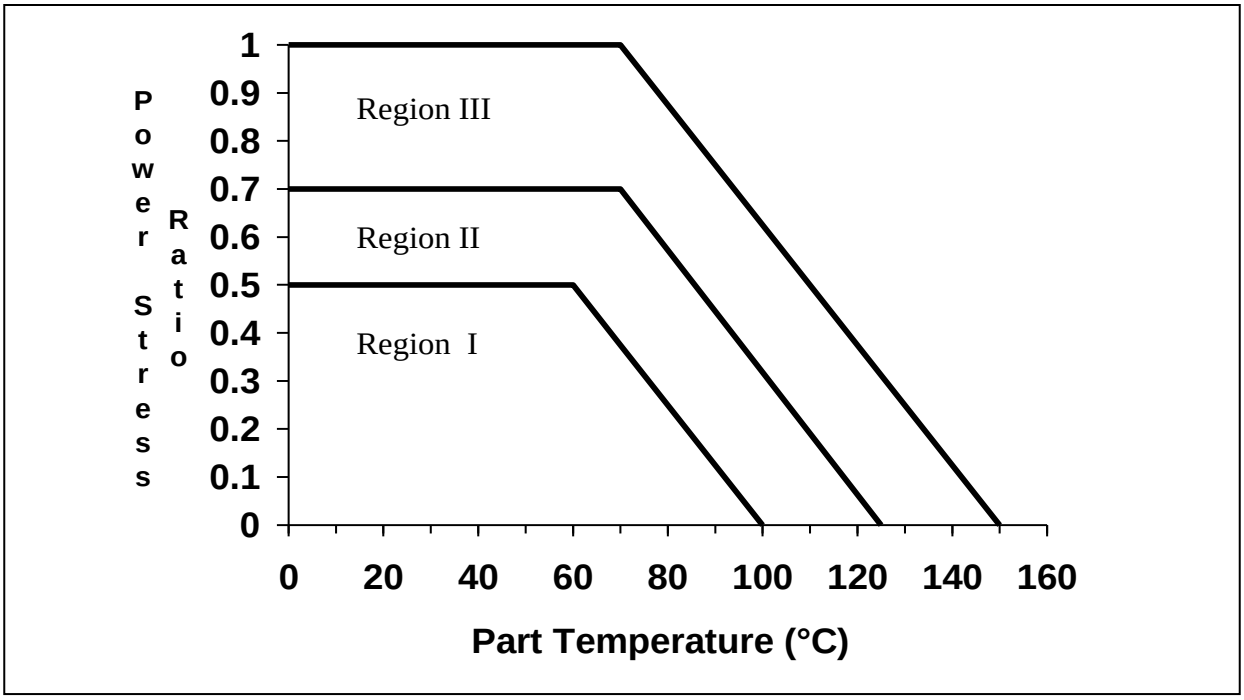

Figure C12-2. Metal Film Resistor (RLR).

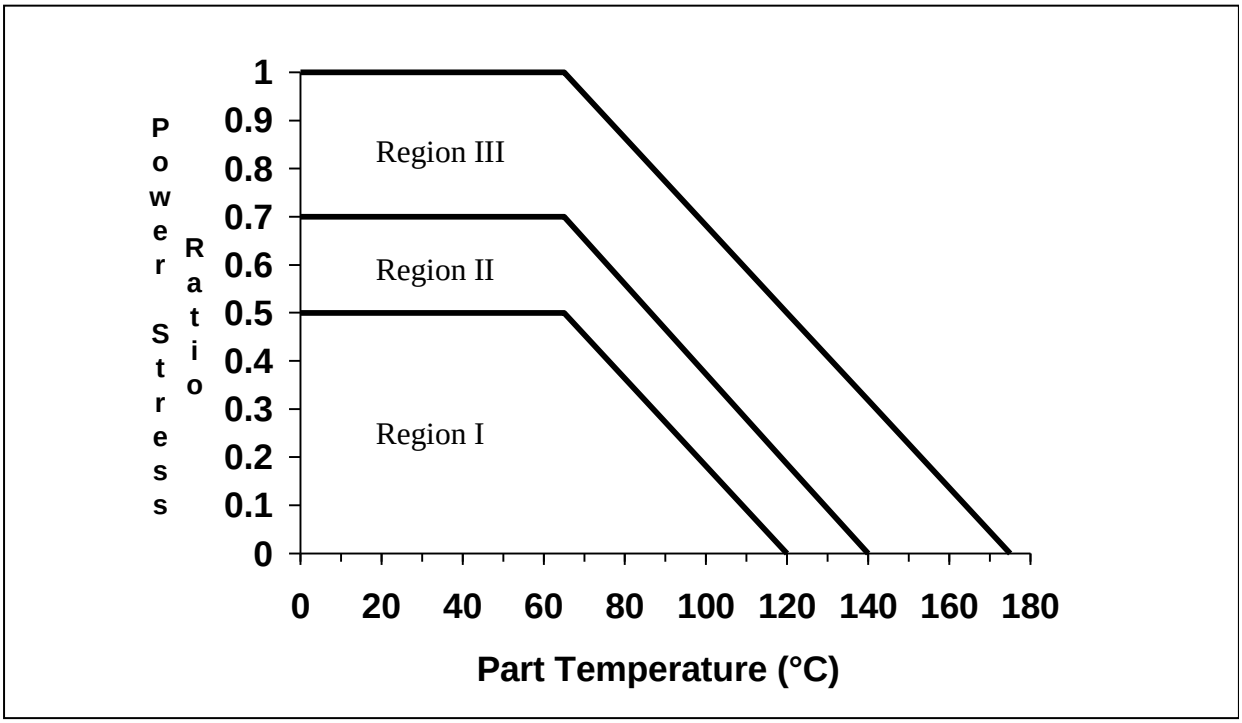

Figure C12-3. Metal film resistor (RNC, RNR).

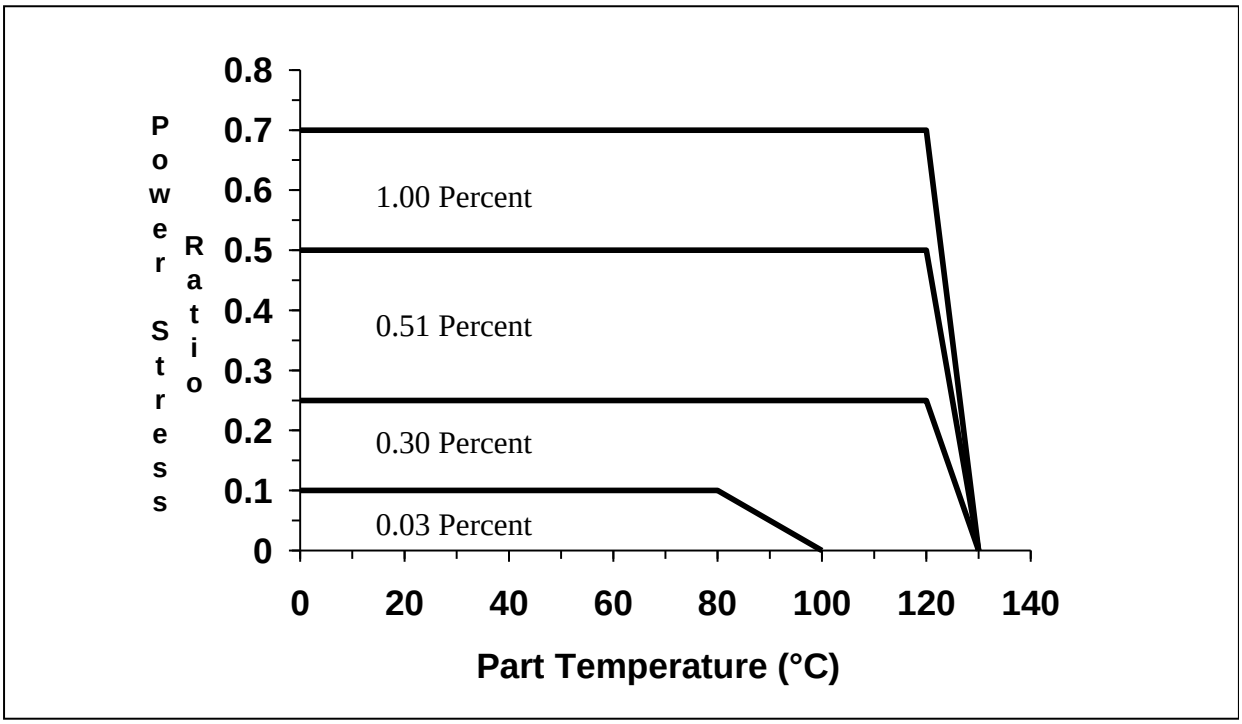

Figure C12-4. Wire wound accurate resistor (RBR).

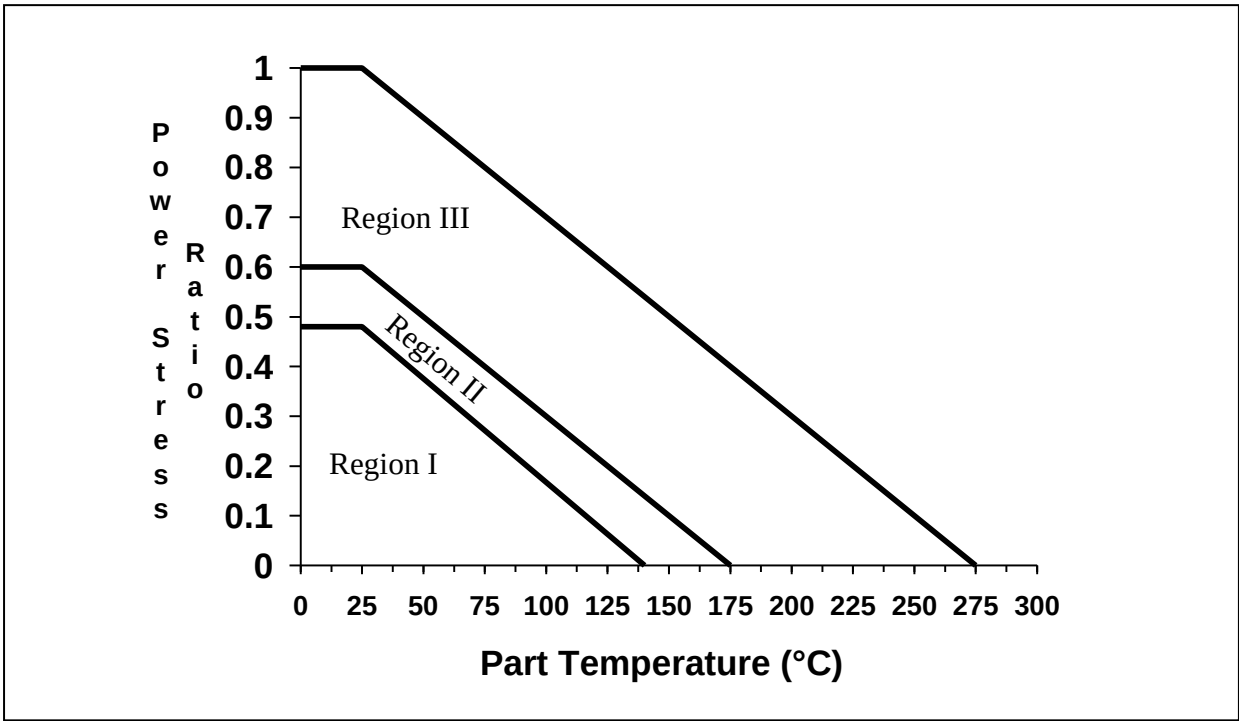

Figure C12-5. Wire wound power resistor (RWR, RER).

1.13 Slip Rings

1.13.1 Derating Criteria. The maximum current in the slip ring shall not exceed 50 percent of the designed current carrying capability of the slip ring. In addition, slip rings shall be designed so that when 50 percent of the rated current is being carried, the temperature rise of the slip rings shall not exceed 50 °C rise above ambient.

1.14 Substrates

1.14.1 Derating Criteria. Alumina substrates shall be derated to 50 percent of the manufacturer's dielectric withstanding voltage.

1.15 Switches

1.15.1 Switch Derating Criteria. The derating requirements for switches are essentially the same as for relay contacts. The notes below table 11-1 that refer to relay contacts also apply to switches.

Thermal switches per MIL-S-24236 are not recommended for space application. Where they must be used, the contacts shall be derated as stated above and proper configurations of series and parallel redundancy shall be employed. In addition, a +4 °C minimum dead band shall be required and a temperature rate of change equal to or greater than 0.11 °C/minute shall be used. If these conditions can not be met, solid-state thermal controls shall be used.

1.16 Transistors

1.16.1 Derating Criteria.

TABLE C16-1. TRANSISTOR, BIPOLAR, JFET		
Parameter	**Maximum Stress Ratio**	**Comments**
Power	0.50 (0.60 WC) (1)	
Voltage	0.75 of maximum rating (2)	
Voltage Transients	0.85 of maximum ratings	Worst case turn-on or repetitive transient.
Current	0.75 (0.85 WC)	
Junction Temperature	125 °C or 20 °C less than the manufacturer's rating	Whichever is lower.

TABLE C16-2. TRANSISTOR, GaAs FET			
Type	**Parameter**	**Maximum Stress Ratio**	**Comments**
GaAs FET Low Noise	Voltage	0.75	
	Current	0.90 (3), (4)	
	Power, Channel	0.50	
	Temperature, Channel	125 °C or 20 °C less than the manufacturer's rating.	Whichever is lower.
GaAs FET Power	Voltage	0.75	
	Current	0.90 (3), (4)	
	Temperature, Channel	125 °C or 20 °C less than the manufacturer's rating.	Whichever is lower.

TABLE C16-3. MOSFET, SMALL SIGNAL AND POWER		
Parameter	**Maximum Stress Ratio**	**Comments**
Voltage, Gate to Source, V_{GS}	0.75	
Channel Power	0.5	
Channel Current	0.9 (3), (4)	
Breakdown Voltage, V_{BGSS}	0.75	
Temperature, Channel	125 °C or 20 °C less than the manufacturer's rating.	Whichever is lower

Notes for Tables C16-1, C16-2, and C16-3:

(1) Usable power at a given case temperature can be found from the following relationship:

$$P = (TJmax - TC)/\phi JC$$

Where:

TJmax is the maximum allowed junction temperature.
TC is the device case temperature.
ϕJC is the thermal resistance from junction to case.

(2) Voltage derating applies to device voltages such as VCBO, VEBO, and VCEX.
(3) Where maximum IDS rating is not specified, the upper IDSS rating will apply.
(4) Devices may be tested briefly with IDS not to exceed the maximum rated value. Forward gate current shall be 0.90 or less of rating, or zero if not specified.

1.17 Wire and Cable

1.17.1 Derating criteria

TABLE C17-1. WIRE DERATING (1), (2)

Wire Size AWG#	Maximum Applied Current (Amps)		Comments
	Bundle/Cable	Single Wire	
30	0.7	1.3	Current ratings for bundles are based on bundles of 15 or more wires at 70 °C in a hard vacuum. For smaller bundles, the allowable current may be proportionally increased as the bundle approaches a single wire.
28	1.0	1.8	
26	1.4	2.5	
24	2.0	3.3	
22	2.5	4.5	Ratings are based on polyalkene insulated copper wire.
20	3.7	6.5	
18	5.0	9.2	
16	6.5	13.0	
14	8.5	19.0	
12	11.5	25.0	
10	16.5	33.0	
8	23.0	44.0	

Notes for Table C17-1:

(1) Use of wire smaller than AWG# 30 is not recommended. However, if wire smaller than AWG# 30 must be used, the maximum current rating for a single wire is 2.63 milliamps per circular mil (3.348 mA/sq. mil) of cross-sectional area. Wire smaller than AWG# 36 shall require reliability review and PMPCB approval prior to use and shall not be used in critical application.

(2) The current in wires terminated in or run through connectors may be restricted further than indicated above by virtue of the connector contact size. See paragraph 1.2.1 Connector Derating Criteria, Table C2-1 and Table C2-2.

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GLOSSARY

Acceptance Tests: Tests conducted to demonstrate acceptability of the unit for delivery. These tests demonstrate performance to purchase specification requirements and act as quality control screens to detect deficiencies in workmanship and materials. The successful completion of such tests denotes acceptance of the unit by the procurement agency.

Active Device: A component that requires power to function or contains electronic parts such as microcircuits, transistors, and diodes. Active components include flight termination receivers, high energy firing units and autonomous FTS units.

All-Fire Level: Specified energy level above the ordnance initiation statistical all-fire test level used as the firing specification. The all-fire level is determined by the Range User to account for uncertainty in operational use such as unit to unit variability, aging, test equipment variations, etc. The all-fire level is used for all system analyses, lot acceptance testing and qualification testing.

Antenna: A device capable of radiating or receiving radio-frequency electromagnetic energy.

Antenna Gain: The ratio of the maximum radiated power intensity from the subject antenna to the maximum intensity from a reference antenna with the same power input. Choosing an ideal lossless isotropic radiator as reference allows gain to be expressed as the ratio of maximum radiated power intensity to average intensity, and unless otherwise specified, the comparison antenna is isotropic.

Antenna, Isotropic: A hypothetical device that radiates or receives radio-frequency energy equally well in all directions; that is, the power radiated or received by an isotropic antenna is completely independent of direction from the antenna. Although an antenna of this nature cannot be constructed, it serves as a convenient mathematical reference.

Antenna Pattern-Radiation Pattern:

Full Pattern. A representation of an antenna's radiation or receiving characteristics in geometric space. The radiation or receiving characteristics are normally expressed as contours of equal gain or in numerical matrix form relative to a convenient reference; for mathematical convenience, the isotropic level is normally used as this reference. Antenna pattern testing is described in RCC 253.

Abbreviated Pattern**.** A limited sample of the full pattern that represents the full range of the antennas capability.

Antenna System: A group of components that provide vehicle antenna radiation characteristics to satisfy radio command coverage requirements. The antenna system may include power splitters, combiners, hybrids, coaxial cables, and other passive components. The antenna system may be independent for each receiver or coupled so that the RF signal power at the antenna system output port is equally divided between each receiver.

Attenuation, Radio Frequency (RF): The decrease in amplitude of a RF wave as it passes through a medium. Attenuation is expressed in decibels (dB).

Attitude: The axial positions of a vehicle in reference to a fixed coordinate system. Usually, the attitude of a vehicle is related to a vehicle's trajectory by its pitch, roll, and yaw angles; in turn, the trajectory is related to an earth-fixed coordinate system.

Audio Output: The composite output from the flight termination receiver (FTR) demodulator that consists of frequency components normally audible to the human ear and in this specific case (FTR) the composite of the IRIG tones.

Autonomous FTS (AFTS): An independent FTS that replaces or supplements the command destruct system which renders a vehicle non-propulsive. The autonomous FTS determines if a vehicle termination is required based on flight vehicle trajectory, on-board tracking data, computing, and pre-designated decision termination criteria.

Automatic Termination System: An independent FTS that is installed on each propulsion system on the launch vehicle, including stages, upper stages, and payload systems, that renders the powered stage non-propulsive in the event of an inadvertent breakup of a vehicle. An Inadvertent Separation Destruct System (ISDS) and automatic destruct systems (ADS) are one type of automatic termination system.

Axis, Pitch: A line through the vehicle's nominal center of gravity perpendicular to both roll and yaw axes. The pitch axis (also called the "lateral" axis) forms a third ordinate of the vehicle's orthogonal coordinate system. For straight and level flight of the vehicle with respect to the earth's surface, the pitch axis is in the horizontal plane. Ordinarily, when viewing the vehicle from its tail or aft position, the positive portion of the pitch axis is to the right when the positive portion of the yaw axis is down.

Axis, Roll: An arbitrarily pre-defined vehicle axis. This axis, ordinarily identical to the vehicle's longitudinal axis, has its origin at the vehicle's nominal center of gravity with its positive portion through a point on the leading end or nose. Once defined, this axis remains fixed with respect to the vehicle body.

Axis, Yaw: A line through the vehicle's nominal center of gravity and perpendicular to the roll axis. This axis (also called the "normal" axis) may be arbitrarily defined or may be related to the vehicle's normal orientation with respect to a reference coordinate system. The following comments give the normal position of the yaw axis under the respective condition.

- For example, the physical body location of the yaw axis of an ill-defined spinning body may be completely arbitrary.

- In the case of a wing-supported aircraft or missile in straight and level flight with respect to the earth's surface, the yaw axis is in line with the gravitational force vector - the positive portion is down in the direction of the gravitational force.

- In the case of a ballistic missile or rocket, the yaw axis is normally associated with the trajectory. Except for minor deviations, the yaw axis is in the plane in which the vehicle programs about the pitch axis. Once defined, the yaw axis remains fixed with respect to the vehicle's body.

Bandwidth: A range of frequencies within which an RF component is expected to meet its performance requirements.

Battery Capacity:

Rated Capacity. The total energy contained within a battery that is assigned by the battery manufacturer based on a set of specific conditions such as discharge temperature, discharge current, end of discharge voltage, and state of charge at start of discharge.

Measured Capacity. The total energy contained within a battery determined by testing based on a set of specific conditions such as discharge temperature, discharge current, end of discharge voltage, and state of charge at start of discharge.

Breakwire: A continuity circuit between stages of multistage vehicle, structural vehicle breakpoints or separation plane interfaces whose breakage is used to initiate FTS actions.

Capture Ratio: The capacity of an FTR to receive and execute a command when an interfering continuous-wave (CW) carrier is simultaneously input to the FTR. The CW signal is increased to the point where it captures the FTR. The capture ratio is the ratio of the desired signal strength to the interfering signal strength at the time of capture.

Center Of Gravity: A point at which the mass of the entire body is concentrated; also sometimes called center of mass.

Certification Testing: A controlled test where a component is verified to comply with design specifications. This test is usually a subset of the acceptance test and certifies the unit for flight use. It has a specified certification period , whereby if the unit is not flown within that specified time, it must be recertified.

Check Channel: A representative tone that is modulated to validate command destruct link integrity.

Circularly Polarized Wave: An electromagnetic wave for which the electric and/or the magnetic field vector at a point describes a circle. This term is usually applied to transverse waves.

Command Termination System: An airborne system that receives a ground initiated flight termination control signal which terminates flight of the launch vehicle. A command destruct system includes all receiving antennas, receiver decoders, explosive initiating and transmission devices, safe and arm devices and ordnance necessary to achieving termination of a flight vehicle.

Compliant: This category documents performance requirements that meet or meet the intent of the requirement.

Fully: This category documents performance requirements that comply as written and are acceptable for the life of the program with no special rules or restrictions which require periodic review.

Conditional**:** This category documents performance requirements that pose low risk or require unique circumstances to maintain their safety. Conditional compliance may be required if procedural controls and personnel are required to maintain safety. These requirements shall be reviewed for each launch to ensure that rationale for their acceptance remains valid.

Component: A piece of equipment, a piece part, or a group of piece parts that are viewed as an entity for purposes of reporting, analyzing, and predicting system reliability.

Connector: A coupling device used to connect cables and wires with other devices or cables and wires.

Continuous Wave (CW) Bandwidth: The FTR CW response at assigned center frequency versus response above and below assigned carrier frequency when the RF input level is increased 60 dB from threshold.

Corona: A visible electric discharge resulting from a partial electric breakdown of gases as the unit under test transits from a state of high-atmospheric pressure to a state of low-atmospheric pressure. Specifically, the air surrounding a wire/component that is at high electrical potential. The result is a radiated radio frequency.

Critical Design Review (CDR): A formal process where the final design of a component or system is presented, reviewed, and approved. The FTS is placed under configuration control after CDR.

Cross Polarization: The component of the electric field vector normal to the desired polarization component.

dBm: A unit used to express an arbitrary power level in terms of its decibel ratio to a reference level of one milliwatt.

Decibel (dB):

A unit of relative power. The decibel ratio between two power levels, P1 and P2, is defined by the relation dB=10log10 (P1/P2). This equation is used to calculate margin for spectral density random vibration, acceleration and shock.

A unit of relative voltage, current or Grms. The decibel ratio between two levels, L1 and L2, is defined by the relation dB=20log10 (L1/L2).

Decoder: A device that will distinguish between the different tones present in a discriminated composite audio signal and is capable of performing logic analysis based on the combination or lack of tones present.

Decoder Abnormal/Normal Logic: An FTR is subjected to tones in various combinations and sequences to determine whether the FTR responds in the prescribed manner.

Detonator: An explosive device that is the first device in an explosive train and is designed to transform an input (electrical) into an explosive reaction.

Deviation Sensitivity: The amount of FM deviation required to cause an FTR to execute a command correctly.

Electroexplosive Device (EED): A electrically initiated low voltage initiator used to initiate other ordnance components.

Electronic Safe and Arm: A high voltage ordnance initiating device that provides electronic interruption and initiation of downstream ordnance with no mechanical safety barriers.

Errant Vehicle (Non-Nominal): Vehicle that violates established flight safety criteria and/or operates erratically in a manner inconsistent with its intended flight performance

Exploding Foil Initiator: An electrically-initiated device using high-voltage discharge through a foil causing a flyer to impact on an explosive media resulting in initiation or detonation of the media.

Fail-Safe: A method built into flight termination systems that will activate a termination output upon the loss of positive FTS control such as power and/or RF signal and/or a tone.

Firing Circuit: The electrical energy path between the power source and the initiating device.

Firmware: Computer programs or data loaded into a class of memory that cannot be dynamically modified by the computer during processing. Firmware is treated as software.

Flight Termination: The process whereby an airborne vehicle's flight control is stopped to constrain it in a controlled area. Flight termination can be performed with ordnance destruct, liquid engine shutdown or aerodynamic instability depending on the type of vehicle.

Flight Termination Receiver (FTR): A generic term used to define the RF radio receiver/decoder employed on flight vehicles to receive ground encoded commands.

Flight Termination System: The entire system on an airborne vehicle used to terminate flight. It includes all wiring, power systems, safing systems and ordnance initiation. Vehicle systems that share or can adversely affect FTS functionality, such as flight computer FTS safing, can be considered part of the FTS.

Flight Unit: A unit that is intended for flight usage.

Fratricide: When one system or component of a system causes harm or failure to another system or component.

Full-Scale Target: Manned-rated operational vehicles with proven control systems that are converted to remote control unmanned vehicles to be used as full-scale aerial targets.

Guaranteed RF Sensitivity: The minimum specified RF input level into an FTR that ensures all FTR performance requirements are met under worst case RF characteristics and test conditions. The guaranteed sensitivity level is specified in the procurement specification and is not an actual measured level. Unless otherwise specified, the guaranteed RF value is used for FTR acceptance, qualification, bench test and pre-launch system checkout.

Hangfire: A condition that exists when the ignition signal is known to have been sent and has reached an initiator, but ignition of the propulsion system is not achieved.

High Voltage Initiator: A device that begins an ordnance event using an electrical impulse greater than 500 Volts to directly initiate a secondary explosive. High voltage initiators include Exploding Bridgewire Detonators (EBW) and Explosive Foil Initiators (EFI).

High Energy Firing Unit: An ordnance initiation component that uses voltages greater than 500V to initiate a high voltage initiator.

Hypergolic: A property of various combinations of chemicals causing self ignition upon contact with each other without a spark or other external initiation source.

In-Line Explosive: An explosive used in an explosive train that has no physical interruption of the explosive.

Initiator: The first element in an explosive train, which upon receipt of the proper mechanical or electrical impulse produces deflagrating or detonating action. The deflagrating or detonating action is transmitted to the following elements in the train. Initiators may be mechanically actuated, percussion primers, or electrically actuated .

Interrange Instrumentation Group (IRIG): Original standing groups formed by the Range Commanders Council. The IRIG is an older term that has been replaced by individual standing groups such as the Range Safety Group (RSG).

IRIG Tones: Replaced by RCC tones.

Lead Range: The range serving as the primary point of contact for program, range safety, and FTS issues. Lead range is usually used in association with multiple-range programs.

Left-Hand Circular Polarization: A circularly polarized transverse electromagnetic wave in which the rotation of the electric-field vector is counterclockwise for an observer looking in the direction of propagation (counterclockwise polarized wave).

Link Analysis: A link is a complete RF path from a transmitter output to the RF input of the airborne radio device or vice versa. Link analyses are performed for nominal trajectories using vehicle attitude and antenna patterns and errant flight which uses the 95 percent spherical coverage antenna gain.

The analysis of the link accounts for all losses such as attenuations, amplification/gains, and free space loss/attenuation in the entire path and then applies a pre-specified margin that ensures the signal-to-noise-ratio (SNR) is sufficient to reliably transmit and receive the desired signals.

Loss-Of-Power: Loss-of-power is a generic term that indicates electrical power (ac/dc) is no longer present at the source or desired destination.

Loss-Of-Tone: Indicates that a specified tone was present and is no longer being decoded.

Low Voltage Initiator: A device that begins an ordnance event using an electrical impulse less than 50 Volts. Low voltage initiators include Electroexplosive Devices (EEDs).

Margin: Additional design or test levels added to allow a component, subsystem or system to meet all required performance requirements when subjected to nominal/errant flight environments, worst-case test tolerances, aging effects, small sample sizes, testing uncertainty/limitations, unit to unit performance variability, flight environment uncertainty and vehicle monitoring system tolerances. Margins may include workmanship screening levels to ensure that flight hardware is free of manufacturing defects.

Maximum Usable RF Input: The capacity of an FTR to properly respond to commands after being subjected to high RF input of a specified level.

Mission Time: The duration of a vehicle's flight time for which the Range Safety Office has safety responsibility.

Modulation: The process by which a RF carrier is varied in accordance with a modulation wave/signal. In the case of an FTR, frequency modulation (FM) is employed. In FM, the carrier is shifted about the assigned frequency at an interval equal to the modulation tone frequency (RCC tone) or the RMS sum of the tones when more than one tone is used. The distance that the carrier is shifted is equal to the amplitude of the modulation tone or the RMS sum of all the tones.

Example: The tone frequency is 2.00 kHz and the amount of deviation is 10 kHz.
The carrier is shifting at a rate of 2.00 kHz and a distance of 10 kHz.

No-Fire:

- A statistically determined energy level representing the highest energy level at which an ordnance initiation device will not fire with a probability of 0.999 at a 95 percent confidence level.
- An energy which will not render an initiator inoperative (duding) or degrade performance.

Non-operating Environment: Environments experienced while the component is powered-off including manufacturing, storage, shipment, installation and pre-launch processing. Non-operating may include temperature (including number of cycles and thermal ramp rates), transportation vibration, handling shock, humidity, dust and fungus.

Non-flight Unit: A unit that is not intended for flight usage. Sometimes referred to as "hangar queens," test articles, sniffers, or engineering development units.

Operating Environment: Environments experienced while a component is powered on including pre-launch checkout, captive carry and flight environments. Operating environments include temperature (including number of cycles and thermal ramp rates), random vibration, pyrotechnic shock, humidity, salt fog and explosive atmosphere.

Operating Firing Level: The system level power, current or energy level that is used in flight for flight termination. The operating firing level includes a margin above the all-fire level. For LVIs, the margin between all-fire and operating current is 150 percent.

Operating Frequency: The RF center frequency in a CW mode that has been assigned by the procurement specification. Also referred to as the assigned frequency.

Operating Life:

- The period of time beginning with activation of the component or installation of the component on a launch vehicle, whichever is earlier, for which the component is capable of satisfying all its performance specifications through the end of flight.
- The period of time in which prime power is applied to electrical or electronic components without maintenance or rework.

Operational Bandwidth: The overall amount, plus and minus added together, that a properly modulated signal operating frequency can be varied, and an RF component will continue to properly receive and decode the signal.

Ordnance Interruptor: A device which provides mechanical interruption of the explosive or pyrotechnic train.

Out-Of-Family: A component, system or flight performance measurement that does not reflect performance data established by previous test or flight results. Out-of-family data is an indication of a potential problem with the component or system requiring further investigation and corrective action. Identification of out-of-family criteria is developed by Range Safety on a case-by-case basis using performance data and engineering assessment. Unless otherwise specified, out-of-family measurements are considered failures for investigation purposes.

Override: Normally used to mean one function prevails over or preempts another function.

Passive Device: A component that does not require power to function or does not contain electronic parts such as microcircuits, transistors, and diodes. Passive components include antennas, RF couplers and cables.

Percussion Actuated Device: An ordnance device that uses an external pull force to strike a primer and initiate an explosive output. These devices are also known as lanyard pull initiators and separation plane initiators.

Performance Specification: A document that provides detailed design, manufacturing and operating characteristics for parts, components and systems. The performance specification is used for design approval and generation of pass/fail criteria during testing.

Pilot Tone: A representative tone that is modulated to validate command destruct link integrity for a high-alphabet FTR.

Polarization: The behavior of the electric vector in a fixed plane normal to the direction of propagation as an electromagnetic wave moves through the antenna/medium.

Preliminary Design Review (PDR): A formal process whereby the design concepts proposed for a component or system are presented, reviewed, and approved.

Primary Battery: A battery not intended to be recharged that is disposed of in controlled conditions when it has delivered all its electrical energy.

Primary Explosive: An explosive which is extremely sensitive to heat and shock and is normally used to initiate a secondary high explosive. A primary explosive is capable of building up from a deflagration to detonation in an extremely short distance and time; it can also propagate a detonation wave in an extremely small diameter column.

Primer: An impact sensitive device used to ignite an explosive or pyrotechnic. Primers are typically used in percussion actuated devices.

Pyrotechnic Ordnance. A gas, light, heat or pressure producing compound used primarily to provide mechanical energy or ignite primary explosives. Pyrotechnic ordnance does not typically have the energy to directly initiate secondary explosives.

Qualification Test: The testing of a device or component to demonstrate that the design, manufacturing, and assembly processes have resulted in hardware and software that conform to the specification.

Range Safety Officer. A generic title used in this document to designate the person responsible for the real-time, pre-launch, and launch range safety operations.

Range User: An individual or organization that conducts or supports any activity using range facilities and equipment to conduct pre-launch and launch operations. Range Users may include the Department of Defense, civil government, commercial; and foreign government agencies.

RCC Tones: A group of 20 standard tone frequencies that are specified in RCC Standard 313. These tones are used to encode commands.

Redundancy: The existence of two or more components, circuits, assemblies, or systems that serve the same objective. Physical redundancy is maximum practical separation between redundant components for breakup survivability.

Reserve Battery: A battery that may be stored in an inactive state and made ready for use by adding electrolyte or in the case of a thermal battery, by melting solidified electrolyte.

Resistance and Isolation: The resistance between any electrical component's terminals that are common (resistance) and those that are not common (isolation).

Response Time: The time from reception of a command signal until the time of an output.

RF Combiner/Coupler: A device that combines and distributes RF inputs from two sources. Typically used to input two antenna inputs and output to two command receivers.

RF Level Monitor: Same as signal strength telemetry output.

RF Gain: The increase in RF power from a reference point.

RF Loss: The loss in RF power from a reference point.

RF Power: The amplitude of the RF signal.

Safe and Arm Device: An ordnance initiation component that provides mechanical interruption (safe) or alignment (arm) of the explosive train and electrical interruption (safe) or continuity (arm) of the firing circuit.

Secondary Battery: A rechargeable battery.

Secondary Explosive: A high explosive which is relatively insensitive to heat and shock and is usually initiated by a primary high explosive. It requires a relatively long distance and time to build up from a deflagration to detonation and will not propagate in extremely small diameter columns. Secondary high explosives are used for boosters and bursting charges. Sometimes called "non-initiating high explosives."

Self-Test: The capability of a component or system to validate that its subsystems, components or internal parts are functioning within its performance specifications prior to flight. Electronic components using memory or a microprocessor use self-test to validate proper functionality.

Service Life: The period extending from the date of completion of lot acceptance test of an explosive ordnance device to a date when it is no longer acceptable for flight.

Shelf Life: The specified period of time a device or component may be stored in a logistical environment and still perform to all specifications when placed in service.

Signal Strength Telemetry Output (SSTO): A voltage that is directly proportional to the amount of RF signal the FTR is receiving. The FTR uses its automatic gain control (AGC) voltage as the basis for SSTO voltage. This output signal is usually scaled from 0 to 5 Vdc and is commonly referred to as AGC, signal strength telemetry (SST), and SS/TLM. The preferred acronym is SSTO.

Squib: A general term used for any one of many small explosive devices loaded with deflagrating explosive so the output is primarily gas and heat. Squibs may be initiators for gas generators and igniters or may be cartridges for cartridge-actuated devices.

Statistical All-fire: A statistical determined energy level representing the lowest energy level at which an ordnance initiation device will fire with a reliability of 0.999 at a 95 percent confidence level. The all-fire level is used primarily to determine the guaranteed firing level and as a measure of production variability between production lots.

Storage Life: That period of time during which the item can remain in storage without having its operability affected. The operating and storage life clocks start at burn-in or acceptance test.

Subscale Target: A target that is usually flown by remote control and is smaller than a full-scale target (FST).

Surveillance Test: A component test that extends the service life of the item.

Telemetry: Measurement data with the aid of a transmission medium that permits measurements to be interpreted at a distance from the detector. The telemetry system is used for range safety system real-time status reporting.

Terminate Command: A command which when received and decoded will cease the flight profile of an airborne vehicle.

Threshold Sensitivity: The actual measured minimum RF signal required to produce a desired output from an FTR under nominal RF characteristics. This sensitivity is different from the guaranteed sensitivity and is usually a lower RF level.

Threshold Trigger/Firing Level: The level at which a control or firing circuit input of an electronic component will reliably respond.

Transition Time: The time required for an FTR to transition from an ARM output to a TERMINATE output.

Voltage Standing Wave Ratio (VSWR): The ratio of transmitted power to reflected power through an RF interface or component. In a perfect system, all transferred energy is accepted and coupled to the next device/system. Any unaccepted/coupled energy is reflected back to the originating device/system. Perfect VSWR is 1:1.

Waiver: Waivers document non-compliances to performance requirements. These non-compliances pose significant risks to mission personnel or public safety and require formal acceptance by the Range Commander.

**** NOTHING FOLLOWS ****