DOCUMENT 319-14

Range Commanders Council
Range Safety Group

FLIGHT TERMINATION SYSTEMS COMMONALITY STANDARD

ABERDEEN TEST CENTER
DUGWAY PROVING GROUND
REAGAN TEST SITE
WHITE SANDS MISSILE RANGE
YUMA PROVING GROUND

NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
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PACIFIC MISSILE RANGE FACILITY

30TH SPACE WING
45TH SPACE WING
96TH TEST WING
412TH TEST WING
ARNOLD ENGINEERING DEVELOPMENT COMPLEX

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FLIGHT TERMINATION SYSTEMS COMMONALITY STANDARD

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Prepared by

RANGE SAFETY GROUP

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TABLE OF CONTENTS

PREFACE ..... **xi**

ACRONYMS ..... **xiii**

Chapter 1. Introduction **1-1**

1.1 Background 1-1
1.2 Basis of Authority 1-3
1.3 Scope 1-3
1.4 Acceptability at any Test Range within the Major Range and Test Facility Bases 1-4
1.5 Lead Range Safety Office 1-4
1.6 Operational Constraints 1-5
1.7 Procurement of Flight Termination System-Peculiar Test Equipment 1-6
1.8 Tailoring 1-6
1.9 Waivers and Equivalent Level of Safety Certifications 1-7
1.10 Grandfathering 1-8
1.11 Range User-Provided Hardware 1-8
1.12 Responsibilities and Authorities 1-8

Chapter 2. Tailoring **2-1**

2.1 Tailoring Overview 2-1
2.2 Tailoring Process 2-1

Chapter 3. Common Flight Termination System and Component Performance Requirements **3-1**

3.1 Flight Termination System Functional Requirements 3-1
3.2 Flight Termination System Design 3-4
3.3 Environmental Design 3-11
3.4 Command Termination System 3-19
3.5 Automatic, Inadvertent-Separation, Fail-Safe, or Autonomous Flight Termination System 3-19
3.6 Flight Termination System Safing and Arming Devices 3-26
3.7 Liquid Propellant Shutdown 3-27
3.8 Flight Termination System Monitoring 3-28
3.9 Flight Termination System Electrical Components and Electronic Circuitry 3-29
3.10 Flight Termination System Monitor, Checkout, and Control Circuits 3-36
3.11 Flight Termination System Ordnance Path 3-37
3.12 Radio Frequency Receiving System 3-38
3.13 Flight Termination Receiver 3-40
3.14 Wiring and Connectors 3-54
3.15 Laser-Initiated Ordnance Fiber-Optic Cable Assembly 3-57
3.16 Batteries 3-58
3.17 Electromechanical Safe-and-Arm Devices with a Low-Voltage Initiator 3-67
3.18 High-Energy Electronic Initiator Firing Unit 3-71
3.19 Laser Firing Unit 3-73
3.20 Ordnance Interrupter 3-76
3.21 Ordnance Initiators 3-79

3.22 Devices Containing Percussion Initiators 3-83
3.23 Propellant-Actuated Devices/Cartridge-Actuated Devices 3-85
3.24 Explosive Transfer System 3-86
3.25 Destruct/Terminate Charge 3-87
3.26 Parachute Systems 3-89
3.27 Flight Termination System Shutdown Valves 3-89
3.28 Vibration and Shock Isolators 3-93
3.29 Autonomous Flight Termination Unit 3-93
3.30 Miscellaneous Components 3-97

Chapter 4. Flight Termination System Component Test and Analysis Requirements 4-1

4.1 Scope and Compliance 4-1
4.2 Component Tests and Analyses 4-1
4.3 Test Plans and Procedures 4-1
4.4 Test Anomalies and Failures 4-1
4.5 Failure Analysis 4-2
4.6 Test Tolerances 4-3
4.7 Test Equipment 4-4
4.8 Rework and Repair of Components 4-10
4.9 Test and Analysis Reports 4-10
4.10 Component Test and Analysis Tables 4-11
4.11 Component Examination 4-15
4.12 Acceptance Testing and Analysis 4-16
4.13 General Qualification Testing and Analysis Requirements 4-26
4.14 Qualification Non-Operating Environments 4-28
4.15 Qualification Operating Environments 4-34
4.16 Radio Frequency Receiving System 4-54
4.17 Flight Termination Receiver - Analog/Tone-Based 4-58
4.18 Enhanced Flight Termination Receiver 4-72
4.19 Autonomous Flight Termination Unit 4-87
4.20 Flight Termination System Shutdown Valves 4-94
4.21 Miscellaneous Components 4-105
4.22 Electrical Connectors and Harnesses 4-107
4.23 Remotely Activated Silver-Zinc Batteries 4-109
4.24 Thermal Batteries 4-116
4.25 Manually Activated Silver-Zinc Batteries 4-123
4.26 Nickel-Cadmium Batteries 4-134
4.27 Lithium-Ion Batteries 4-152
4.28 Lead-Acid Batteries 4-168
4.29 Safe-and-Arm Devices, Low-Voltage Initiators, Rotor Leads, and Booster Charges 4-184
4.30 High-Energy Firing Units 4-201
4.31 Laser Firing Units, Fiber-Optic Cable Energy Transfer Systems, and Laser-Initiated Detonators 4-215
4.32 Ordnance Interrupters 4-231
4.33 Percussion-Initiated Device 4-239

4.34 Explosive Transfer System, Ordnance Manifolds, and Destruct Charges 4-246
4.35 Ordnance Interfaces and Manifold Qualification 4-251
4.36 Shock and Vibration Isolators 4-253

Chapter 5. Flight Termination System Component, Subsystem, and System Prelaunch Test and Launch Requirements 5-1

5.1 General 5-1
5.2 Pre-flight Component Tests 5-4
5.3 Pre-launch Subsystem and System-Level Tests 5-10
5.4 Range and Vehicle Compatibility 5-16
5.5 Special Tests 5-16
5.6 Post-Mission Data Analysis 5-16

Chapter 6. Flight Termination System Ground Support and Monitoring Equipment Design Requirements 6-1

6.1 General 6-1
6.2 Ordnance Initiator Simulator 6-1
6.3 Laser Test Equipment 6-2
6.4 Range Safety Console 6-2
6.5 Ground Support Equipment Provided by the Range User 6-4

Chapter 7. Flight Termination System Analysis 7-1

7.1 General 7-1
7.2 System Reliability 7-1
7.3 Single-Point Failure 7-1
7.4 Fratricide 7-2
7.5 Bent Pin 7-2
7.6 Radio Frequency Link 7-2
7.7 Sneak Circuit 7-2
7.8 Software and Firmware 7-2
7.9 Battery Capacity 7-3
7.10 Component Maximum Predicted Environment 7-3
7.11 Failure Analysis 7-4
7.12 Qualification-by-Similarity Analysis 7-5
7.13 Vehicle Power Analysis 7-5
7.14 Radio Frequency Radiation Analysis 7-5
7.15 Flight Termination System Breakup Analysis 7-5
7.16 Tip-Off Analysis 7-6
7.17 Automatic Destruct System Timing Analysis 7-6
7.18 Ordnance Initiator Simulator Analysis 7-6
7.19 In-Flight Flight Termination System Analysis 7-6
7.20 Flight Termination System Laser-Initiated Detonator Heat Dissipation Analysis 7-6

Chapter 8. Documentation 8-1

8.1 General 8-1
8.2 Flight Termination System Report 8-1
8.3 Flight Termination System Report Submittal Process 8-2

8.4 Final Approval 8-2
8.5 Flight Termination System Report Format 8-2
8.6 Telemetry Measurement 8-5
8.7 Flight Termination System Report Appendixes 8-6

Appendix A. Software/Firmware Independent Verification and Validation A-1

A.1 Independent Verification and Validation Analysis Support A-1
A.2 Requirements A-1
A.3 Design and Development A-1
A.4 Operational Evaluation and Test A-2
A.5 Reporting Anomalies A-3
A.6 Reviews A-5
A.7 Configuration Audit A-5
A.8 Reliability Analysis A-5
A.9 Human Factors Analysis A-5

Appendix B. Electronic Piece-Part Procurement Requirements B-1

B.1 Piece-Part Program Plan B-1
B.2 US Military-Quality Piece-parts B-1
B.3 Custom or Non-Military Piece-parts B-2

Appendix C. Electronic Piece-Part Derating Requirements C-1

C.1 General C-1
C.2 Capacitors C-1
C.3 Connectors Reliability Application Derating Guidelines C-7
C.4 Crystal Reliability Application Derating Guidelines C-8
C.5 Diode Reliability Application Derating Guidelines C-8
C.6 Electromagnetic Interference Filters - Reliability Application Derating Guidelines C-10
C.7 Fuses - Reliability Application Derating Guidelines C-10
C.8 Inductor and Transformer Reliability Application Derating Guidelines C-11
C.9 Integrated Circuits C-13
C.10 Motors - Derating Criteria C-15
C.11 Printed Wiring Boards and Printed Circuit Boards C-15
C.12 Relays Derating Criteria C-18
C.13 Resistors C-19
C.14 Slip Rings - Derating Criteria C-25
C.15 Substrates - Derating Criteria C-25
C.16 Switches - Derating Criteria C-25
C.17 Transistors - Derating Criteria C-26
C.18 Wire and Cable - Derating Criteria C-27

Appendix D. Glossary D-1

Appendix E. References E-1

LIST OF FIGURES

Figure 1-1. Typical Flight Safety System with Flight Termination System 1-1
Figure 3-1. Battery Performance Operational Capacity Overview 3-61
Figure 4-1. Example of Allowable Spikes 4-6
Figure 4-2. Example Cross-Talk Response Acceptable Region 4-7
Figure 4-3. Acceptance Thermal Cycle Temperatures - Non-Ordnance 4-18
Figure 4-4. Workmanship Random Vibration Profile 4-23
Figure 4-5. Qualification Thermal Cycle Temperature Requirements - Non-Ordnance, Upper Maximum Predicted Environment 4-35
Figure 4-6. Qualification Thermal Cycle Temperature Requirements - Non-Ordnance, Lower Maximum Predicted Environment 4-35
Figure 4-7. Pressure Lapse Rate for the Altitude (Low Pressure) Step 4-42
Figure 4-8. Temperature/Humidity/Altitude Test Profile 4-44
Figure 4-9. Procedure for Hardmount Qualification of Components on Vibration Isolators 4-49
Figure 4-10. Electrostatic Discharge Test 4-196
Figure C-1. Example of a Derating Curve Plot C-1
Figure C-2. Ceramic or Ceramic Chip (CKR, CCR, CKS, CDR) C-4
Figure C-3. Glass, Porcelain (CYR) C-5
Figure C-4. Mica (CMS) C-5
Figure C-5. Tantalum Foil (CLR 25, 27, 35, 37) C-6
Figure C-6. Solid Tantalum (CSR, CSS) C-6
Figure C-7. Wet Tantalum-Tantalum (CLR 79) C-7
Figure C-8. Solid-Body Fuses C-11
Figure C-9. Printed Circuit Board Derating Curves - Full Scale C-16
Figure C-10. Printed Circuit Board Derating Curves - Expanded Scale C-17
Figure C-11. Carbon Composition Resistor (RCR) C-23
Figure C-12. Metal Film Resistor (RLR) C-23
Figure C-13. Metal Film Resistor (RNC, RNR) C-24
Figure C-14. Wire-Wound Accurate Resistor (RBR) C-24
Figure C-15. Wire-Wound Power Resistor (RWR, RER) C-25

LIST OF TABLES

Table 3-1. Fail-Safe Cross-Strapping Logic 3-21
Table 3-2. Tone Logic for 4-Tone Flight Termination Receiver with Fail-Safe (Commanded Fail-Safe Enable/Disable) 3-23
Table 4-1. Test Tolerances 4-3
Table 4-2. Workmanship Random Vibration Profile 4-23
Table 4-3. Minimum Transportation Random Vibration Profile 4-31
Table 4-4. Minimum Qualification Random Vibration Profile 4-48
Table 4-5. Minimum Breakup Qualification Shock Profile 4-52
Table 4-6. Radio Frequency Receiving System Acceptance Test Requirements 4-54
Table 4-7. Radio Frequency Receiving System Qualification Test Requirements 4-55
Table 4-8. Flight Termination Receiver Acceptance Test Requirements 4-58
Table 4-9. Flight Termination Receiver Qualification Test Requirements 4-59

Table 4-10. Out-of-Band Signal Rejection Test Frequencies for Flight Termination Receivers 4-69
Table 4-11. Thermal Performance Tests for Flight Termination Receivers 4-72
Table 4-12. Enhanced Flight Termination Receiver Acceptance Test Requirements 4-72
Table 4-13. Enhanced Flight Termination Receiver Qualification Test Requirements 4-73
Table 4-14. Receiver Status Telemetry Output Voltage Levels 4-77
Table 4-15. Out-of-Band Rejection Test Frequencies for Enhanced Flight Termination Receivers 4-84
Table 4-16. Thermal Performance Tests for Enhanced Flight Termination Systems 4-86
Table 4-17. Autonomous Flight Termination Unit Acceptance Test Requirements 4-87
Table 4-18. Autonomous Flight Termination Unit Qualification Test Requirements 4-88
Table 4-19. Electro-Mechanical Valve Acceptance Test Requirements 4-95
Table 4-20. Electro-Mechanical Valve Qualification Test Requirements 4-96
Table 4-21. Pneumatically Actuated Valve Acceptance Test Requirements 4-97
Table 4-22. Pneumatically Actuated Valve Qualification Test Requirements 4-98
Table 4-23. Electro-Pneumatic (Pilot) Valve Acceptance Test Requirements 4-99
Table 4-24. Electro-Pneumatic (Pilot) Valve Qualification Test Requirements 4-100
Table 4-25. Miscellaneous Component Acceptance Test Requirements 4-106
Table 4-26. Miscellaneous Component Qualification Test Requirements 4-106
Table 4-27. Electrical Connector and Harness Test Requirements 4-107
Table 4-28. Remotely Activated Silver-Zinc Battery Lot Acceptance Test Requirements 4-109
Table 4-29. Remotely Activated Silver-Zinc Battery Qualification Test Requirements 4-111
Table 4-30. Thermal Battery Lot Acceptance Test Requirements 4-116
Table 4-31. Thermal Battery Qualification Test Requirements 4-118
Table 4-32. Manually Activated Silver-Zinc Coupon Cell and Battery Acceptance Test Requirements 4-123
Table 4-33. Manually Activated Silver-Zinc Cell and Battery Qualification Test Requirements 4-124
Table 4-34. Manually Activated Silver-Zinc Cell Age Surveillance Test Requirements 4-126
Table 4-35. Nickel-Cadmium Cell Lot Acceptance Test Requirements 4-135
Table 4-36. Nickel-Cadmium Battery Acceptance Test Requirements 4-135
Table 4-37. Nickel-Cadmium Cell Lot and Battery Qualification Test Requirements 4-137
Table 4-38. Nickel-Cadmium Cell Lot and Battery Service Life Extension Test Requirements 4-138
Table 4-39. Lithium-Ion Cell Lot Acceptance Test Requirements 4-152
Table 4-40. Lithium-Ion Battery Acceptance Test Requirements 4-153
Table 4-41. Lithium-Ion Cell Lot and Battery Qualification Test Requirements 4-154
Table 4-42. Lithium-Ion Cell and Battery Age Surveillance and Service Life Extension Test Requirements 4-155
Table 4-43. Lead-Acid Cell Lot Acceptance Test Requirements 4-168
Table 4-44. Lead-Acid Battery Acceptance Test Requirements 4-169
Table 4-45. Lead-Acid Cell Lot and Battery Qualification Test Requirements 4-170
Table 4-46. Lead-Acid Cell and Battery Service Life Extension Test Requirements 4-171
Table 4-47. Safe-and-Arm Device Acceptance Test Requirements 4-184
Table 4-48. Safe-and-Arm Device Qualification Test Requirements 4-185

Table 4-49. Low-Voltage Initiator Lot Acceptance Test Requirements 4-186
Table 4-50. Low-Voltage Initiator Qualification Test Requirements 4-187
Table 4-51. Low-Voltage Initiator Service Life Extension Test Requirements..... 4-189
Table 4-52. Safe-and-Arm Rotor Lead and Booster Charge Lot Acceptance Test Requirements 4-189
Table 4-53. Safe-and-Arm Rotor Lead and Booster Charge Qualification Test Requirements 4-190
Table 4-54. Safe-and-Arm Rotor Lead and Booster Charge Service Life Extension Test Requirements 4-191
Table 4-55. Default Test Frequencies and Modulation 4-198
Table 4-56. High-Energy Firing Unit Acceptance Test Requirements 4-201
Table 4-57. High-Energy Firing Unit Qualification Test Requirements..... 4-202
Table 4-58. Exploding Bridgewire And Exploding Foil Initiator Lot Acceptance Test Requirements 4-203
Table 4-59. Exploding Bridgewire and Exploding Foil Initiator Qualification Test Requirements 4-204
Table 4-60. Exploding Bridgewire and Exploding Foil Initiator Service Life Extension Test Requirements 4-206
Table 4-61. Default Test Frequencies and Modulation 4-214
Table 4-62. Laser Firing Unit Acceptance Test Requirements 4-216
Table 4-63. Laser Firing Unit Qualification Test Requirements..... 4-216
Table 4-64. Laser-Initiated Detonator Lot Acceptance Test Requirements..... 4-218
Table 4-65. Laser-Initiated Detonator Qualification Test Requirements 4-219
Table 4-66. Laser-Initiated Detonator Service Life Extension Test Requirements 4-221
Table 4-67. Fiber-Optic Cable Assembly Acceptance Test Requirements 4-222
Table 4-68. Fiber-Optic Cable Assembly Qualification Test Requirements 4-222
Table 4-69. Default Test Frequencies and Modulation 4-230
Table 4-70. Ordnance Interrupter Acceptance Test Requirements 4-231
Table 4-71. Ordnance Interrupter Qualification Test Requirements..... 4-232
Table 4-72. Ordnance Interrupter Rotor Lead and Booster Charge Lot Acceptance Test Requirements 4-233
Table 4-73. Ordnance Interrupter Rotor Lead and Booster Charge Qualification Test Requirements 4-234
Table 4-74. Ordnance Interrupter Rotor Lead and Booster Charge Service Life Extension Test Requirements 4-235
Table 4-75. Percussion-Initiated Device Lot Acceptance Test Requirements 4-239
Table 4-76. Percussion-Initiated Device Lot Qualification Test Requirements 4-240
Table 4-77. Percussion-Initiated Detonator Primer Charge Lot Acceptance Test Requirements 4-241
Table 4-78. Percussion-Initiated Detonator Primer Charge Qualification Test Requirements 4-242
Table 4-79. Percussion-Initiated Detonator Service Life Extension Test Requirements.... 4-243
Table 4-80. Explosive Transfer System, Ordnance Manifold, and Destruct Charge Lot Acceptance Test Requirements..... 4-246
Table 4-81. Destruct Charge Qualification Test Requirements 4-247

Table 4-82. Explosive Transfer System and Ordnance Manifold Qualification Test Requirements 4-248
Table 4-83. Explosive Transfer System, Explosive Manifold, and Destruct Charge Service Life Extension Test Requirements 4-249
Table 4-84. Shock And Vibration Isolator Acceptance Test Requirements 4-253
Table 4-85. Shock and Vibration Isolator Qualification Test Requirements 4-253
Table A-1. Problem Severity Categories A-3
Table A-2. Problem Probability Categories A-4
Table C-1. Capacitors, Mil-Spec Listing (For Reference) C-2
Table C-2. Capacitor Derating C-2
Table C-3. Derating Curve Figures by Capacitor Type C-3
Table C-4. Connectors C-7
Table C-5. Connector Derating C-8
Table C-6. Crystals C-8
Table C-7. Diode (Switching, Small-Signal, Rectifier, and Transient Suppressors) C-9
Table C-8. Diode (Step Recovery, Varactor, and Varicap) C-9
Table C-9. Zener Diode (Reference and Regulator) C-9
Table C-10. Diode, Shottky Barrier C-10
Table C-11. Diode (Tunnel, Germanium) C-10
Table C-12. Diode (Photo, Light-Emitting Diode) C-10
Table C-13. Electromagnetic Filters C-10
Table C-14. Fuse Derating C-10
Table C-15. Inductors and Transformers C-12
Table C-16. Complementary Metal Oxide Semiconductor and Transistor-Transistor Logic Integrating Circuits C-13
Table C-17. Integrated Cuircuit, Linear, Op Amp, Comparator C-13
Table C-18. Integrated Circuit, Linear Voltage Regulator C-14
Table C-19. Values for K C-14
Table C-20. Motor Derating C-15
Table C-21. Relay Derating C-18
Table C-22. Mil-Spec Listing (For Reference) C-19
Table C-23. Resistor Derating C-20
Table C-24. Derating Curve Figures by Resistor Type C-22
Table C-25. Bipolar Junction and Junction-gate Field Effect Transistors C-26
Table C-26. GaAs Field Effect Transistor C-26
Table C-27. Metal Oxide Semiconductor Field Effect Transistors, Small-Signal, and Power Transistors C-27

PREFACE

This document presents the results of Task RS-52 assigned to the Range Safety Group / Flight Termination Systems Committee to update Range Commanders Council (RCC) Document 319, Flight Termination Systems Commonality Standard. This standard has been written to conform to the intent of a guide specification per Defense Standardization Program SD-15.[1] The intent of the format is to levy performance requirements, allow the range user flexibility to develop innovative technical solutions, and simultaneously ensure adequate detail for contractual enforcement. The format includes performance requirements in plain text with text boxes placed directly after each performance requirement. Text boxes present recommended solutions that reflect the standard practice and lessons learned and are tailored for each unique application. Once tailored, these text boxes become mandatory, contractually enforceable requirements. Details on this format can be found in Chapter 1 and Chapter 2.

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[1] Department of Defense. Guide for Performance Specifications. SD-15. 24 August 2009. May be superseded by update. Available at http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/SD_15%202009.pdf.

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ACRONYMS

AC	alternating current
ADS	automatic destruct system
AFTS	autonomous flight termination system
AFTU	autonomous flight termination unit
Ag-Zn	silver-zinc
AM	amplitude modulation
ATP	acceptance test procedure
AWG	American Wire Gauge
BIT	built-in test
BPSK	binary phase shift keying
CC	constant current
CCTO	check channel telemetry output (EFTR)
CDR	critical design review
C_{FS}	flight self-discharge in amp-hrs
C_R	remaining capacity for determining operational stand time capacity
C_{RF}	remaining capacity for determining capacity loss due to self-discharge
CSCI	critical software configuration item
CV	Constant Voltage
CVTO	command valid telemetry output (EFTR)
CW	continuous wave
DC	direct current
DoD	Department of Defense
DOE	Department of Energy
DOP	dilution of precision
DOT	Department of Transportation
DPA	destructive physical analysis
DSCC-VQ	Defense Supply Center, Columbus Sourcing and Qualification Unit
DWV	dielectric withstanding voltage
EAFD	electronic arm-and-fire device
EBW	exploding bridgewire
EED	electro-explosive device
EFI	exploding foil initiator
EFTR	enhanced flight termination receiver
EFTS	enhanced flight termination system
ELS	equivalent level of safety
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EOCV	end-of-charge voltage
EODV	end-of-discharge voltage
ESAD	electronic safe-and-arm device
ESD	electrostatic discharge
ETL	explosive transfer line
ETS	explosive transfer system
FAA	Federal Aviation Administration
FCDC	flexible confined detonating cord

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	flight termination system report
GIDEP	Government/Industry Data Exchange Program
GPS	Global Positioning System
GSE	ground support equipment
HWCI	hardware configuration item
IAW	in accordance with
IEEE	Institute of Electrical and Electronics Engineers
IF	intermediate frequency
IMU	inertial measurement unit
INS	inertial navigation system
IRIG	Inter-Range Instrumentation Group (An RCC group)
ISDS	inadvertent separation destruct system
IV&V	independent verification and validation
LAT	lot acceptance test
LFU	laser firing unit
Li-ion	lithium-ion
LID	laser-initiated detonator
LRSO	Lead Range Safety Office
LVI	low-voltage initiator
MEOP	maximum expected operating pressure
MPE	maximum predicted environment
MRTFB	Major Range and Test Facility Base
MSL	mean sea level
N/A	not applicable
NASA	National Aeronautics and Space Administration
Ni-Cd	nickel-cadmium
NIST	National Institute of Standards and Technology
NSA	National Security Agency
OCV	open circuit voltage
PAD	propellant-actuated device
PCB	printed circuit board
PI	percussion initiator
PID	percussion-initiated device
PIND	particle impact noise detection
PMPCB	Parts, Materials, and Process Control Board
PWB	printed wiring board
QA	quality assurance
QML	qualified manufacturers list
QPL	qualified products list
QTP	qualification test procedure
RCC	Range Commanders Council

RF	radio frequency
RH	relative humidity
RMS	root mean square
RSC	range safety console
RSO	Range Safety Office
RSTO	receiver status telemetry output
RV	reentry vehicle
S&A	safe-and-arm
SAD	safe-and-arm device
sDOF	statistical degrees of freedom
SLC	standard leak conditions
SLE	service life extension
SOC	state of charge
SRS	shock response spectrum
SS	statistical sample
SSTO	signal strength telemetry output
TIM	technical interchange meeting
TM	telemetry
UDDP	user-defined data port
UN	United Nations
VSWR	voltage standing wave ratio
WC	worst case

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CHAPTER 1

Introduction

1.1 Background

In an effort to establish a set of common design and testing requirements for programs operating from or on multiple ranges, several key organizations have worked together and set forth this standard to assist the range users in the determination of flight termination system (FTS) design and test requirements. 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.

1.1.1 Terms and Use of This Document

For purposes of this document, the following applies.

a. An 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. See Figure 1-1.

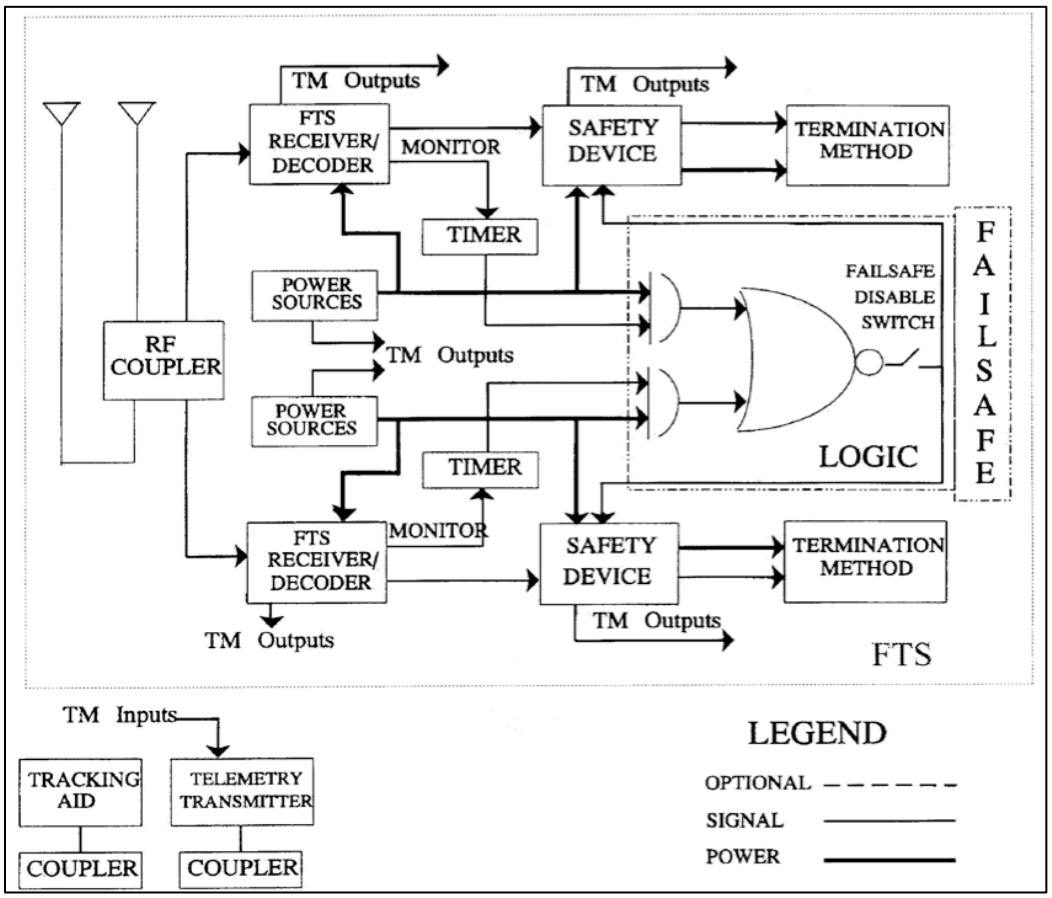

Figure 1-1. Typical Flight Safety System with Flight Termination System

c. This standard only applies if the cognizant range safety office (RSO) (also referred to herein as "Range Safety") determines that an FTS is required.

1.1.2 Mandatory Systems Testing

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.

1.1.3 Flight Safety System Requirements

The FSS requirements established in this document do not negate, supersede, or include other range requirements, such as ground safety.

1.1.4 Organization of This Document

The chapters of this standard address different phases in the development and approval process: requirement generation, development, design, testing, analysis, and documentation.

a. Open Text. The open text contains the mandatory performance-based requirements. Normally, the only tailoring expected for these requirements would be the deletion of non-applicable requirements. Due to the wide range of vehicles and FTS systems that this standard covers it is understood that there may be open-text requirements that are not appropriate for a particular system. These requirements may be tailored as long as an appropriate evaluation is performed and documented that demonstrates an equivalent level of safety (ELS) to the original open-text requirement. The tailored requirements must be approved by Range Safety.

b. Text Boxes. Text box paragraphs demonstrate detailed solutions that meet the required parent performance requirement. They may also provide additional detail for a particular device that will be used in the design. 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.

(1) These technical solutions are provided for the following reasons.

i. To aid the tailoring process between Range Safety and range users in evaluating a potential system against all performance requirements.

ii. To aid Range Safety and range users in implementing lessons learned.

iii. To provide benchmarks or a standard that demonstrate what Range Safety considers an acceptable technical solution/implementation of the performance requirement.

iv. To help convey the level of safety the performance requirement is intended to achieve.

(2) The technical solutions in the text box paragraphs may be adopted, modified, or replaced with another solution. This process accomplishes the following.

- It provides an appropriate level of detail necessary for contractual efforts.
- It promotes efficiency in the design process.
- It avoids 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.

(3) 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 ELS and must be approved by Range Safety.

(4) 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 Instruction 3200.18[2] establishes the requirements for the management and operation of Major Range and Test Facility Bases (MRTFBs) and assigns safety responsibilities to the range commander.

b. NASA Procedural Requirement 8715.5[3] establishes range safety responsibilities for all NASA activities.

c. The FAA establishes its safety requirements for commercial launches through 14 CFR 417.[4]

NOTE	The responsibilities identified in this section 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 (GSE). These requirements have been shown to ensure a minimally acceptable level of safety and reliability during installation, test, and flight of the airborne FTS. Facilities and ranges at NASA, DOE, and FAA are considered to be MRTFB activities for purposes of this document. The following guidance applies.

[2] Department of Defense. Management and Operation of the Major Range and Test Facility Base (MRTFB). DoDI 3200.18. 1 February 2010. May be superseded by update. Available at http://www.dtic.mil/whs/directives/corres/pdf/320018p.pdf.
[3] National Aeronautics and Space Administration. Range Flight Safety Program. NPR 8715.5A. 17 September 2010. May be superseded by update. Available at http://www.hq.nasa.gov/office/codeq/doctree/87155.htm.
[4] Federal Aviation Administration. Launch Safety. 14 CFR 417. N.d. May be superseded by update. Available at http://www.faa.gov/regulations_policies/faa_regulations/commercial_space/.

a. There is no RCC commonality document for ground operations safety, which 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. Tracking and telemetry (TM) top-level safety performance requirements are contained in the latest released version of RCC 324.[5] Though RCC 324 is primarily intended for global positioning systems (GPS) and inertial navigation systems (INS), the system performance requirements shall be used for all tracking sources.

NOTE	The RCC 324 document contains GPS and TM inertial guidance requirements. If a C-band beacon is used as a tracking source, beacon requirements shall be tailored into the program RCC 324 requirements.

c. The FTS shall be effective throughout the portion of flight for which the RSO has safety responsibility.

1.4 Acceptability at any Test Range within the Major Range and Test Facility Bases

This document is intended to provide a common set of FTS requirements that can be used at any MRTFB test range.

1.4.1 Multiple Ranges

If a program intends to operate on multiple ranges, all affected ranges shall be involved in the tailoring of this document. An 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 original requirements or impose other requirements.

1.4.2 Untailored RCC 319

Adherence to all of the requirements (untailored) in this document will, in general, produce an airborne system that can be flown at any MRTFB without modification or retest provided the vehicle and environment are identical to those used for the initial qualification.

1.5 Lead Range Safety Office

For programs that launch/fly from multiple ranges, the range user is responsible for keeping each RSO informed about any changes that affect the FTS. The lead RSO (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.

[5] Range Commanders Council. Global Positioning and Inertial Measurements Range Safety Tracking Systems Commonality Standard. RCC 324-11. February 2011. May be superseded by update. Available to RCC members with private portal access at https://wsdmext.wsmr.army.mil/site/rccpri/Publications/Forms/AllItems.aspx.

1.5.1 Lead Range Safety Office 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 vehicle 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 Flight Termination System Operational Control

a. The control of the 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 vehicle assembly and readiness process through final countdown and launch/flight. 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/flight 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) and documentation and approval of any ELS certifications.

c. Development of any waiver requests for requirements in the tailored RCC 319 that cannot be met. The requirement for which the waiver is being written will be retained in the tailored RCC 319.

d. Design of FTS to the tailored requirements and support of design reviews (Chapter 3).

(1) System requirements review 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.

e. Testing of FTS components (Chapter 4).

f. Vehicle assembly, FTS subsystem/system testing, countdown, and post-flight (see Chapter 5).

g. Final FTS approval through the FTS report (FTSR) (Chapter 7), analysis (Chapter 6), and testing (Chapter 4 and Chapter 5).

h. Final documentation and approval of any waivers.

1.6.3 Flight Termination System Frequencies

a. General. 421 MHz, 425 MHz, and 428 MHz are currently common FTS frequencies for all ranges. Efforts are currently underway to move US Government FTS frequencies to the 370 MHz - 380 MHz band due to increasing conflict with other DoD and commercial entities; however, there may be exceptions and operational constraints on some ranges for use of these frequencies. The use of any specific 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 Flight Termination System-Peculiar Test Equipment

a. The range user shall provide or fund for the procurement of any special instrumentation or hardware to test the FTS.

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

1.8 Tailoring

Requirements shall be tailored by agreement between the range user and all RSOs 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, pre-bid conferences with bidders, concept technical interchange meetings (TIMs), PDRs, etc.

c. Tailoring agreements and the design/test/inspection concepts upon which the tailoring is based shall be formally documented, including any required 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 Waivers and Equivalent Level of Safety Certifications

1.9.1 General Information

Waivers document noncompliance with one or more performance requirements that will result in a significant increase in risk to mission personnel or public safety. The ELS certifications document noncompliance with one or more performance requirements that's an insignificant increase in risk to mission personnel or public safety. Waivers and ELS certifications may have either limited or lifetime effectiveness.

a. Limited Effectiveness. Time-limited waivers are set for a limited period of time or a limited number of flights/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.

b. Lifetime Effectiveness. 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 flight/launch to ensure that rationale for their acceptance remains valid.

1.9.2 Submitting Waivers and Equivalent Level of Safety Certifications

The range user shall submit adequate justification for waivers and ELS certifications from these requirements to those ranges originally involved. All waivers and ELS certifications shall be approved by all RSOs involved. Ranges that were not involved in the original process have the right to restore the requirements of this volume for any program wishing to conduct test operations at these ranges.

1.9.3 Supporting Data

Supporting data for a waiver or ELS certifications request must include:

a. a statement of the technical or other requirements that make the waiver or ELS certification necessary;

b. a discussion of the effect on FTS performance functions if the waiver or ELS certification is granted;

c. a discussion of the effect on the program if the waiver or ELS certification 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 meet the requirements in question by the time the approved waiver/ELS effectiveness expires.

1.10 Grandfathering

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.

b. The 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 for which a noncompliance was not identified.

d. Accident and incident investigations and reports dictate compliance to this document.

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

1.11 Range User-Provided Hardware

The range user may be required to provide FTS components to Range Safety to support pre-flight 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 RSO.

1.12 Responsibilities and Authorities

1.12.1 Range Commanders

Range commanders are responsible for the following.

a. Serving as final authority and responsibility for safety at the launch range;

b. Implementing the requirements of this volume and handle noncompliances as they apply to range user programs on their range.

1.12.2 Range Users

Range users are responsible for the following.

a. Meeting the requirements of this standard when launching vehicles from multiple MRTFBs.

b. Meeting local range safety requirements for vehicle, payload systems, and ground safety equipment designs.

c. Submitting FSS design and test documentation in a timely manner.

d. Notifying Range Safety of meetings, design reviews, tests, and installation of the FSS on the vehicle at least 30 calendar days in advance to allow sufficient time to review documentation, design material, and test plans to provide meaningful comments and recommendations. The 30-day constraint applies if travel is required by range personnel. If no travel is required and the subject is a near-term flight constraint or other emergency issue, the meeting may be scheduled as required. It is important to note that FTS approval cannot be granted unless Range Safety is fully aware of all aspects of the FTS.

   (1) Meetings or tests shall not be conducted without Range Safety or a designated representative in attendance unless otherwise approved by Range Safety.

   (2) A schedule shall be submitted to Range Safety that includes estimated start and completion dates for each task or related sequence of events, including estimated dates for important reviews such as PDR, CDR, and first use of the vehicle at any MRTFB.

e. Ensuring FTS compatibility with the local range ground support and monitoring equipment.

1.12.3 Range Safety Office Responsibilities

The RSO is responsible for the following:

a. reviewing and approving the conceptual design, detail design, and test requirements for the FSS;

b. resolving problems associated with the design, installation, checkout, and use of the FSS;

c. reviewing and recommending action on all noncompliances;

d. attending design reviews, procedure reviews, system safety meetings, and other meetings and monitoring tests conducted on any FSS component or system, including installation of such components on launch vehicles.

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CHAPTER 2

Tailoring

2.1 Tailoring Overview

A tailored version of RCC 319 shall be developed by the affected RSOs for a specific program with the participation of the range user. To tailor the document, the following steps are to be taken.

a. Delete requirements that do not have any relation to or bearing on the affected system. Major paragraph numbers and titles of deleted requirements shall be retained followed by an annotation of Not Applicable, N/A, or other such notation. These paragraph numbers are retained in order to maintain the original paragraph numbering for the document. The paragraph numbers and titles of any subparagraphs of a deleted requirement do not need to be retained.

b. Develop new requirements or rewrite existing requirements for any new technologies or unique applications.

c. Document in text boxes the specific solution that will be used to satisfy any performance requirement.

d. Begin new designs or tests for specific components only after applicable tailoring for that item has been completed.

2.2 Tailoring Process

Step 1: An initial TIM is required where the project shall describe, in detail, the type of testing planned at each range, the vehicle configuration(s), 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 CDR.

Step 2: A line-by-line assessment is performed with all applicable RSOs 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 in the original document shall be documented as Not Applicable (N/A) or Applicable.

(1) Requirements that do not apply shall be deleted and replaced with an N/A.

(2) Requirements that are not annotated shall be considered applicable as written.

b. Applicable requirements outside a text box that cannot be strictly met by the range user may be modified under certain conditions. The range user may propose a modification to the requirement so long as compliance with the modified requirement does not result in a significant increase in risk to personnel or property over what would have resulted from the original requirement. Justification for approval of the modified requirement with supporting data and analyses required by Range Safety will be submitted to Range Safety for evaluation. Approval will result in an ELS certification from Range Safety after which the modified requirement and an associated rationale may be included in the tailored RCC 319.

c. 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.

Step 3: The tailored version of the document shall be denoted as RCC 319 [T-program name] or other such designation as required by agency or range policy and placed under configuration control. The tailored document 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 detailed knowledge about their system is known 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.

CHAPTER 3

Common Flight Termination System and Component Performance Requirements

3.1 Flight Termination System Functional Requirements

When initiated, by command or other means, an FTS shall perform the following.

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.

3.1.1 All Vehicle Types

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. Acceptability of shutdown-only systems will be range- and vehicle-dependent.

NOTE	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 endangering any protected area.

NOTE	For aeronautical systems, employing aerodynamic control surface manipulation to cause the vehicle to depart from controlled flight may be more desirable than using explosives.

g. The FTS terminate action shall not detonate solid or liquid propellant.

h. 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.

NOTE	Some solid-propellant formulations (e.g., double-base composites like DDP-70 and cross-linked polyethylene glycol high-energy formulations) are sensitive to shock and have the potential to detonate or explode on impact with the ground following a flight termination. For this reason it is important to break up the propellant to reduce the probability of ground impact detonation.

i. For multiple-stage vehicles, the flight termination of one propulsion system shall not interfere with the flight termination of any other propulsion system.

3.1.2 Manned Vehicles

In addition to the requirements in Subsection 3.1.1, the FTS requirements for manned vehicles shall also include the following.

a. The powered portion of a manned vehicle shall comply with all requirements of this document.

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

b. If vehicles that are capable of being manned 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.

NOTE	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.

3.1.3 Re-entry Vehicles (Excluding Warheads)

In addition to the requirements in Subsection 3.1.1 and Subsection 3.1.2, the FTS requirements for manned vehicles shall include the following.

NOTE	When applying the requirements of this document, the term flight shall include the reentry and landing phases for vehicles that will reenter the atmosphere. Also, with regard to reentry vehicles (RVs), the word “termination” in flight termination system includes both destructive and non-destructive means to control hazards.

a. An FTS determination analysis shall be performed for payloads and upper stages of expendable launch vehicles during ascent. It will determine whether an FTS, and what type of flight termination action, is required on any stage of an RV for the ascent and reentry phases of flight.

b. For reentry, the RV will be required to have an FTS designed with the purpose of placing the vehicle into a zero-lift/zero-thrust ballistic reentry state and mitigate the consequences of any impact to the maximum extent practicable. Consequence mitigation may include dispersing large quantities of liquid propellants if on board, fragmenting solid propellants to eliminate or mitigate explosive potential on impact, and breaking up components to maximize aero-thermal demise.

c. An RV FTS may be a command system or another range safety-approved system.

d. Reentry and landing-phase FTSs may include any system that will reduce the risk to the public to acceptable levels. Any vehicle system, such as a parachute or aerosurface controller that is used to perform an FTS function, shall meet FTS requirements.

e. In order to protect the public in the event of a vehicle failure, FTS components shall be designed to survive and function properly in the vehicle-induced environment plus a margin over the entire timeframe of the mission.

f. A TM, autonomous, or other system shall be designed to provide verification to Range Safety that vehicle range safety requirements are met so that it is safe to proceed with the reentry phase of flight. This TM shall include any data needed to indicate whether any RV system critical to safe reentry and landing is no longer capable of functioning such that it poses an unacceptable risk to the public. (This data will be used to decide whether reentry should or should not be initiated or be planned and executed so that the RV will impact in the safest possible area.)

g. A TM, autonomous, or other system shall be designed to provide verification to Range Safety that the reentry FTS has been enabled. (This verification is required prior to allowing the initiation of reentry.)

h. All FTSs that employ explosives or other hazardous systems must have a safe-and-arm (S&A) device (SAD) that can be placed in the safe position and its status verified for mission periods when it is not needed and after landing.

i. An RV that could return with a payload (either intentionally or unintentionally) shall be evaluated for the need for a payload FTS.

j. Any FTS components intended to be reused from flight to flight shall be designed to withstand the intended number of mission cycles and environments, plus margin, and still meet its performance requirements.

- Instrumentation shall be used to validate FTS component flight environments.
- All FTS components shall be designed to allow for the following testing.
    - Components shall pass recertification tests between flights that may require them to be designed to be easily removed.
    - An acceptance test or a range-approved modified acceptance test plus an end-to-end test shall be used for recertification.
- If a component cannot be tested between flights it shall be replaced between flights, unless it can be demonstrated that it will function properly for N number of flights without degrading the FTS system reliability of 0.999 at a 95% confidence level. (N is the number of mission cycles, including tests and handling, that an FTS component

has been designed to withstand and still meet its performance and reliability requirements.)

k. If flight data indicates that any FTS components are exposed to environments higher than predicted, the design of those components shall be re-qualified to the new maximum predicted environment (MPE) plus a margin of 6 dB prior to any subsequent flight. Additionally, acceptance testing shall be adjusted to reflect the new MPE.

3.2 Flight Termination System Design

3.2.1 Margins

Design margins shall be sufficient to allow a component, subsystem, or system to satisfy all 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.

Test margins shall account for test equipment and vehicle monitoring and TM tolerances.

NOTE	The performance requirements in this document contain margins based on lessons learned from numerous nominal and errant vehicle flights from all MRTFBs. In general, meeting these RCC 319 margins satisfies the margin requirement. Margins occurring in a text box may be reduced or increased depending on the specific component and vehicle application.

3.2.2 Reliability

An FTS shall have a statistically predicted reliability with a 95% single-sided lower confidence boundary of at least 0.999. This statistically predicted reliability shall also apply when phrases such as “a reliability of 0.999 at the 95% confidence level” appear in other sections of this document. A range user shall establish the predicted reliability of the system by satisfying the requirements for system reliability analysis. Note: Point estimates of reliability must be higher than 0.999 to meet this requirement.

1. The number of FTS components and piece-parts shall be kept to an absolute minimum.
2. The Terminate command output signal from the flight termination receiver (FTR) shall be designed to go directly to FTS arming devices.
3. The reliability requirement will be considered met through compliance with this document, which incorporates the following:

- performance-oriented design requirements for components;
- comprehensive acceptance and qualification testing of components; and
- pre-flight confidence tests of the entire system.

3.2.3 Redundancy

An FTS, including monitoring and checkout circuits, shall not have a single-failure point capable of any of the following.

a. Inhibit functioning of the system during the Range Safety responsibility portion of the flight. Single-fault tolerance includes maximum achievable physical separation (e.g., 180-degree separation of two redundant components) to ensure FTS survivability as described in Subsection 3.2.4.

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. a non-redundant destruct/terminate charge (if specifically approved by Range Safety).
2. A non-redundant destruct/terminate charge shall initiate at both ends by separate initiation sources.
3. There shall be one dedicated power source for each redundant leg of the FTS.
4. 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 that may result in an inadvertent termination shall be analyzed to ensure that initiation does not affect personnel safety or resource protection.
2. Single-point failures that may result in an inadvertent termination must be formally accepted by the range user for mission risk.
3. A hazard analysis shall be performed on all software/firmware to ensure that no single-point failures result in inadvertently initiating a termination.

3.2.4 Survivability

a. The FTS shall be designed to meet the reliability requirements during nominal flight, errant flight, or vehicle breakup. This survivability includes protection against vehicle-induced environments, fratricide between FTS components, and 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 feasible.
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 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.

1. Remotely piloted vehicles shall have redundant methods of terminating flight. Activation of an FTS 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 the 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 are required to have an independent single-path FTS independent of the tactical command-control system. This includes aircraft that are capable of being manned, but have been converted into targets. The onboard autopilot will be capable of maintaining vehicle stability in the event of a loss-of-uplink command, which operates within line of sight and a constant tactical command-control uplink.

   a. The tactical command-control system shall have a command flight termination capability. The combination of an independent single-path FTS 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 FTS.
   d. The tactical command-control FTS components will be required to be qualified but not to overstress levels.
   e. A flight termination 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.

NOTE	Recovery of the vehicle by a parachute system is at the option of the range user.

3. Full-scale aerial target aircraft, which are manned aircraft converted into targets containing an onboard autopilot, are required to have at least one independent single path for FTS. The FTS is independent of the tactical command-control system. The onboard autopilot is capable of maintaining vehicle stability that operates with a constant tactical command-control uplink.

   a. In applications with an independent single-path FTS:

(1) The tactical command-control system shall have a command flight termination capability. The combination of the independent single-path FTS and the tactical command-control system shall be considered to meet the FTS redundancy requirement.
(2) The independent FTS path shall be the primary means of termination, with the tactical command-control system the secondary means.
(3) The independent FTS path 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 FTS.
(4) The tactical command-control FTS components will be required to be qualified but not to overstress levels.

b. In applications with an independent redundant-path FTS, the tactical command-control system is not required to have any command flight termination capability. The independent redundant path shall meet all the requirements for a redundant FTS established in this document.
c. A flight termination 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.

NOTE	A loss-of-RF fail-safe may be designed such that it only activates if both the tactical command-control RF uplink and the independent FTS uplink are lost. Caution must be exercised in determining failure modes that would prevent the communications system from recognizing a loss of valid command-control RF uplink and preventing the fail-safe from operating.

3.2.5 System Independence

An FTS shall be capable of operating independently of any other vehicle systems. The failure of another vehicle system shall not inhibit the functioning of an FTS.

1. Primary FTS power sources shall be independent of other vehicle systems.
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/or safing;
   b. provide data to the TM system;
   c. accomplish any engine shutdown.

   Other functions require specific approval.

3. 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 in detail how the component or part satisfies the requirements.

3.2.7 Ability to Test

The FTS, components, ground support, and monitoring equipment design must allow the required tests of Chapter 4 and Chapter 5 to be performed.

1. All 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 TM.
3. All ordnance initiators shall be testable.
4. High-energy electrical ordnance initiation systems greater than 500 V such as electronic arm-and-fire devices (EAFDs), electronic safe-and-arm devices (ESADs), or exploding bridgewire (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. All EAFDs or ESADs that incorporate acceleration-activated switches or other similar 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 (Li-ion) battery design to permit open circuit voltage (OCV) testing of each cell when assembled in the battery case. This testing shall take place at the range. Individual cell testing is not required for remotely activated batteries (chemical or thermal).
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 allow for final electrical connections to the initiator to be made as late in the countdown as possible.
10. Explosive devices contained in a SAD assembly such as low-voltage initiators (LVIs) (e.g., electro-explosive devices [EEDs] and semiconductor bridge initiators), booster charges, or rotor leads shall be designed to be individually subjected to acceptance and qualification testing.
11. Recyclable valves used for termination shall be capable of functioning during 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 Safety Critical Software and Firmware

All software and firmware used in the FTS shall:

Software and firmware subject to this requirement include non-FTS systems used to control the FTS such as guidance computer safing code.

a. be designed to eliminate the possibility a single-point software failure inhibits redundant FTS functions or initiating an inadvertent termination;

b. be designed with no hidden features or "backdoor" capabilities (all features shall be documented);

c. be subjected to independent verification and validation (IV&V) in accordance with (IAW) 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 Range Safety before further production. These requirements apply to any computing system, software, or firmware that is associated with an FTS and performs a safety-critical function. Note: Appendix A contains IV&V requirements.

3.2.9 Microprocessors, Programmable Logic Units, and Memory

a. Microprocessors shall provide at least 20% spare capacity above the device's worst-case processing load.

b. Programmable logic devices shall provide at least 5% spare capacity above the device's worst-case input/output pin assignment and routing capacity. Note: Some devices are only routable to a fraction (85% - 90%) of their gate capacity. The requirement is for actual/ usable spare routing capacity.

c. Memory devices (volatile or non-volatile) shall provide at least 20% spare capacity above the device's worst-case memory requirements.

3.2.10 Component Service Life

Each FTS component shall have a specified service life and shall satisfy all of the following.

a. Each component shall satisfy all of its performance requirements after being subjected to the full length of its specified service life.

b. The component service life shall not expire before the end of flight. A range user may extend the service life of some components by satisfying the applicable service life extension (SLE) tests.

Electronic and ordnance components shall be designed to have a minimum service life of at least 10 years. Note: The minimum design service life of 10 years does not necessarily mean that the specified service life will be 10 years.

3.2.11 Consistency of Components

A range user shall ensure that each flight component and system are 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 IAW documented procedures and process control.
2. Manufacturer process controls shall provide a supplier-controlled baseline that ensures 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 shall 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 re-qualification. Approval of any proposed modification shall 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. When the original manufacturer of a component experiences a change in manufacturing location or a break in production for more than three years, the component shall undergo re-qualification to the original environments. For batteries, the maximum allowable break in production shall be one year unless a very similar battery has been produced during the break period.
6. For electrical components that have been in a continuous production process for more than five years after the most recent qualification, the vendor shall do one of the following:
   a. perform a configuration audit that compares the most recent qualification test unit to the new production units and shows no configuration changes;
   b. perform qualification testing using new production units.
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.

3.2.12 Flight Termination System 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.

NOTE	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 all delays due to tracking data input, range ground systems/displays, RSO reaction time, ground transmission systems, and airborne vehicle FTS. Additional FTS delays may affect allowable flight trajectories (may limit mission profiles), launch availability (e.g., due to a more conservative wind criteria), or mission assurance (may not allow an errant vehicle to continue to some usable mission).

3.3 Environmental Design

3.3.1 General

The FTS and each of its components shall satisfy all of their performance requirements when subjected to an environment that envelopes their respective MPEs and applicable workmanship levels plus a margin. The MPEs shall be determined by the range user and shall include all environmental levels, rates, durations, etc., as appropriate. All FTS component-mounting hardware, cables, and wires shall be considered to be FTS components for the purposes of this document.

1. All FTS components shall be designed to satisfy all performance requirements when subjected to any predicted combined environments (e.g., thermal/acceleration, thermal/vibration, thermal/shock) to which the component may be exposed.
2. Modifications made to the vehicle that result in a harsher environment than the FTS was qualified for or that modify or interfere with FTS performance will require evaluation and possible re-qualification of the FTS.

NOTE	The 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.

3.3.2 Maximum Predicted Environments

a. A range user shall determine all maximum predicted non-operating and operating environmental levels, rates of change, durations, etc., that each component of an FTS will experience.

All MPE determination shall be based on analysis, modeling, testing, and/or monitoring.

NOTE	Non-operating and operating environments include temperature (including number of thermal cycles and thermal ramp rates), random and/or sinusoidal vibration, shock, acceleration, acoustic vibration, humidity, salt fog, dust, fungus, explosive atmosphere, or electromagnetic energy that apply to a specific vehicle and launch/flight site.

NOTE	Some vehicles are soft-landing and/or recoverable that may allow the re-use of FTS components. The MPE for each piece of equipment must envelope all the anticipated environments and levels and the total durations

	to which that equipment will be exposed over its lifetime.

b. Each MPE for an FTS component shall account for uncertainties due to flight-to-flight variability and any analytical uncertainty.

1. For vehicle configurations and flight profiles for which there have been fewer than three flights, the MPE shall include an additional 4 dB for random, sinusoidal, or acoustic vibration and 4.5 dB for shock to account for environmental modeling uncertainties.
2. Once data from three representative flights has been obtained, the vibration MPEs shall be defined by the maximum enveloped peak levels at each frequency from all flight data taken at the measurement location. This new MPE does not need to include the environmental modeling uncertainty margins from item 1 above.
3. Flight data used to develop a new MPE shall be shown to envelope the predicted environment for all flights for which the new MPE is being established.

NOTE	If the new MPE exceeds the old MPE, Range Safety will determine if any of the FTS equipment needs to be re-qualified.

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 MPE vibrations 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 MPE for any future flight 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 partially or fully built at the factory and then transported to ensure that expected MPE levels are not violated.
2. Components that are sensitive to certain environments, e.g., battery sensitivity to 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 Hz to 2 kHz is definable.
4. Shock measurements from 100 Hz to 10 kHz may be performed on ground-test setups that duplicate the flight configuration.
5. To generate the MPE random vibration profile a maxi-max approach, which envelopes the highest value within a frequency band throughout the pre-flight/flight trajectory, shall be used. 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.
6. Significant changes in vehicle configuration may require additional flight monitoring.

d. All MPEs 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 type of launch/ flight platform that will be used.

3.3.3 Thermal Environment

A component shall satisfy all of its performance requirements when exposed to the maximum predicted thermal levels, thermal transition rates, number of thermal cycles, and durations plus a margin.

A component shall satisfy all of its performance requirements when exposed to the qualification thermal levels, thermal transition rates, number of thermal cycles, and durations determined in Chapter 4.

1. The minimum acceptance number of thermal cycles for each component shall be 150% of the maximum number of thermal cycles that the component could experience during pre-launch/pre-flight processing (including diurnal cycling) and flight, including all launch/flight delays and recycling, rounded up (i.e., a 50% margin on number of thermal cycles) or eight cycles, whichever is greater.
2. The MPE high temperatures for any component shall include consideration of any internal thermal conditioning systems, such as battery heaters.
3. 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.
4. Where testing at temperatures colder than the lower MPE is impractical, the number of thermal cycles may be increased to produce a thermal fatigue (screening strength) in the component that is equivalent to exposure to the calculated acceptance and qualification levels, ramp rates, and durations. Note: The number of thermal cycles needed to produce an equivalent fatigue level (screening strength) may be determined by methods such as those outlined in SMC-S-016,[6] Section 6.3.8.3. Additional guidance for electronic assemblies may be found in MIL-HDBK-344A,[7] section 5.4.3.

a. A passive electrical component shall satisfy all of its performance requirements when subjected to the following.

(1) The minimum thermal cycle temperature range shall be from −34°C to 71°C (the minimum workmanship range plus 10°C at each end). If an MPE is outside the workmanship level, the minimum thermal cycle temperature shall include an additional 10% of the difference between the MPE and the workmanship level.

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

The minimum acceptance number of thermal cycles shall be eight.

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

The minimum thermal cycle transition ramp rate of change shall be 3°C per minute.

[6] Space and Missile Systems Center. Test Requirements for Launch, Upper-Stage and Space Vehicles. SMC-S-016. 13 June 2008. May be superseded by update. Available at http://www.vibrationdata.com/tutorials/SMC-S-016_13JUN2008.pdf.

[7] Department of Defense. Environmental Stress Screening (ESS) of Electronic Equipment. MIL-HDBK-344A. 16 August 1993. May be superseded by update. Available at http://quicksearch.dla.mil/.

b. An electronic FTS component, including any component that contains an active electronic piece-part such as a microcircuit, transistor, or diode, shall satisfy all of its performance requirements when subjected to the following.

(1) The minimum thermal cycle temperature range shall be from −34°C to 71°C (the minimum workmanship range plus 10°C at each end). If an MPE is outside the workmanship level the minimum thermal cycle temperature shall include an additional 10% of the difference between the MPE and the workmanship level.

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

1. The minimum acceptance number of thermal cycles shall be eight.
2. Electronic boxes shall be powered and subjected to a minimum of 10 burn-in thermal cycles prior to the commencement of testing. The burn-in thermal cycles shall not be included in the count of the acceptance number of thermal cycles.

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

The minimum thermal cycle transition ramp rate of change shall be 3°C per minute.

c. An FTS power source shall satisfy all of its performance requirements when exposed to pre-flight 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. A remotely activated silver-zinc (Ag-Zn) or thermal battery in an unactivated state shall satisfy all of its performance requirements after being subjected to eight qualification thermal cycles from −40°C to 71°C or the MPE ±10°C, whichever is more severe.
2. A manually activated Ag-Zn battery shall satisfy all of its performance requirements after being subjected to eight qualification thermal cycles from −40°C to 71°C or the MPE ±10°C, whichever is more severe. If the battery's operating temperature will be monitored in real time with an accuracy better than ±1.5°C, the margin on both the upper and lower MPEs may be reduced from 10°C to 5.5°C.
3. The Li-ion battery qualification thermal levels shall be a minimum of the predicted temperature range (−24°C to 40°C) or the MPE ±10°C, whichever is more severe.
4. Nickel-cadmium (Ni-Cd) battery qualification thermal levels shall be a minimum of the predicted temperature range (−34°C to 40°C) or the MPE ±10°C, whichever is more severe.
5. Lead-acid battery qualification thermal levels shall be a minimum of the predicted temperature range (−10°C to 71°C) or the MPE ±10°C, whichever is more severe.
6. Any other power source shall satisfy all of its performance requirements after being subjected to eight qualification thermal cycles from 10°C lower than its minimum predicted temperature to 10°C higher than its maximum predicted temperature (−34°C to 71°C) or the MPE ±10°C, whichever is more severe.

(2) The minimum qualification number of thermal cycles shall be three times the acceptance number of thermal cycles. For batteries that are not acceptance thermal

cycled, the qualification number of thermal cycles shall be the MPE number of thermal cycles plus a margin.

1. For primary (non-rechargeable) batteries and secondary (rechargeable) manually activated Ag-Zn batteries, the minimum qualification number of thermal cycles shall be eight. Note: Primary (non-rechargeable) batteries are not acceptance thermal cycled.
2. For secondary (rechargeable) batteries, the minimum acceptance number of thermal cycles is eight. Note: This requirement does not apply to manually activated Ag-Zn batteries that may be rechargeable as they are not acceptance thermal cycled.

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

The minimum thermal cycle transition ramp rate of change shall be 3°C per minute.

d. An electromechanical FTS device, including SADs, relays, valves, interrupters, and safety switches, shall satisfy all of its performance requirements when subject to the following.

(1) The minimum thermal cycle temperature range shall be from −34°C to 71°C (the minimum workmanship range plus 10°C at each end). If an MPE is outside the workmanship level, the minimum thermal cycle temperature shall include an additional 10% of the difference between the MPE and the workmanship level.

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

The minimum acceptance number of thermal cycles shall be eight.

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

The minimum thermal cycle transition ramp rate of change shall be 3°C per minute.

e. Ordnance Components.

(1) The minimum thermal cycle temperature range shall be from −54°C to 71°C (the minimum workmanship range plus 10°C at each end). If an MPE is outside the workmanship level, the minimum thermal cycle temperature shall include an additional 10% of the difference between the MPE and the workmanship level.

(2) The qualification 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 of its performance requirements when subjected to the acceptance number of thermal cycles.
2. For SADs, the minimum acceptance number of thermal cycles shall be eight.
3. For ordnance systems that are not part of an electrical/electromechanical assembly, the minimum qualification number of thermal cycles shall be eight.

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

The minimum thermal cycle transition ramp rate of change shall be 3°C per minute.

3.3.4 Acceleration Environment

An FTS component shall satisfy all of its performance requirements when exposed to vehicle breakup acceleration levels or two times the maximum predicted flight acceleration levels, whichever is higher, for 3 times the maximum predicted acceleration duration in each of three mutually perpendicular axes.

The minimum qualification duration for this environment shall be five minutes.

3.3.5 Sinusoidal Vibration

A component shall satisfy all of its performance requirements when exposed to the maximum predicted sinusoidal vibration levels and durations plus a margin.

A component shall satisfy all of its performance requirements when exposed to the qualification sinusoidal vibration levels and durations determined in Chapter 4 and to the following.

1. Test vibration shall be three times the MPE duration on each of three mutually perpendicular axes.
2. The sweep frequencies shall be from 50% lower than the predicted lowest frequency to 50% higher than the predicted highest frequency.
3. The dwell at any sinusoidal frequency shall be three times the MPE of the three axes.

3.3.6 Transportation Random Vibration

A component shall satisfy all of its performance requirements after exposure to 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.

A component shall satisfy all of its performance requirements when exposed to the qualification transportation random vibration levels and durations determined in Chapter 4.

1. The component shall satisfy all of its performance requirements after being exposed to three times the maximum predicted transportation duration or one hour per axis, whichever is higher.
2. If the component is resonant below 10 Hz, the test vibration profile shall extend to the lowest resonant frequency.

3.3.7 Operational Random Vibration

A component shall satisfy all of its performance requirements when exposed to the maximum predicted composite random vibration profile plus a margin on each of three mutually perpendicular axes and for all frequencies from 20 Hz to 2 kHz.

A component shall satisfy all of its performance requirements when exposed to the qualification random vibration levels and durations determined in Chapter 4.

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 Range Safety. Longer low-level vibration durations shall use a factor between 1.3 and 3 depending on application and vibration level.
2. The minimum qualification test duration shall be three times acceptance test duration.
3. The MPE random vibration duration shall also include a factor of three over each critical phase of flight (e.g., liftoff, maximum Q, transonic, etc.). 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.

3.3.8 Acoustic Environment

An FTS component shall satisfy all of its performance requirements when exposed to the maximum predicted sound pressure levels and durations plus a margin.

A component shall satisfy all of its performance requirements when exposed to the qualification acoustic random vibration levels and durations determined in Chapter 4.

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 Range Safety. Longer low-level acoustic vibration durations shall use a factor between 1.3 and 3 depending on application and vibration level.
2. The minimum qualification duration shall be three times the flight duration or three minutes, whichever is higher, per axis.
3. The MPE vibration duration shall also include a factor of 3 over each critical portion of the flight (e.g., liftoff, maximum dynamic pressure, transonic, etc.). Note: 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. The frequency shall range from 50 Hz to 10 kHz.

3.3.9 Transportation Shock

An FTS component shall satisfy all of its performance requirements after being exposed to the maximum predicted packaged transportation shock environment plus a margin.

3.3.10 Bench Handling Shock

An FTS component shall satisfy all of its performance requirements after being exposed to the maximum predicted shock to be experienced during handling in its unpacked configuration plus a margin.

3.3.11 Operational Shock

An FTS component shall satisfy all of its performance requirements after being exposed to the maximum predicted operational shock levels plus a margin on each of three mutually perpendicular axes in both the positive and negative directions.

a. An FTS component shall satisfy all of its performance requirements when exposed to pre-launch/pre-flight, 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 kHz

For multi-stage vehicles, a component shall satisfy all of its performance requirements when exposed to the qualification multi-stage vehicle minimum breakup shock determined in Chapter 4.

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

3.3.12 Electromagnetic Vulnerability

The design of a system shall eliminate the possibility the maximum predicted electromagnetic interference (EMI) emissions or susceptibilities, whether conducted or radiated, affects FTS performance. The EMI susceptibility level shall ensure that subsystems and components satisfy all of their performance requirements 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[8] 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 or third-party transmitters.
   b. MIL-STD-464[9] 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 of its performance requirements and not create a hazardous condition after experiencing any environment that it could experience during transportation, storage, pre-flight processing, or pre-flight system testing plus a margin.

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, or motors in an explosive atmosphere shall be designed to prevent ignition under all component operating conditions.

[8] Department of Defense. Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment. MIL-STD-461F. 10 December 2007. May be superseded by update. Available at http://quicksearch.dla.mil/.

[9] Department of Defense. Electromagnetic Environmental Effects Requirements for Systems. MIL-STD-464C. 1 December 2010. May be superseded by update. Available at http://quicksearch.dla.mil/.

3.4 Command Termination System

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

b. A command termination 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 termination system shall result in accomplishing all the FTS functions.

d. A command termination system shall be provided with an RF input signal for each launch/flight. The signal shall:

- have an electromagnetic field intensity of at least 12 dB above the minimum level required for reliable operation over 95% of the radiation sphere surrounding the vehicle;
- maintain its signal at any point along the nominal trajectory from liftoff/release until the no-longer-terminate time or end of flight, as applicable.

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

f. For any liquid-propellant vehicle, a command termination system shall allow a flight safety official to execute a shutdown of any thrusting liquid-fueled engine prior to termination of the vehicle.

3.5 Automatic, Inadvertent-Separation, Fail-Safe, or Autonomous Flight Termination System

3.5.1 Automatic or Inadvertent-Separation Flight Termination System

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. The FTS configuration for orbital inserted stages and payloads is as follows.
   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. Propulsion systems may require an FTS if the systems:

- Are not considered a stage of the vehicle (e.g., staging system, retro-rockets, attitude control systems, or escape rockets, etc.); and
- present radiological, toxicological, explosive, or other hazards in the event of premature ignition or separation.

3.5.2 Fail-Safe System

NOTE	Typical fail-safe conditions are loss-of-power and loss-of-command-link.

NOTE	A fail-safe system does not fulfill the redundancy requirement.

NOTE	Range Safety will determine the need for a fail-safe system on a case-by-case basis.

a. Fail-Safe Conditions. A fail-safe system shall generate Arm and Terminate outputs when it has been enabled and any specified fail-safe condition occurs.

(1) Loss-of-power fail-safe.

- A loss-of-power fail-safe condition exists when the fail-safe system has been enabled and the power source voltage falls below a predefined level for longer than a predefined duration. This voltage level shall be set above the minimum specified operating voltage for all FTS components that depend on the same power source.
- The loss-of-power timer shall be reset to 0 if the power is reacquired prior to the timeout and remains present for longer than a predefined duration.

1. (Non-enhanced FTR [EFTR]) The loss-of-power fail-safe response shall occur within 5 ms after the voltage drops below the fail-safe voltage threshold for longer than the loss-of-power fail-safe duration.
2. (EFTR) The loss-of-power fail-safe duration shall be between 10 and 20 ms.
3. (EFTR) The loss-of-power timer shall be reset to 0 between 10 and 20 ms after the power is restored and remains present until the reset occurs.

(2) Receiver loss-of-command-link fail-safe.

- A loss-of-command-link fail-safe condition exists when the fail-safe system has been enabled and a specified receiver monitor tone, command message, or command message component is not detected for more than a predefined duration.
- The predefined duration for the loss-of-command-link fail-safe timer shall be based on vehicle performance characteristics.
- The loss-of-command-link timer shall be reset to 0 if the command link is reacquired prior to the timeout and remains present for longer than a predefined duration.

1. (Non-EFTR) A loss-of-command-link timer shall be reset to 0 if the command link is reacquired and remains present for at least 10 ms.
2. (EFTR) A loss-of-command-link timer shall be reset to 0 if at least one valid command is received.

b. Fail-Safe Inhibit. A fail-safe system may be configured such that it will not generate an Arm or Terminate output unless a second fail-safe system also detects a fail-safe condition. Connecting the redundant fail-safe systems together is known as cross-strapping.

(1) If a fail-safe system is capable of being cross-strapped then, once it is enabled, it shall have the capability of generating and receiving inhibit signals.

(2) Upon being enabled, the fail-safe system shall generate an inhibit signal (fail-safe output) that will remain on until a fail-safe condition is detected, at which point it shall turn off.

(3) If the fail-safe system is enabled it shall not generate an Arm or Terminate signal while it is receiving an inhibit signal (fail-safe input).

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 occur 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, it will ignore the input from the other path and output an Arm and Terminate if it experiences a fail-safe condition.

Table 3-1 displays logic for fail-safe cross-strapping.

Table 3-1. Fail-Safe Cross-Strapping Logic

Fail-Safe Enable Function		Fail-Safe Event		Fail-Safe 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	0
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

Fail-Safe Enable Function	0	Fail-Safe Not Enabled
	1	Fail-Safe Enabled
Fail-Safe Event	0	Does Not Occur
	1	Low Voltage or Loss of Tone Occurs
	X	Do Not Care State
Fail-Safe Interface Logic	0	Low
	1	High
Receiver Command Output	0	Arm and Terminate Output Off
	A/T	Arm and Terminate Output On

FSI Fail-Safe Input
FSO Fail-Safe Output

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

1. A means shall be provided to permanently deactivate the fail-safe system by use of 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 the 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 pulse or voltage level to the receiver.

1. The following apply to FTRs with fail-safe enable via the application of power to pins on the input connector.

   a. The fail-safe shall be enabled by the application of a specified voltage signal to a specified pin on the FTR input connector. The fail-safe shall not be enabled with a pulse duration of less than 5 ms but shall be enabled by a pulse duration of 18 ms.
   b. Application of a steady-state enabling signal shall not degrade the fail-safe enable circuit.
   c. Once enabled, the fail-safe shall latch and shall not become disabled by the removal of the enabling signal from the specified FTR input connector pin.
   d. For laboratory testing purposes, the fail-safe latching feature shall be reset by removing the unit input power.

2. The following apply to FTRs with fail-safe enable/disable via reception of FTR tones through the RF port.
   a. The fail-safe shall be enabled by a reception of FTR tones A and D. The fail-safe shall not be enabled by reception of these tones for less than 5 ms but shall be enabled by reception of these tones for 18 ms.
   b. Application of steady-state transmission of the enabling tones shall not degrade the fail-safe enable circuit.
   c. Once enabled, the fail-safe shall latch and shall not become disabled by the removal of either or both of the tones.
   d. The fail-safe shall be disabled by a transmission of FTR tones C and D. The fail-safe shall not be disabled by reception of these tones for less than 5 ms but shall be disabled by reception of these tones for 18 ms.
   e. Application of steady-state transmission of the disabling tones shall not degrade the fail-safe disable circuit.
   f. Once disabled, the fail-safe shall not become enabled by the removal of either or both of the transmitted tones.

Table 3-2 describes tone logic for four-tone FTRs.

Table 3-2. Tone Logic for 4-Tone Flight Termination Receiver with Fail-Safe (Commanded Fail-Safe Enable/Disable)

	Tone A	Tone B	Tone C	Tone D
Monitor	X	X	1	X
Optional	X	1	1	X
Arm	1	X	1	X
Terminate	1	1	-1	X
F/S Enable	1	0	0	1
F/S Disable	0	0	1	1

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.

   d. Command Termination Interference. A fail-safe system shall not interfere with or inhibit a commanded termination.

3.5.3 Autonomous Flight Termination System

   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, such as GPS

receivers, GPS antennas, batteries, and INSs, used to make termination decision.

b. An AFTS shall terminate flight when a vehicle violates flight safety parameters, when the vehicle is performing erratically, or during breakup.

c. Tracking systems and components needed to support the AFTS function shall meet both RCC 324 and RCC 319 requirements.

1. 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.
2. Requirements associated with accuracy, data latency, sample rate, and quality indicators shall be tailored as critical to FTSs.
3. Tracking systems used for the AFTS function shall not have single points of failure that would produce undetectable out-of-specification dynamic state data.

NOTE	Exceptions for systems such as inertial measurement units (IMUs) may be granted on a case-by-case basis if the IMU data is validated with another tracking source.

NOTE	RCC 324 performance requirements are not written to specifically address safety critical applications. RCC 324 requirements must be tailored using the more stringent criteria in RCC 319.

d. Two AFTS data transfer issues are as follows.

(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 GSE 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 field-programmable gate arrays (FPGAs) 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.

1. 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 seconds.
2. Vehicle guidance tracking sources that exceed the two required tracking sources may be used as autonomous flight termination unit (AFTU) inputs. The weighting and mission rules for these additional tracking sources shall be determined on a case-by-case basis.
3. When a shared vehicle/FTS INS is used as one of the Range Safety tracking sources, it shall be validated against an independent tracking source after every critical vehicle event before it can be accepted as a single valid tracking source.

NOTE	Tracking sources meeting the requirements of RCC 324, including "no single failures that would create undetectable false position data," are regarded as adequate.

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 credible common-cause software single-point failures. This requirement shall be met by using a Range Safety-approved software development and test standard along with IV&V.

NOTE	IEC 61508-3,[10] DOD Joint Software Systems Safety Engineering Handbook,[11] or DO-178C[12] are acceptable standard for software development and testing. These documents must be tailored for each specific application.

NOTE	Hardware and software single-point failures and deficiencies can be mitigated through the use of an independent termination circuit that activates if critical parts fail. This includes processor(s) on redundant AFTUs that stop processing data normally or other parts not meeting Range Safety requirements. 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 three 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 AFTU:

   a. a remotely switchable power input to the AFTU logic for testing;
   b. a remotely switchable power input into the AFTU Master Arm.

   The two power inputs shall be controlled separately by GSE.

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 modes that could result in inadvertent initiation during pre-launch/pre-flight testing.

[10] International Electrotechnical Commission. Part 3 - Software Requirements in *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*. IEC 61508 Edition 2.0. Geneva: International Electrotechnical Commission, 2010.
[11] Joint Software Systems Safety Engineering Workgroup. DoD Joint Software Systems Safety Engineering Handbook. 27 August 2010. May be superseded by update. Available at https://acc.dau.mil/adl/en-US/683698/file/75175/SOFTWARE_SYSTEM_SAFETY_HDBK_2010.pdf.
[12] RTCA. *Software Considerations in Airborne Systems and Equipment Certification*. RTCA DO-178C. Washington, D.C.: RTCA , Inc., 2011.

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

3.6 Flight Termination System Safing and Arming Devices

NOTE	Arming devices used on FTSs include electromechanical arm-and-fire devices, SADs, high-voltage EBW firing units, laser firing units (LFUs)/ordnance interrupters, EAFDs, and 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.

NOTE	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 Flight Termination System 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 or 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 Pre-flight Safing

Vehicles armed prior to first motion shall provide for remote and redundant safing of all FTS ordnance before launch/flight and during any launch/flight 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 safing criteria before normal thrust termination, the range user shall demonstrate that the greatest remaining thrust, assuming a 3-sigma maximum engine performance, cannot result in the stage or strap-on motor reaching a populated or other protected area. This will apply to meeting the safing criteria for one of the two safing parameters or conditions before normal thrust termination of the stage or strap-on motor.

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 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.

a. 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.

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

1. A 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 a redundant valve's ability to operate.

c. 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 pre-launch/ pre-flight testing.

3.8 Flight Termination System 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 TM requirements specified in Subsection 3.8.2 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 TM or through a hard line to the GSE.

3.8.1 Health and Status

An FTS shall interface with the vehicle's TM system to provide the data that the FSS personnel require in order to evaluate the health and status of the FTS before and during flight.

3.8.2 Telemetry Data

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

The TM data shall contain the following.

1. Signal strength for each FTR.
2. Power status to each flight termination subsystem.
3. Status of output commands for each FTR and each automatic or inadvertent-separation termination system.
4. The S&A status of each SAD.
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. The TM data indicating the enabled and disabled status of the fail-safe system.
c. Fail-Safe Timer. The TM data indicating when the fail-safe time has started and reset.

13. Missile Separation Switch Status: The TM data indicating that the missile has separated from the launcher.

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

3.8.3 Monitor Circuit Output

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 signal strength TM output (SSTO), check channel, pilot tone, battery voltage, and battery current, the minimum TM data rate shall be 100 samples per second.

3.8.4 Flight Termination System 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 vehicle 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 Flight Termination System 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. All FTS components for 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 or other derating standard approved by Range Safety.
3. Parts not directly associated with issuing FTS action or that do not degrade FTS performance, such as TM 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 Maximum, Transient, and Reverse-Polarity Voltage Protection

For components that are directly powered by the FTS power source, the component shall operate nominally after being subjected to any voltage from 0 V to the maximum power source voltage plus a margin as well as transients and reverse polarity.

1. All FTS components shall be designed to withstand, without damage, the OCV of the power source or 45 Vdc, whichever is higher.
2. An FTS electronic component shall satisfy all of its performance requirements after being subjected for a duration of no less than five minutes to a reverse-polarity voltage that could occur before flight.
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 V to the maximum specified voltage and back to 0 V without damage or producing a spurious output regardless of the voltage transition rate. The component shall function nominally after this test.

3.9.4 Redundant Circuits

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

3.9.5 Input Power

Components shall satisfy all performance requirements when power is applied.

a. 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.

b. Transient power dropout. A component shall not change state. Processors and memory devices shall be capable of returning to a fully functional configuration after experiencing a power dropout for up to a specified period of time plus a margin.

1. The component shall retain its last state during transient power dropouts of up to 50 ms.
2. Processors or memory devices shall not reinitialize or require reloading unless the component will be fully functional within 50 ms of power restoration.

NOTE	Examples of components subject to this requirement include, but are not limited to, power controls, memory or switching circuits, solid-state power transfer switches, and arm-and-enable circuits.

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, from causing interference that would inhibit the FTS from functioning or cause an undesired output of the

system. This will include energy sources such as electromagnetic energy, static electricity, or stray electrical currents.

1. If the design of an FTS component requires the use of electrostatic discharge (ESD)-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 (PCBs), 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 10 kΩ and 100 kΩ.
3. All LVI firing circuits shall be isolated from vehicle ground except for static-bleed resistors.
4. All LVI 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 direct current (DC) bonding resistance between connection points of the shielded system, to include the mechanical connection of a shielded cable/connector to a metallic enclosure/connector (such as a receiver, SAD, etc.), shall be 2.5 mΩ or less. The DC bonding resistance between the metallic enclosure and vehicle structure/ground (e.g., bolted connection) should be 2.5 mΩ or less, but exceedances may be acceptable on a case-by-case basis, typically if less than 10 mΩ. The EMI testing of the metallic enclosure should include worst-case structural bonding.
8. The shielding for firing circuits shall provide a minimum 20-dB safety margin between worst-case electrical noise and the 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% optical coverage ratio.
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 360° 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. The 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 of their performance requirements when any of its monitor outputs are subjected to a short circuit for a minimum of five minutes.
2. An FTS electronic component's critical circuits shall satisfy all of their performance requirements when any of its monitor outputs are subjected to the forward and reverse-polarity OCV of the vehicle system power source for a minimum of five minutes. This requirement shall be met in both the powered-up and unpowered modes. The minimum OCV shall be 45 V.
3. An FTS electronic component shall satisfy all its performance requirements or have a detectable failure after being subjected to a short circuit of any output for a minimum of five minutes. A component that is unable to pass the required tests is considered to have experienced a detectable failure 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 of its performance requirements 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 of its performance requirements after being subjected to repetitive functioning for at least five times the expected number required for acceptance, checkout (including re-tests caused by schedule or other delays), and operations (i.e., a 400% margin on repetitive functioning).
2. The test power-on time shall be at least 150% of nominal in-flight power-on time, at maximum temperature extremes, and shall include a 30-minute hang-fire wait period for solid-rocket motors (i.e., a 50% margin on power-on time). The test power-on time shall not be less than 45 minutes and shall be repeatable after a power-off period of not more than two minutes.
3. Firing units, without the initiators or ordnance, shall have an operating life of at least five times the expected number of firings or 1000 firings, whichever is higher, into an agreed-upon test load without degradation (i.e., a 400% margin on number of firings).
4. If the firing unit cannot meet the required number of firings in item 3 above, the ranges shall approve the total number of expected firings (acceptance test, bench test, pre-launch/ pre-flight 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 (i.e., at least a 100% margin on repetitive functioning). 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 quality assurance (QA) stamp (or initials of the person performing the test), and the results of the test. All EAFDs (or ESADs) that exceed 50% 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 at least 50%.

5. Recyclable FTS shutdown valves shall satisfy all their performance requirements after undergoing either: at least five times the maximum number of open/close cycles required for acceptance, pre-launch/pre-flight checkout, and flight; or 500 cycles, whichever is greater. Valves shall be designed with a minimum pressure cycle life of at least five times the maximum expected number of operating pressure cycles (i.e., a 400% margin on open/close cycles and pressure cycles).
6. Connectors shall satisfy all their performance requirements after undergoing either: at least five times the maximum expected number of mate/demate cycles required for acceptance tests, pre-flight tests, and flight operations, including an allowance for potential retests due to schedule delays; or 100 cycles, whichever is greater (i.e., a 400% margin on mate/demate cycles).
7. Laser-ordnance-initiator fiber-optic cable assemblies shall satisfy all their performance requirements after undergoing at least five times the maximum expected number of firings or 100 firings, whichever is higher, all at least two times the maximum firing optical power and for at least 10 times the duration of the maximum firing pulse (i.e., a 400% margin on number of firings and a 900% margin on firing duration).

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/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 TM.

A self-test shall be automatically performed upon power up and when commanded.

a. Execution of the self-test shall not inhibit normal processing or cause a normal (non-self-test) output to change.

b. Failure of a self-test shall not disable the component.

c. A software/firmware integrity test using an approved authentication technique shall be applied to all FTS software/firmware components.

d. For any units employing a cryptographic module, a cryptographic algorithm test using a known answer shall be conducted for all applicable modes to verify proper operation.

3.9.11 Electromagnetic Interference and Compatibility Protection

The design of an FTS component shall eliminate the possibility the maximum predicted EMI emissions or susceptibilities, whether conducted or radiated, affects the component's performance. A component's EMI susceptibility level shall ensure that the component satisfies all of its performance requirements when subjected to the maximum predicted emission levels of all other vehicle components and external sources to which the component would be exposed.

1. All FTS components shall be designed to meet the requirements of MIL-STD-461. 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 higher.

3.9.12 Ordnance Initiator Circuits

a. All LVI firing circuits that function at less than 50 V shall meet the following requirements.

(1) The firing circuit shall deliver the specified all-fire current plus a margin. The current shall be delivered at the lowest battery voltage and under the worst-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.

The firing circuits shall deliver a minimum of 150% of the specified all-fire current for no less than 10 times the worst-case initiator firing time (i.e., a 50% margin on the specified all-fire current and a 900% margin on the specified initiator firing time.).

(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 dc no-fire power.

b. High-voltage initiator firing circuits that function at greater than 500 V shall meet the following requirements.

(1) The firing unit shall deliver the specified all-fire voltage plus a margin to the initiator.

The firing unit shall deliver a minimum of 150% of the specified all-fire voltage (i.e., a 50% margin on the specified all-fire voltage).

(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 Subsection 3.2.11.

1. A commanded output function shall be generated no later than 50 ms after receipt of the completed command signal.
2. An FTR shall generate a command output between 4 ms and 25 ms after receipt of the completed command signal.
3. An AFTS shall initiate a terminate output within 250 ms of a terminate criteria violation.

NOTE	The output of a commanded function should occur within 5 ms of receipt of a completed command signal.

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 IAW the specification. All 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 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

All FTS components shall be protected to withstand non-operating and operating environments.

1. Non-operating and operating environments shall include salt fog, humidity, altitude, storage, explosive atmosphere, transportation, pre-flight, and flight.
2. The FTS component case finish and construction shall provide protection against corrosion, cracking, peeling, and degradation of electrical connections and impedance paths necessary to ensure performance within the requirements of the procurement specification under all environmental testing conditions.
3. Low-voltage electronic components (less than 50 V) shall be sealed so as to admit a gas

leak rate no greater than the equivalent of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at standard leak conditions (SLC).

4. High-voltage electronic components (greater than 500 V) shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

3.9.17 Power Circuits

Components used in an FTS' power circuits shall be capable of delivering the worst-case operating current and voltage at the worst-case operating duration plus a margin.

The components shall be capable of delivering 150% of the highest operating current and voltage for 10 times the worst-case operating time (i.e., a 50% margin on the specified operating current and voltage and a 900% margin on the specified operating time).

3.9.18 Leakage Current

The maximum leakage current through any uncommanded 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 in any downstream electrical system.

Leakage current shall meet the requirement that when the component is subjected to power-up, power-down, power dropout, and steady-state operation, there shall be a minimum 20-dB safety margin between the component leakage output and the specified no-fire stimulus level for down-stream electronic circuits or ordnance initiation systems.

1. The component shall not produce any command outputs greater than 1 V in amplitude into a 10-kΩ load (100 μA) for more than 200 μs during a voltage transient and shall meet its performance requirements after the transient.
2. For enhanced flight termination system (EFTS) receivers, the component shall not produce any command outputs greater than 9 V in amplitude into a 10-kΩ load (900 μA) for more than 100 μs during a voltage transient and shall meet its performance requirements after the transient.
3. For steady-state input power, the leakage current from any uncommanded output port shall be no more than 50 μA.
4. The LFU's optical output power while in the safe condition shall be at least 60 dB less than the guaranteed no-fire level at the main firing and BIT frequencies.

3.9.19 Warm-Up Time

An electronic component shall satisfy all its performance requirements after being powered for the specified warm-up time.

3.10 Flight Termination System 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 pre-launch/ pre-flight and flight.

b. Any monitor and checkout current in an LVI system firing line shall not exceed 10% of the no-fire current of the LVI.

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 Flight Termination System Ordnance Path

1. Ordnance items shall be assigned to the appropriate DoD or United Nations (UN) hazard classification and storage compatibility group IAW DoD 6055.9-STD[13].
2. Ordnance items that have not previously been classified and cannot be classified based on similarity with previously classified items shall be tested IAW TB 700-2/NAVSEAINST 8020.8B/TO 11A-1-478,[14] and classified accordingly.
3. Ordnance items shall have a Department of Transportation (DOT) classification.
4. Only explosives listed in MIL-STD-1316[15] for in-line use or that are approved by the associated safety evaluation board will be allowed in the initiator and explosive path.
5. If modified secondary (composition) explosives are used, their sensitivity characteristics shall be established by test IAW AOP-07,[16] ADA086259,[17] or the equivalent. Approval of any modified secondary explosive shall be approved by Range Safety on a case-by-case basis.

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.

1. Explosive paths containing cylindrical donor and receptor charges shall use the end-to-end

[13] Department of Defense. DoD Ammunition and Explosives Safety Standards. DoD 6055.09-STD. 29 February 2008. May be superseded by update. Available at https://www.dtic.mil/DTICOnline/downloadPdf.search?collectionId=tr&docId=ADA507516.

[14] Departments of the Army, the Navy, and the Air Force. Department of Defense Ammunition and Explosives Hazard Classification Procedures. TB 700-2/NAVSEAINST 8020.8C/TO 11A-1-47. 30 July 2012. May be superseded by update. Available at https://www.ddesb.pentagon.mil/docs/TB700-2.pdf.

[15] Department of Defense. Fuze Design, Safety Criteria For. MIL-STD-1316E. 10 July 1998. May be superseded by update. Available at http://quicksearch.dla.mil/.

[16] North Atlantic Treaty Organization. Manual of Data Requirements and Tests for Qualification of Explosive Material for Military Use. AOP-07 Ed. 2. 18 December 2005. May be superseded by update. Available to users with appropriate credentials at https://nsa.nato.int/protected/.

[17] Joint Technical Coordinating Group for Air Launched Non-Nuclear Ordnance Working Party for Explosives. Joint Services Evaluation Plan for Preferred and Alternative Explosive Fills for Principle Munitions Volume 4: Joint Services Safety and Performance Manual for Qualification of Explosives for Military Use. 19 September 1972. May be superseded by update. Available at http://www.dtic.mil/get-tr-doc/pdf?AD=ADA086259.

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.

3.11.2 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% confidence level.

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 pre-launch/pre-flight configuration.
4. All ordnance connections shall be capable of connection and disconnection for a minimum of five times the number of planned cycles or 10 cycles, whichever is higher, without causing any damage or degradation of performance (i.e., a 400% margin on mate/demate cycles for ordnance connectors).

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 Radio Frequency 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 to each FTR when subjected to performance degradation caused by the command transmitter system variations, vehicle flight conditions, and FTS hardware performance variations.

1. Unless otherwise specified, RF receiving system components shall be designed for a nominal 50-Ω impedance and shall yield an overall voltage standing wave ratio (VSWR) of 2:1 or less across the specified passband for all operating environments.
2. There shall be no more than a 4-dB RF power 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 minimize the fluctuation of the received signals as the vehicle rolls.
5. The RF receiving system 3-dB band edges shall be more than 180 kHz above and below the assigned center frequency.

3.12.2 Sensitivity

An RF receiving system shall provide command signals to each FTR at an electromagnetic field intensity of no less than 12 dB above the level required for reliable receiver operation. The system shall satisfy the 12-dB margin over 95% 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 losses due to plume or flame attenuation, and vehicle trajectory. For each flight, the system shall satisfy the 12-dB margin at any point along the nominal trajectory until the end of Range Safety responsibility.

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

1. locally induced RF noise sources;
2. vehicle plume;
3. the maximum predicted noise floor (including interference sources and high-power pulse radars);
4. range command transmitter performance variations;
5. vehicle trajectory; and
6. flight hardware performance variations.

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 greater 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.

NOTE	Current range command systems employ left-hand circular polarized antennas.

3.12.4 Radio Frequency Coupler

An FTS shall use a passive RF coupler to combine the RF input signals 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 and from all output ports.

c. Each output port shall be isolated from all other output ports.

d. 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.

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.

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 electronic parts requirements of Section 3.9;

d. satisfy all of its performance requirements and reliably process a command signal when subjected to range command transmitter 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);

e. accept all specified input signals (including any receiver set-up commands, the command RF link and associated command messages, fail-safe inputs, etc.); and

f. produce all specified output signals (including command outputs, monitor outputs, fail-safe outputs, user-defined message outputs, etc.)

3.13.2 Radio Frequency Processing – Standard and High-Alphabet Tone-Based Flight Termination Receivers

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 pre-flight and flight environments.

a. Voltage Standing Wave Ratio. The RF port 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.

1. The FTR shall have an RF port input impedance of 50 Ω.
2. The FTR shall have an RF port VSWR of 2:1 or less over the specified 60-dB passband.

b. 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 VSWR.

c. Radio Frequency Input Characteristics.

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

1. An FTR's measured threshold sensitivity shall remain within 3 dB of its initial acceptance test value throughout its service life.
2. The measured threshold sensitivity shall not be less than −116 dBm.

(2) Guaranteed Sensitivity. The FTR shall satisfy 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 guaranteed sensitivity shall be the value used for the RF link analysis.
2. The guaranteed sensitivity shall be derived using a margin above the design threshold sensitivity level.
3. The guaranteed sensitivity of the FTR shall be between −116 dBm and −107 dBm.

(3) Radio Frequency Dynamic Range. The FTR shall satisfy all of its performance requirements 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 FTR shall operate with input RF power levels up to +13 dBm (20 mW).

(4) Noise Immunity. The FTR shall be designed such that noise will not interfere with FTR performance (i.e., RF commands shall not be inhibited by noise) and such that noise shall not result in an inadvertent output.

The guaranteed sensitivity shall have a minimum 3-dB margin above the noise floor. The noise floor shall include thermal noise, range RF transmitting sources, interfering sources, and vehicle-generated noise.

d. Signal Strength Monitor.

(1) The FTR shall include a signal-strength-monitoring circuit that accurately monitors and outputs the strength of the RF input signal during flight.

(2) The output of the monitor circuit (the SSTO) shall be directly related and proportional to the strength of the RF input signal from the receiver threshold to monitor circuit saturation.

(3) The SSTO quiescent (no RF signal) 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 signal level shall be compatible with vehicle TM system interfaces and provide a response time that allows detection of RF-interfering sources and dropouts.

The response time of the signal-strength-monitoring circuitry shall be 4 ms or less.

(6) The slope of the monitor circuit output shall not change polarity from threshold to circuit saturation.

1. The FTR SSTO voltage, while operating into a 10-kΩ and flight-representative TM load, shall be IAW the following requirements.
   a. The quiescent condition shall produce an SSTO of 0.5 ± 0.25 Vdc.
   b. An input RF signal at the measured threshold sensitivity level shall result in an SSTO greater than 0.1 Vdc above that for a quiescent input.
   c. The SSTO output level shall reach 4.5 Vdc with an RF input between −60 dBm and −50 dBm
   d. The slope 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 the measured threshold to circuit saturation. From saturation to +13 dBm there shall be no more than a 50-mV drop.
2. The SSTO voltage shall not be used as a command output monitor.

e. Operational Band. The FTR shall reliably process all tones and commands modulated on a carrier that is centered within the specified minimum operational band.

1. The minimum operational band edges shall be more than 45 kHz above and below the assigned center frequency.
2. The operational bandwidth margin shall include the following:
   a. 2 times 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.

3. The intermediate frequency (IF) peak-to-valley ratio requires that for a carrier input at the guaranteed threshold sensitivity level, the received signal strength as indicated by the SSTO shall not vary by more than 3 dB across the operational band.

f. Decoder Channel FM Deviation. The FTR shall reliably process the intended frequency-modulated tone 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 two times the maximum to minus half the minimum of the total combined tolerances of all applicable RF performance factors.
2. The following are the requirements of the RF deviation threshold for each channel.
   a. The FTR shall satisfy all of its performance requirements when the input RF carrier is deviated over the range of ±27 kHz to ±33 kHz per tone.
   b. The tone decoder deviation operating threshold region shall be between ±9 kHz and ±18 kHz.

NOTE	Current range command systems employ nominal FM tone deviations of ±30 kHz per tone.

g. Decoder Channel Band edges. 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 Decoders:
   a. The decoder channel band edges shall be more than 1% above and below the assigned center frequency at 2 dB above the threshold deviation.
   b. The decoder channel band edges shall be less than 4% above and below the assigned center frequency at 14 dB above the threshold deviation when tested at the box level.
   c. The decoder channel band edges shall be less than 4% above and below the assigned center frequency at 20 dB above the threshold deviation when tested at the board level.
2. High-Alphabet Tone Decoders:
   a. The decoder channel band edges shall be more than 40 Hz (~0.25%) above and below the assigned center frequency at 2 dB above the threshold deviation.
   b. The decoder channel band edges shall be less than 600 Hz (~4%) above and below the assigned center frequency at 20 dB above the threshold deviation.

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

A tone decoder for a particular tone that is actively decoding that tone shall not drop the tone due to the presence of any combination of other tones frequency-modulated with deviations set at ±50 kHz per tone.

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

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

1. A high-alphabet FTR shall meet performance requirements during timing variations between symbols.
2. A high-alphabet FTR shall process command signals having timing variations from two times the maximum to half the minimum timing specification of the ground system.

k. Acquisition and Re-Acquisition Time. Upon initial RF reception, the FTR shall acquire and synchronize the command signal and generate the first command and TM outputs within the specified time and reliability at any RF power level within the dynamic range.

l. Command Response Time. After appropriate signal acquisition and synchronization, the FTR shall generate all appropriate command and TM outputs within the specified time after receipt of a complete command or command message.

For standard FTRs (not high-alphabet) the command response time from the time the RF signal is applied to the input to the output of the appropriate command shall be between 4 ms and 25 ms.

m. Message Format (High-Alphabet). The FTR shall process the specified command format and messages.

The FTR shall process the command format and messages as specified in the RCC 319-14 supplement.[18]

n. Check Channel. The FTR shall decode a check-channel tone (Standard FTR) or pilot tone (High-Alphabet) and provide a TM output. The presence or absence of this tone signal shall not affect any other FTR command processing or output capability.

o. Termination Sequence. The FTR shall provide the required command output IAW the design specification. The FTR shall generate 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. Apply RCC tones A and C. Removal of tone C during Arm-to-Terminate switching shall not cause loss-of-arm output.
2. Flight Terminate Command.
   a. With RCC tones A and C on (Arm), remove tone C, and apply tone B.
   b. There may be a tone overlap during transition; that is, tone B may be applied before

[18] Range Commanders Council. Flight Termination Systems Commonality Standard Supplement. RCC 319-14. September 2014. May be superseded by update. Available to people with sufficient credentials from the RCC private page: https://wsdmext.wsmr.army.mil/site/rccpri/Publications/Forms/AllItems.aspx.

tone C is removed.

c. If overlap occurs, neither the Arm nor the Terminate shall be lost or inhibited.

d. Once the Terminate command is activated, it shall be continuous as long as tones A and B are being applied.

Example Tone Combinations for Multiple Vehicles.

Logic Sequence	Decoder Output
Tone C	Monitor
Tone D (if available)	Check Channel
Tones B and C on	Optional
Tones A and C on	Arm
Tones A, B, and C on Followed by Tone C off	Arm Terminate
Tones A and C on Tone B on Followed By Tone C Off	Arm Arm Terminate
Tones A and C on Followed by Tone C off Then Tone B on	Arm Arm Terminate

Vehicles	Check Channel	Optional	Arm	Terminate
A	See Note	2 & 5	1 & 5	1 & 2
B	See Note	2 & 3	1 & 3	1 & 2
C	See Note	2 & 6	1 & 6	1 & 2
D	See Note	2 & 7	1 & 7	1 & 2
E	See Note	2 & 8	1 & 8	1 & 2
Note: Check channel is the same for all vehicles in this example.				

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

a. The decoder input command message shall consist of a frequency-modulated 11-character tone pattern.

b. Each character shall consist of two simultaneously modulated tones as specified in the supplement.

NOTE	High-alphabet command codes are provided to the range user by an National Security Agency-approved process.

NOTE	Further information on the high-alphabet message format may be found in RCC 319-14 Supplement.

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

NOTE	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 outside the FTR specified RF passband plus a margin.

The FTR shall continue to process commands when subjected to any interfering frequency from 10 MHz to 1 GHz (excluding the FTR-specified RF passband) at a power level up to 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 Band edges: The FTR shall have an IF at 3 dB with band edges more than 90 kHz above and below the assigned center frequency and at 60 dB with band edges less than 90 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned RF center frequency.
2. Image Rejection: The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious-Response/Rejection: The FTR shall provide at least 60 dB of rejection (referenced to the receiver response at the assigned center frequency) of signals from 10 MHz to 1 GHz, excluding the 60-dB passband of the receiver.
4. Range Transmissions Rejection: The FTR shall satisfy all performance requirements when subjected to all intended and unintended range transmitting sources.

NOTE	Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

q. In-Band Interference. The FTR shall satisfy all performance requirements when subjected to specified in-band interference.

NOTE	The specific requirements for an interfering signal will be determined on a case-by-case basis.

(1) FM White Noise Rejection. The FTR shall satisfy all performance requirements when subjected to specified frequency-modulated white noise generated by the range command transmitter or other sources plus a margin.

The FTR shall be capable of processing all command inputs when the FTR is subjected to an RF input signal with a carrier at the assigned center frequency and RF power set at −95 dBm that is frequency-modulated by white noise containing all frequencies between 1 Hz and 600 kHz at a deviation 12 dB higher than the highest measured deviation threshold of any of the individual RCC tones.

(2) Capture Ratio. The FTR shall satisfy all performance requirements and reject any interfering signal of less than 80% of the intended signal power level.

3.13.3 Inadvertent Command Output - Tone-Based Receiver

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. 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.

b. Dynamic Stability. The FTR shall not produce an inadvertent output when subjected to an RF input short circuit, open circuit, or changes in input VSWR.

c. Tone Decoder Noise Rejection. The FTR shall not trigger any tone channel outputs for tone inputs less than the specified maximum FM noise guard deviation plus a margin.

A tone decoder shall not produce an output for a tone frequency-modulated with a deviation of less than ±9 kHz.

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

A tone decoder for a particular tone shall not respond to any combination of other tones frequency-modulated with deviations set at ±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. Out-of-Band Signal Rejection. The FTR shall not produce an inadvertent output in response 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 pre-launch/pre-flight and flight plus a margin.

(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 Band edges: The FTR shall have an IF at 3 dB with band edges more than 90 kHz above and below the assigned center frequency and at 60 dB with band edges less than 180 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned RF center frequency.
2. Image Rejection: The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious-Response/Rejection: The FTR shall provide at least 60 dB of rejection, (referenced to the receiver response at the assigned center frequency) of signals from 10 MHz to 1 GHz, excluding the 60 dB passband of the receiver.
4. Range Transmissions Rejection: The FTR shall satisfy all performance requirements

when subjected to all intended and unintended range transmitting sources.

NOTE	Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

g. In-Band Noise Immunity. The FTR shall not produce an inadvertent output when subjected to specified in-band noise sources.

(1) Quiescent Response. The FTR shall not produce an inadvertent output when no RF input is applied (i.e., when the receiver's signal detection circuitry is only exposed to its own internal noise).

(2) Frequency-Modulated White Noise Rejection. The FTR shall reject the specified frequency-modulated white noise generated by the range command transmitter or other sources plus a margin.

The FTR shall not respond to a frequency-modulated white noise RF input that has a minimum FM deviation 12 dB above the measured threshold deviation.

(3) Amplitude Modulation 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 any command outputs when the FTR is subjected to 100% amplitude modulation (AM).

NOTE	This requirement addresses an AM signal modulated on the range-transmitted FM signal.

3.13.4 Radio Frequency Processing - Enhanced Flight Termination Receivers

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 EFTR shall satisfy all of the following for all pre-flight and flight environments.

a. Voltage Standing Wave Ratio. The RF port 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.

1. The FTR shall have an RF port input impedance of 50 Ω.
2. The FTR shall have an RF port VSWR of 2:1 or less over the specified 60-dB passband.

b. 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 VSWR.

c. Radio Frequency Input Characteristics.

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

1. An FTR's measured threshold sensitivity shall remain within 3 dB of its initial acceptance test value throughout its service life.
2. The measured threshold sensitivity shall not be less than −116 dBm.

NOTE	The measured threshold sensitivity is the lowest RF power level that yields a message error rate no greater than 1 in 10,000 messages.

(2) Guaranteed Sensitivity. The FTR shall satisfy 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 guaranteed sensitivity shall be the value used for the RF link analysis.
2. The guaranteed sensitivity shall be derived using a margin above the design threshold sensitivity level.
3. The guaranteed sensitivity of the FTR shall be between −116 dBm and −107 dBm.

(3) Radio Frequency Dynamic Range. The FTR shall satisfy all of its performance requirements 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 FTR shall operate with input RF power levels up to +13 dBm (20 mW).

(4) Noise Immunity. The FTR shall be designed such that noise will not interfere with FTR performance (i.e., RF commands shall not be inhibited by noise) and such that noise shall not result in an inadvertent output.

d. Signal Strength Monitor.

(1) The FTR shall include a signal-strength-monitoring circuit that accurately monitors and outputs the strength of the RF input signal during flight.

(2) The output of the monitor circuit (the SSTO) shall be directly related and proportional to the strength of the RF input signal from the FTR threshold to monitor circuit saturation.

(3) The SSTO quiescent 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 signal level shall be compatible with vehicle TM system interfaces and provide a response time that allows detection of RF interfering sources and dropouts.

The response time of the signal-strength-monitoring circuitry shall be 4 ms or less.

(6) The slope of the monitor circuit output shall not change polarity from threshold to circuit saturation.

1. The FTR SSTO voltage, while operating into a 10-kΩ and flight-representative TM load, shall be IAW the following requirements.
   a. The quiescent condition shall produce an SSTO of 0.5 ± 0.25 Vdc.
   b. An input RF signal at the measured threshold sensitivity level shall result in an SSTO greater than 0.1 Vdc above that for a quiescent input.
   c. The SSTO output level shall reach 4.5 Vdc with an RF input between −60 dBm and −50 dBm.
   d. The slope 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 the measured threshold to circuit saturation. From saturation to +13 dBm there shall be no more than a 50-mV drop.
2. The SSTO voltage shall not be used as a command output monitor.

e. Operational Band. The FTR shall reliably process all commands modulated on a carrier that is centered within the specified minimum operational band.

1. The minimum operational band edges shall be greater than 35 kHz above and below the assigned center frequency.
2. The operational bandwidth margin shall include the following:
   a. Two times 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.
3. The IF peak-to-valley ratio requires that for a carrier input at the guaranteed threshold sensitivity level, the received signal strength as indicated by the SSTO shall not vary by more than 3 dB across the operational band.

f. Command Signal Frequency Modulation Deviation. The FTR shall reliably process the intended frequency-modulated command signal using a nominal FM deviation plus a margin.

1. The margin shall be at least two times the maximum to minus half the minimum of the total combined tolerances of all applicable RF performance factors.
2. The FTR shall satisfy all of its performance requirements when the input RF carrier is deviated over the range of ±45 kHz to ±55 kHz.

NOTE	Current EFTS range command systems employ nominal command signal FM deviations of ±50 kHz.

g. Inverted Modulation. The FTR shall detect and compensate for signals that are inverted at the transmitter (i.e., a positive voltage generating a negative frequency offset and a negative voltage generating a positive frequency offset).

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

The FTR shall process commands at two times the maximum and half the minimum timing specification of the ground system.

i. Acquisition and Reacquisition Time. Upon initial RF reception, the FTR shall acquire and synchronize the command signal and generate the first command and TM outputs within the specified time and reliability at any power level within the dynamic range.

The time from initial RF reception of an appropriately modulated EFTS command signal to output of the first command and TM outputs by the FTR shall be within 60 ms (3 times nominal frame length of 20 ms) for at least 95% of the samples and within 100 ms for all samples.

j. Command Response Time. After appropriate signal acquisition and synchronization, the FTR shall generate all appropriate command and TM outputs within the specified time after receipt of a complete command or command message.

The FTR shall generate a command output within 1 ms after receipt of the completed command signal when tested at the specified threshold sensitivity.

k. Message Format. The FTR shall process the specified command format and messages.

The FTR shall process the command format and messages as specified in the EFTS Command Link Interface Requirements Document .[19]

l. Message Error Rate. The FTR shall receive and process messages that are within the specified signal variation limits with an error rate no greater than 1 in 10,000 messages.

m. Termination Sequence. The FTR shall provide the required command output IAW the design specification. The FTR shall generate a Terminate command only if preceded by an Arm command.

n. Out-of-Band Signal Rejection. The FTR shall satisfy 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 commands when subjected to interfering signals outside the receiver-specified RF passband plus a margin.

The FTR shall continue to process commands when subjected to any interfering frequency from 10 MHz to 1 GHz (excluding the receiver-specified RF passband) at a power level up to 60 dB above the guaranteed sensitivity signal level.

[19] Range Safety Group. Enhanced Flight Termination System (EFTS) Command Link Interface Requirements Document (IRD) Version 2.6. FA9300-04-D-0002. 24 September 2007. May be superseded by update. Available on request by people with appropriate credentials to Range Commanders Council Secretariat, usarmy.wsmr.atec.list.rcc@mail.mil.

(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 Band edges: The FTR shall have an IF at 55 dB with band edges less than 180 kHz above and below the assigned center frequency and at 60 dB with band edges less than 275 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned center frequency.
2. Image Rejection: The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious-Response/Rejection: The FTR shall provide at least 60 dB of rejection of continuous wave (CW) signals from 10 MHz to 1 GHz (excluding the frequency band $F_0 \pm 275$ kHz). In addition it will provide 55 dB of rejection of CW signals within the frequency band $F_0 \pm 275$ kHz (excluding the frequency band $F_0 \pm 180$ kHz). The rejection levels shall be referenced to the response at the assigned center frequency of the receiver.
4. Range Transmissions Rejection: The FTR shall satisfy all performance requirements when subjected to all intended and unintended range transmitting sources.

NOTE	Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

o. In-Band Interference. The FTR shall satisfy all performance requirements when subjected to specified in-band interference.

The FTR shall be capable of processing all command inputs when it is subjected to an interfering RF input signal with a carrier at the assigned center frequency and RF power set at −17 dBm (−107 dBm + 90 dB) that is modulated by a signal with the following characteristics:

1. modulation - binary phase shift keying (BPSK);
2. processor clock frequency - 5 Mbps;
3. bit sequence - pseudo-random bit sequence generated with a 15-bit generator ($2^{15}-1$ bit sequence);
4. burst repetition rate - 100 Hz;
5. burst duration - 1.06 ms.

NOTE	The specific requirements for an interfering signal will be determined on a case-by-case basis.

For capture ratio, the FTR shall satisfy all performance requirements and reject any interfering signal of less than 80% of the intended signal power level.

3.13.5 Inadvertent Command Output - EFTR

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. 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.

b. Dynamic Stability. The FTR shall not produce an inadvertent output when subjected to an RF input short circuit, open circuit, or changes in input VSWR.

c. Out-of-Band Signal 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 pre-launch/pre-flight and flight plus a margin.

The FTR shall not generate an inadvertent command when subjected to any interfering frequency from 10 MHz to 1 GHz (excluding the FTR-specified RF passband) at a power level up to 60 dB above the guaranteed sensitivity signal level.

NOTE	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 Band edges: The FTR shall have an IF at 55 dB with band edges less than 180 kHz above and below the assigned center frequency and at 60 dB with band edges less than 275 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned center frequency.
2. Image Rejection: The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious-Response/Rejection: The FTR shall provide at least 60 dB of rejection of CW signals from 10 MHz to 1 GHz (excluding the frequency band $F_0 \pm 275$ kHz). In addition it will provide 55 dB of rejection of CW signals within the frequency band $F_0 \pm 275$ kHz (excluding the frequency band $F_0 \pm 180$ kHz). The rejection levels shall be referenced to the response at the assigned center frequency of the receiver.
4. Range Transmissions Rejection: The FTR shall satisfy all performance requirements when subjected to all intended and unintended range transmitting sources.

NOTE	Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

d. In-Band Noise Immunity. The FTR shall not produce an inadvertent output when subjected to specified in-band noise sources.

The FTR shall be capable of processing all command inputs when it is subjected to an interfering RF input signal with a carrier at the assigned center frequency and RF power set at −17 dBm (−107 dBm + 90 dB) that is modulated by a signal with the following characteristics:

1. modulation - BPSK;
2. processor clock frequency - 5 Mbps;
3. bit sequence - pseudo-random bit sequence generated with a 15-bit generator (2^{15}−1 bit

sequence);
4. burst repetition rate - 100 Hz;
5. burst duration - 1.06 ms.

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 Section 3.9.

3.14.2 Flight Termination System 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, pre-flight, flight, and reuse environments.

3.14.3 Shielding

All wiring and connectors shall have shielding that ensures the FTS will not experience an inadvertent termination output when subjected to EMI levels 20 dB higher than the highest EMI induced by vehicle and launch site systems. The shielding shall ensure the FTS satisfies all of its performance requirements.

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 360° 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 5 Ω or less.
9. Firing circuits and control circuits shall be shielded from each other.

3.14.4 Dielectric Withstanding Voltage

The dielectric withstanding voltage (DWV) between mutually insulated portions of wires or connectors shall satisfy all of its performance requirements at its rated voltage and any momentary over-potential due to switching, surge, or any other similar phenomenon plus a margin.

1. This test shall be performed at a minimum of 150% of the operating voltage or 500 Vdc, whichever is higher. 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.

3.14.5 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 of its performance requirements when subjected to workmanship testing, 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 2 MΩ or more at a minimum of 500 Vdc.
2. For high-voltage circuits, the insulation resistance between the shield and conductor shall be 50 MΩ or more at 150% of the rated output voltage or 500 Vdc, whichever is higher.

3.14.6 Wiring Capacity

If any wiring or connector will experience continuous electrical loads for 100 seconds or longer, that wiring or connector, including each connector pin, shall have a capacity of no less than 150% of the design load (i.e., a 50% margin on the design electrical 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.

3.14.7 Tensile Load

All wiring, including any cable or connector, shall satisfy all of its performance requirements when subjected to the required qualification test pull force per Subsection 4.14.11.

A mated connector shall satisfy all of its performance requirements after an axial pull on the cable or harness of at least 133 N (30 lbf) for a minimum of one minute.

3.14.8 Redundant Circuits and Reliability

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

3.14.9 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.

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

3.14.10 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.

3.14.11 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.

3.14.12 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 of its performance requirements.

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 not result in any dropouts of more than 0.1 ms in duration. All other connectors shall be limited to dropouts of no more than 5 ms. Note: The 0.1-ms dropout limit is based on a typical EED firing time of 1 ms. The 5-ms dropout limit is based on the requirement for FTS components to not change state during dropouts of up to 50 ms.

3.14.13 Connector Locking

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

3.14.14 Wiring and Cable Protection

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

3.14.15 Connector mate-demate requirements

All connectors shall meet their performance requirements after being subjected to at least five times the number of planned mate/demate cycles.

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

3.14.16 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.

NOTE	These connectors include umbilical and staging connectors.

NOTE	Environments that can cause pin-to-pin shorting include rocket motor plasma and condensation.

NOTE	Dead-face connectors may be an acceptable solution. A dead-face connector employs any of several methods to prevent an electrical hazard following a demating event. See, for example, NASA/CR-2002-211839.[20]

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 laser-initiated detonator (LID) functioning when subjected to stressing conditions such as aging, operating environments, non-operating 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.

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 of its performance requirements for the maximum number of operating outputs at the maximum optical power output and duration expected throughout its life plus a margin.

1. The fiber-optic cable assembly shall withstand, without degradation in performance, repetitive firing for five times the total expected number of cycles required for acceptance tests, pre-flight tests, and flight operations, including an allowance for potential retests due to schedule delays (i.e., a 400% margin on firing cycles).
2. The fiber-optic cable assembly shall have the capacity to output at least 150% of the maximum firing optical power for no less than 10 times the duration of the maximum firing pulse (i.e., a 50% margin on firing optical power and a 900% margin on firing duration).

3.15.4 Bend Radius

The fiber-optic cable assembly shall satisfy 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 damage 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

[20] J.M. Berki and N.B. Sargent. SEE Design Guide and Requirements for Electrical Deadfacing. NASA/CR-2002-211839. July 2002. Available at http://see.msfc.nasa.gov/publications/CR-2002-211839.pdf.

the no-fire level of the LID.

3.15.6 Handling

Optical cables and connectors shall not degrade in performance when subjected to the greatest pull force that could be experienced during manufacturing, installation, and flight plus a margin.

A cable or connector shall satisfy all of its performance requirements after being subjected to an axial pull force of at least 133 N (30 lbf) for a minimum of one minute.

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 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 meet their performance requirements when subjected to worst-case optical misalignment, contaminants, or condensation plus a margin.

3.15.10 Built-In Test 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 Section 3.9 and the manufacturer's performance specification.

3.16.2 Capacity

An FTS battery shall have a manufacturer-specified capacity that is no less than the required operational capacity plus a margin. Operational capacity shall be calculated using the following elements.

1. The specified capacity shall include a margin of at least 0.5 A-h over the required capacity.
2. Batteries shall have a lifetime of at least 150% of the required mission time from transfer to internal power to end of Range Safety responsibility (i.e., a 50% margin on lifetime).
3. Charge capacity shall be based on the voltage level at the knee in the discharge curve or above the minimum FTS component voltage requirement, whichever is higher.
4. Secondary batteries and cells shall have repeatable performance.

a. Any self discharge plus margin (C_S).

1. The self-discharge value used in determining battery capacity shall be at least 150% of the demonstrated worst-case self-discharge value (i.e., a 50% margin on the demonstrated worst-case self-discharge value).
2. Worst-case self-discharge at the maximum preoperational and operational temperature shall be specified.
3. A secondary or manually activated primary cell or battery must retain a minimum of 90% of its fully charged total capacity after three days at ambient temperature.

NOTE	Remotely activated batteries produce a high-power output for a short period of time and so are not held to the long-duration charge-retention requirement.

b. All load and activation checks (C_P).

c. All flight countdown checks and potential rechecks due to flight delays that the battery could experience before it would have to be recharged or replaced plus a margin (C_L).

1. The minimum margin for capacity and time shall be 50%.
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 for time shall be 50%.

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

1. Flight capacity of at least 150% of the time and capability needed to support a normal flight from launch until the time in which FTS is no longer required (i.e., a 50% margin on flight capacity).
2. 2 terminate functions.

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

NOTE	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 (e.g., 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 (A-h). Actual measured capacity of a fully charged cell or battery.

C_P = Pre-launch testing capacity used (A-h). Battery capacity consumed by any pre-launch testing conducted between final battery charging/activation and final transfer to internal power during countdown.

C_{ST} = Operational stand time capacity used (A-h). Battery capacity lost between final battery charging and beginning of the final launch countdown procedure.

N = Countdown attempts. Number of launch attempts planned (including recycles) during

final launch operations where battery power is consumed.

C_L = Launch countdown capacity used (A-h). 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.

C_{FS} = Flight self-discharge (A-h). Battery capacity lost due to self-discharge between launch and end of Range Safety responsibility.

C_F = Flight capacity used (A-h). Battery capacity consumed during a normal flight from liftoff to the no-longer-endanger time plus the capacity required to execute two arm commands and two terminate commands.

C_H = Hang-fire capacity used (solid propellants only) (A-h). The battery capacity consumed during a 30-minute hang-fire hold.

C_O = Operational capacity used (A-h). The battery capacity needed to meet Range Safety requirements (with margin).

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

Figure 3-1 provides an overview of battery performance operational capacity.

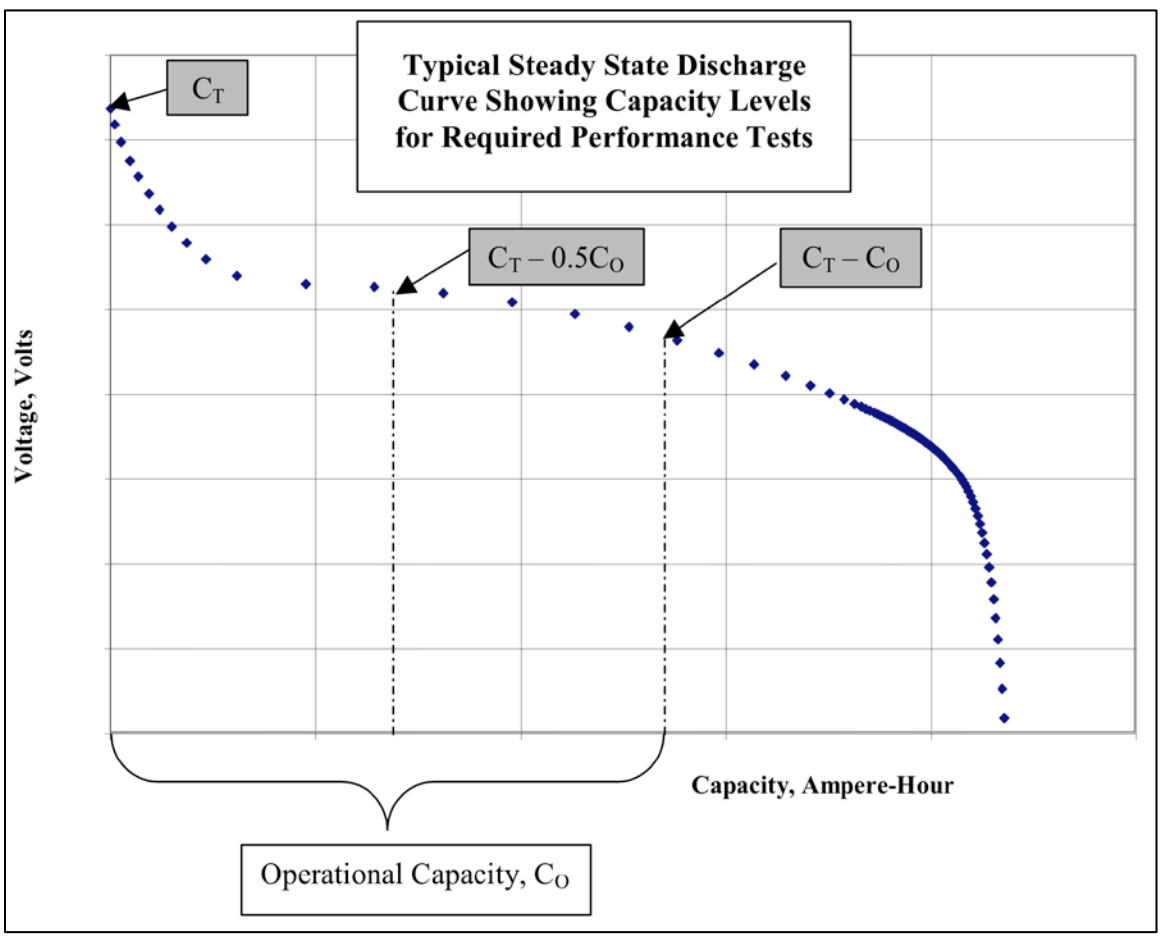

Figure 3-1. Battery Performance Operational Capacity Overview

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 battery shall be capable of delivering 150% of the worst-case (highest) operating current (i.e., a 50% margin on worst-case operating current).
2. 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 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 V and there is 0.5 V line loss due to resistance in the cable/ connectors from the battery, then the minimum criteria would be 22.5 V.

NOTE	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 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 workmanship screening pulse duration for Ag-Zn batteries shall be 100 ms.
2. The current pulse shall be 10 times longer than the duration required to initiate ordnance or other termination event (i.e., a 900% margin on current pulse duration).
3. The current shall be a minimum of 150% of the current pulse at the lowest system battery voltage using the worst-case system tolerances (i.e., a 50% margin on the current).
4. Minimum component voltage can be specified for transient voltage events. For example, a receiver 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 two times the expected number of arm and terminate command sets planned to occur

during vehicle processing, pre-flight 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 pre-launch 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 across all cells in the battery.

1. Minimum soak time for manually activated Ag-Zn 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 Ni-Cd 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 are electrically connected, pin-to-pin resistance shall be 0.05 Ω or less.
2. For pins that are electrically isolated, pin-to-pin and pin-to-case resistance shall be 2 MΩ or more.
3. Pin-to-case insulation resistance shall be 2 MΩ or more 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 shall ensure uniform cell voltage.

3. Capacity for rechargeable cells shall be repeatable within 1% for each charge and discharge cycle.
4. Manually activated primary (non-rechargeable) batteries shall be validated by comparing test data from coupon cells with qualification test data.

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 Ag-Zn batteries, the qualification temperature margins may be reduced from 10°C to 5.5°C if a temperature sensor and TM-combined measurement tolerance is less than ±1.5°C.
3. Batteries requiring heating or cooling to sustain performance shall have a TM channel indicating the temperature of each battery with a resolution of 0.5°C. The TM channel temperature indicators shall be provided during pre-launch 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 GSE and TM systems must have accuracy tolerances of ±0.05 V and ±0.05 A.
6. Battery temperature monitoring output to GSE and TM systems must have an accuracy tolerance of ±0.25°C.
7. The thermostat tolerances shall ensure that the battery remains within its thermal design limits.
8. All Li-ion batteries shall have individual cell voltage monitoring.

3.16.5 Identification

Identification requirements include the following.

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% of the relief pressure average. The maximum vent pressure shall be no higher than 67% 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 150% of 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. Sealed batteries shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at SLC.
2. For any cell that may vent electrolyte mist as part of normal operations, the battery shall satisfy all of its performance requirements for pin-to-case and pin-to-pin resistances after the battery experiences the maximum normal venting.
3. Any vented products, such as hydrogen, shall not create a hazardous condition.
4. Cells with liquid electrolyte shall be designed not to leak when exposed to qualification environments.

3.16.8 Battery and Battery Flight Cell Parts

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 (commercial off-the-shelf) cells shall have a manufacturing code indicating that they are from a large, continuous, automated production run, that materials are from the same source, and that they were 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 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. All FTS batteries and cells shall satisfy all performance requirements (including capacity, electrical characteristics, and environmental survivability) at the beginning, middle, and end of their activated service life.

b. All FTS batteries and cells shall have their activated and unactivated storage life specified where applicable. The battery shall satisfy the activated service life requirements after experiencing its storage life in an activated or unactivated state.

c. Storage and transportation environments for FTS batteries and cells shall be specified and shall 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 temperatures shall not exceed 35°C for short-term exposure.
3. The maximum 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 that 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 for activation of each cell after all the cells are installed in the battery.
2. Manually activated batteries shall allow for voltage monitoring of each cell during OCV and load tests of the battery.

NOTE	Manually activated batteries will be subjected to a high level of materials, production, and process scrutiny since workmanship deficiencies cannot be screened by acceptance testing.

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 cell or battery shall satisfy all the requirements of this section for each charge-discharge cycle.

Cell matching for Ni-Cd batteries shall be performed at 0°C and 20°C.

NOTE	Cell matching at 0°C and 20°C provides sufficient data to characterize capacity at all operating temperature ranges (including below 0°C and above 20°C).

a. Charge-Discharge Cycle Life. The battery shall satisfy all of its performance requirements 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, pre-flight testing, and flight.

1. With the exception of any Ag-Zn 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, pre-flight testing, and flight.
2. An Ag-Zn rechargeable battery shall satisfy all of its performance requirements for each operating charge-discharge cycle expected of the battery throughout its life, including all acceptance testing, pre-flight testing, and flight.
3. All Ag-Zn 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; and
   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 shall 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 (EOCV) shall be specified.
6. For Li-ion batteries and cells, a minimum end-of-discharge voltage (EODV) shall be specified.
7. The equipment and configuration used for qualification and pre-launch charging shall be the same.

3.16.12 Remotely Activated Battery Requirements

Remotely activated batteries, including Ag-Zn and thermal batteries, shall be designed to ensure reliable activation and repeatable electrical performance that meets component and system performance requirements.

1. Battery initiators shall be designed to the applicable initiator requirements of this document.
2. Activated batteries shall satisfy 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% higher 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.

3.16.13 Vehicle Generator

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 two times the capacity required for nominal FTS power to initiate a terminate action.

3.17 Electromechanical Safe-and-Arm Devices with a Low-Voltage Initiator

This section applies to any electromechanical SAD that has an internal LVI. A SAD shall provide for safing and arming of the FTS ordnance IAW the requirements of this chapter.

3.17.1 Safe and Arm in Arm Position During Environmental Tests

A SAD in the Arm position shall remain in the Arm position and satisfy all of its performance requirements when subjected to the design environmental levels.

Mechanical Latching: The SAD 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 a SAD shall satisfy the applicable wiring and connector requirements of Section 3.14.

3.17.3 Electronic Component Requirements

The SAD shall satisfy the applicable electronic component requirements of Section 3.9.

3.17.4 Low-Voltage Initiator

A SAD's internal LVI shall satisfy the ordnance initiator requirements of Section 3.21.

3.17.5 Safe and Arm Adjustment

A SAD shall not require any adjustment throughout its service life.

3.17.6 Firing Pulse

A SAD shall deliver a firing pulse to the internal LVI without any dropout that could affect LVI performance when subjected to the design environmental levels.

3.17.7 Drop Qualifications

A SAD shall satisfy all of its performance requirements 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 SAD shall satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) drop onto a steel plate.

3.17.8 Worst-Case Abnormal Drop

A SAD 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 SAD shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 12-m (40-ft) drop onto a steel plate. The device is not required to function after this test.

3.17.9 Safe-and-Arm Device Body (No Fragmenting)

When a SAD's LVI is initiated, the SAD's body shall not fragment, regardless of whether the explosive transfer system (ETS) is connected or not.

All SADs 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 SAD, the design shall ensure that one LVI does not affect the performance of the other initiator.

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

3.17.11 Safe-and-Arm Performance Testing

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

All SADs shall be designed to withstand at least 1000 cycles of transition between safe and arm (two transitions per cycle) without any malfunction, failure, or deterioration in performance.

3.17.12 Safe-and-Arm Device in Safe Position

A SAD in the safe position shall satisfy all of the following.

a. While in the safe position, a SAD shall protect each internal LVI from any condition that could degrade its performance and prevent inadvertent initiation when subjected to any external energy source, such as ESD, RF energy, or firing voltage during transportation, storage, pre-flight testing, and any pre-flight fault conditions.

When the SAD is in the safe position, it shall provide mechanical isolation of the LVI from the

explosive path and electrical isolation of the firing circuit from the initiators by means of the following.

1. The power and return lines of the firing circuit shall be disconnected.
2. The bridge wire shall be shorted and grounded through a resistor having a resistance value between 10 kΩ and 100 kΩ.
3. The explosive path shall be interrupted by a mechanical barrier capable of containing the output energy of the LVI without initiating the target explosive.

b. While in the safe position, a SAD shall prevent the propagation of the ordnance path with a reliability of 0.999 at a 95% confidence level if the LVI is initiated.

c. A SAD shall satisfy all of its performance requirements when in the safe and locked position and subjected to the worst-case operational arming voltage that could be applied during pre-launch processing.

The SADs shall be designed to satisfy all performance requirements after applying maximum operational arming voltages continuously for periods of up to five minutes with the safing pin installed.

d. A SAD shall not initiate its LVI 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 one hour with the safing pin installed.

e. A SAD 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 SAD has progressed beyond the 0.999 at 95% no-fire transition position.

1. The electrical continuity of one status circuit of the electromechanical SAD (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 SAD has progressed more than 50% beyond the 0.999 at 95% no-fire transition position.

f. A SAD that is armed prior to vehicle first motion shall be capable of being remotely safed.

A SAD shall have a remote means of moving its rotor or barrier to the safe position from any rotor or barrier position.

g. A SAD shall have a manual means of moving its rotor or barrier to the safe position.

h. A SAD 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 SAD 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 LVI 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 SAD shall be between 90 N and 180 N (20 lbf and 40 lbf) of force and/or between 2.25 N-m and 4.5 N-m (20 in-lbf and 40 in-lbf) 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 445 N (100 lbf) tension or a torque of 11.3 N-m (100 in-lbf) 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 a 90° rotation of the pin. The removal force shall be between 0.3 N-m and 1.1 N-m (3 in-lbf and 10 in-lbf) of torque.
8. A safing pin shall be used in the SAD to prevent movement from the Safe to the Arm position when arming power is applied.

i. For SADs armed after launch, the interrupter shall be mechanically locked in the Safe position with at least two but not more than three independent safety interlocks.

3.17.13 Safe-and-Arm Device in Arm Position

A SAD in the Arm position shall satisfy all of the following.

a. When a SAD is in the Arm position, it 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% confidence level.

b. A SAD 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 SAD has progressed beyond the 0.999 at 95% all-fire transition point and the SAD is locked in the Armed position.

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

c. A SAD shall provide for remote arming of the device.

d. For SADs 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. A SAD shall satisfy all of its performance requirements after transitioning to the arm position and being subjected to the continuous operational arming voltage that could be applied during pre-launch processing.

The SADs shall be designed to satisfy all performance requirements after the application of maximum operational arming voltages continuously for periods of up to five minutes.

3.18 High-Energy Electronic Initiator Firing Unit

3.18.1 General

This section applies to any firing unit that uses voltages higher than 500 V to directly initiate a secondary explosive. A firing unit shall provide for safing and arming of the FTS ordnance IAW the requirements of this chapter. A firing unit shall satisfy all applicable requirements of this document, including Section 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.

1. The functioning of one side of the initiator shall not inhibit or cause the functioning of the other side.
2. The status of the initiator shall be individually made available for monitoring.
3. 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-V signal is applied for five 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% amplitude and 50% 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% amplitude and 150% 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% confidence level. The energy (in terms of voltage, current, and time) specified above is the minimum all-fire energy for the exploding foil initiators (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 at least 150% the required all-fire voltage (i.e., a 50% margin on all-fire voltage).
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 of not less than 100 V.
4. Any high-energy trigger circuit used to initiate the firing unit's main firing capacitor shall deliver an output signal of at least 150% of the nominal voltage threshold level (i.e., a 50% margin on the nominal voltage threshold).

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 vehicle is capable of attaining.
2. The isolation resistance between each firing unit circuit and any other circuit shall not be less than 50 MΩ at 500 Vdc.
3. A high-energy firing unit shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

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%.

2. Arm indication - The firing unit shall be considered armed when the monitoring circuit indicates a capacitor bank voltage at least 95% of the nominal operating voltage value of the device and at least 100 V 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 below 20% of the 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 modes 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 armed safe/arm ordnance interrupters, may be required.

3.19 Laser Firing Unit

3.19.1 General

The design of an LFU shall meet the requirements for electronic components in Section 3.9.

3.19.2 Command Processing

The firing unit's input trigger circuitry shall satisfy all of its performance requirements 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-V signal is applied for five 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% of the amplitude and 50% 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% amplitude and 150% of the pulse duration of the highest firing signal that could be delivered during flight.

3.19.3 Output Firing Circuit

An LFU 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% 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 150% of the required all-fire optical energy (i.e., a 50% margin on all-fire optical energy).

a. The LFU shall be sealed to prevent optical degradation due to environmental exposure.

An LFU shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

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 two times 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 modes 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 armed SAD interrupters, may be required. This may include remotely armed SAD optical interrupters.
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.

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:

1. the status of all inhibits;
2. continuous spurious energy monitor and/or detection circuit on the input firing line capable of detecting as low as 10% of the minimum input firing voltage;
3. indication of termination firing output;
4. the status of the Master Arm/Safe circuit;
5. 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 of 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 more than 10% of 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

This section applies to any ordnance interrupter that does not have an internal LVI. An ordnance interrupter shall provide for safing and arming of the FTS ordnance IAW the requirements of this chapter.

a. An ordnance interrupter in the arm position shall remain in the arm position and satisfy all of its performance requirements 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.

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

c. The ordnance interrupter shall satisfy the applicable electronic component requirements of Section 3.9.

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

e. An ordnance interrupter shall satisfy all of its performance requirements 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 satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) drop onto a steel plate.

f. 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.

An ordnance interrupter shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 12-m (40-ft) drop onto a steel plate. The device is not required to function after this test.

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

An ordnance interrupter shall be designed such that when the device is functioned in either the Arm or Safe condition, the body shall not fragment.

h. 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.

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

An ordnance interrupter shall be designed to withstand at least 1000 cycles of transition between safe and arm (2 transitions per cycle) without any malfunction, failure, or deterioration in performance.

j. An ordnance interrupter in the safe position shall satisfy all of the following.

(1) While in the safe position, an ordnance interrupter shall prevent the propagation of the ordnance path with a reliability of 0.999 at a 95% confidence level if the LVI is initiated.

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

(2) An ordnance interrupter shall satisfy all of its performance requirements when in the safe and locked position and subjected to the worst-case operational arming voltage that could be applied during pre-launch processing.

An ordnance interrupter shall be designed to satisfy all performance requirements after the application of maximum operational arming voltages continuously for periods of up to five minutes with the safing pin installed.

(3) 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 one hour with the safing pin installed.

(4) 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 0.999 at 95% 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% beyond the 0.999 at 95% no-fire transition position.

(5) 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.

(6) An ordnance interrupter shall have a manual means of moving its rotor or barrier to the safe position.

(7) 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:

1. Rotation and/or transition of the mechanical barrier to the aligned explosive path 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 interrupter shall be between 90 N and 180 N (20 lbf and 40 lbf) of force and/or between 2.25 N-m and 4.5 N-m (20 in-lbf and 40 in-lbf) 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 445 N (100 lbf) tension or a torque of 11.3 N-m (100 in-lbf) 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 between 0.3 N-m and 1.1 N-m (3 in-lbf and 10 in-lbf) of torque.
8. 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.

(8) For interrupters armed after launch, the interrupter shall be mechanically locked in the Safe position with two or three independent safety interlocks.

k. An ordnance interrupter in the Arm position shall satisfy all of the following.

(1) 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% confidence level.

(2) 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 0.999 at 95% 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.

(3) An ordnance interrupter shall provide for remote arming of the device.

(4) For interrupters 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.

(5) An ordnance interrupter shall satisfy all of its performance requirements after transitioning to the arm position and being subjected to the continuous operational arming voltage that could be applied during pre-launch processing.

An ordnance interrupter shall be designed to satisfy all performance requirements after the application of maximum operational arming voltages continuously for periods of up to five minutes.

3.21 Ordnance Initiators

3.21.1 General

a. An ordnance initiator shall have a specified all-fire stimulus level. When the specified all-fire stimulus level is applied, the initiator shall fire with a reliability of no less than 0.999 at a 95% confidence level.

b. Initiators shall be designed to reliably initiate when subjected to operating stimulus levels plus a margin.

1. All LVIs shall be designed to reliably function at 200% of the operating current level (i.e., a 100% margin on operating current).
2. High-voltage initiators shall be designed to reliably function at 150% of the operating voltage level (i.e., a 50% margin on operating voltage).
3. Percussion initiators (PIs) (primers) shall be designed to reliably function at 200% of the operating impact energy (i.e., a 100% margin on operating impact energy).
4. All LIDs shall be designed to reliably function at 200% of the operating firing power level (i.e., a 100% margin on operating firing power).

c. An ordnance initiator shall have a specified no-fire stimulus level. An initiator shall not fire when exposed to the specified no-fire stimulus level with a reliability of no less than 0.999 at a 95% confidence level.

d. An electrical or optical ordnance initiator shall satisfy all of its performance requirements after being subjected to continuous application of the no-fire stimulus level.

e. An electrical ordnance initiator shall not fire and shall satisfy all of its performance requirements after being subjected to the maximum expected ESD that it could experience from contact with personnel or conductive surfaces.

An electrical ordnance initiator shall not fire and shall satisfy all of its performance requirements after being subjected to a pin-to-pin discharge through a 5-kΩ resistor from a 500-pF capacitor charged to no less than 25 kV and a 25-kV, 500-pF pin-to-case discharge with no resistor.

f. An electrical or optical ordnance initiator shall not initiate and shall satisfy all of its performance requirements after being subjected to stray electrical or optical energy that is 20 dB greater than the largest 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. All LVIs shall be shorted and connected to case ground through a static-bleed resistor(s) having a resistance of 10 kΩ to 100 kΩ.
2. The outer case of an LVI main body shall be made of conductive material.

g. An ordnance initiator shall satisfy all of its performance requirements after being exposed to the tension loads, compression loads, and handling drops that the device could experience during transportation, handling, or installation

For initiators that will not be contained in an assembly that will prevent connector and wire loading, such as a SAD, all connector pins shall be capable of withstanding tension and compression loads of at least 80 N (18 lbf) for not less than one minute.

h. An ordnance initiator shall satisfy all of its performance requirements after being exposed to the handling drop required during qualification.

The ordnance initiator shall be required to satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) drop onto a steel plate.

i. An ordnance initiator shall not initiate and shall allow for safe disposal after being exposed to the abnormal drop required during qualification.

1. An initiator shall not fire or be damaged to the extent it is unsafe to handle after being subjected to a 12-m (40-ft) drop onto a steel plate. The initiator is not required to function after a 12-m 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 an LVI within a SAD, this requirement applies only before installation.

j. An ordnance initiator shall be sealed to prevent degradation due to exposure to non-operating and operating environments, such as salt fog, humidity, and pressure experienced during long-term storage, transportation, pre-flight, and flight.

An ordnance initiator shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

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

1. For LVIs the pin-to-case resistance shall be 2 MΩ or more at 500 Vdc.
2. For high-voltage initiators the pin-to-case resistance shall be 50 MΩ or more at 500 Vdc.

l. All internal ordnance interfaces within an ordnance initiator shall have a minimum ordnance transfer reliability of 0.999 at 95% confidence.

m. The lowest temperature at which the ordnance material in the initiator would experience auto-ignition, sublimation, 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 be greater than 150°C.

3.21.2 Low-Voltage Initiators

An LVI shall use electrical energy of less than 50 V to trigger an explosive charge that initiates the FTS ordnance.

1. Initiators shall be designed to withstand a constant DC firing pulse of 1 A minimum and 1 W power minimum for a period of five 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. Carbon bridgewires and conductive mixes without bridgewires are prohibited.

3.21.3 Exploding Bridgewire Initiators

a. An EBW shall use high-voltage electrical energy of 500 V 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.

1. Connectors, pins, wiring, and header assembly shall withstand 150% of the maximum operating voltage delivered by the EBW firing unit (i.e., a 50% margin on operating voltage).
2. 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.
3. The bridgewire degradation current shall be specified. This current is defined as the highest DC current level that, when applied continuously for a minimum of five minutes, will not damage or degrade the initiator at the highest system temperature or 71°C, whichever is higher.
4. The initiator shall be capable of being exposed to 50% of the bridgewire degradation current for five minutes and one 45-V firing pulse without degrading in performance.
5. The RF-induced no-fire level shall be specified for all applicable frequency ranges and used in the 20-dB RF environmental analysis.

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

The initiator shall not fire and shall satisfy all of its performance requirements after exposure to 500 Vdc for five minutes.

3.21.4 Exploding Foil Initiators

The EFIs, also called “slapper” detonators, are used in EAFDs and ESADs.

1. The foil degradation current shall be specified. This current is defined as the highest DC current level that, when applied continuously for a minimum of five minutes, will not damage or degrade the initiator at the highest system temperature or 71°C, whichever is higher.
2. The initiator shall be capable of being exposed to 50% of the foil degradation current for five minutes and one 45-V 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

The initiator shall not fire when exposed to the worst-case voltage from GSE or vehicle systems plus a margin.

The initiator shall not fire and shall satisfy all of its performance requirements after exposure to 500 Vdc for five minutes.

3.21.5 Laser-Initiated Detonator

a. All 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 133 N (30 lbf) pull of the pigtail without degradation in performance.

b. A LID system, using a BIT, shall locate the optical reflector in a location that validates LID connector and performance integrity.

1. The reflective coating shall be located just prior to the LID initiation ordnance.
2. The LID all-fire specification shall include all parameters necessary for reliable operation, such as spot size, pulse width, energy density, power, and wavelength. These specifications shall include tolerances that have been derived by test or analysis.
3. All LIDs in flight configuration shall be designed to not initiate or degrade in performance when subjected to any stray energy sources such as strobes, sunlight, arc welders, flash-lamps, lightning, RF, and alternating current (AC)/DC electrical energy present during pre-launch processing and in the flight environment.
4. At a minimum, statistical testing shall include spot size, pulse width, energy density, and wavelength.
5. The LID no-fire power shall be 20 dB greater than any credible stray power source.
6. All 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.
7. All LIDs shall be designed to prevent any differential voltage potential from occurring across the LID ordnance.

3.21.6 Percussion Initiators (Primers)

a. The PI firing pin mechanism shall have a specified all-fire pull force and all-fire pull distance. When the specified all-fire pull force is applied, the firing pin mechanism shall retract to at least the specified all-fire pull distance and then release with a reliability of no less than 0.999 at a 95% confidence level.

b. The PI firing pin mechanism shall have a specified no-fire pull force and no-fire pull distance. When the specified no-fire pull force or the pull force required to retract the firing pin mechanism to the specified no-fire pull distance, whichever is higher, is applied, the firing pin mechanism shall not release with a reliability of no less than 0.999 at a 95% confidence level.

1. The minimum no-fire pull force shall be 222 N (50 lbf).
2. The minimum no-fire pull distance shall be 6.4 mm (0.25 in).

c. The PI ordnance element shall meet the requirements of Subsection 3.21.1 with the firing pin kinetic energy at impact as the stimulus.

3.22 Devices Containing Percussion Initiators

This section applies to any percussion-initiated device (PID) that is part of an FTS. A PID uses mechanical energy to trigger an explosive charge (percussion primer) that initiates the FTS ordnance.

NOTE	Previous versions of this document referred to these devices as percussion-activated devices. The acronym PAD has long been used in the ordnance device community for a propellant-actuated device. In order to prevent confusion, the acronym here has been changed to percussion-initiated device (PID).

a. A percussion primer within the PID shall meet the applicable initiator requirements of Section 3.21.

b. A PID shall not fragment upon initiation.

c. A firing pin mechanism shall have a guaranteed no-fire pull force at which the firing pin shall not be released. The guaranteed no-fire pull force shall ensure the initiator cannot be inadvertently initiated due to an accidental pull during pre-launch installation/checkout or due to any flight hardware loading forces plus a margin.

d. A firing pin mechanism shall not release when pulled with its no-fire pull force and 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 to the all-fire distance, the mechanism shall automatically release and allow the firing pin to strike the primer.

e. A PID shall deliver an operating energy to the percussion primer of no less than two times the primer guaranteed all-fire energy level.

NOTE	The spring pull force and potential energy are both functions of the spring constant and pull distance.

f. A PID primer shall satisfy all of its performance requirements when subjected to two times the operational impact energy.

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

h. A PID shall satisfy all of its performance requirements after experiencing any handling drop and additional transportation, handling, or installation environment that the device could experience.

1. The PID shall be required to satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) drop onto a steel plate.
2. The PID shall not initiate or be damaged to the extent it is unsafe to handle after being subjected to a 12-m (40-ft) drop onto a steel plate. The device is not required to function after this test.
3. The PID mechanisms shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at SLC.

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

The PID shall reliably function when pulled at a ±45° angle in two perpendicular planes.

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

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

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

The PID assembly shall not move more than 50% of the guaranteed no-fire pull distance when pulled at the worst-case expected accidental pre-launch pull force.

(1) A safing interlock shall positively lock into place and shall have a means of verifying proper function of the interlock.

(2) 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 44 N (10 lbf) when the lanyard is pulled with the no-fire pull force or greater.

(3) With the safing interlock installed, the PID 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 PID shall not fire when exposed to a minimum lanyard pull force of 890 N (200 lbf) with the safing interlock installed.

(4) The safing interlock shall have a positive means of locking into the PID assembly to prevent accidental disengagement.

(5) The safing pin shall have a red warning streamer.

3.23 Propellant-Actuated Devices/Cartridge-Actuated Devices

a. The PAD initiator shall meet the applicable requirements of Section 3.21 for ordnance initiators.

b. The firing of either one or both initiators in a single-PAD system or the firing of either one or both PADs in a dual PAD system shall provide operational success. The firing of the first LVI or PAD shall have no detrimental effect on the second LVI or PAD.

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

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

e. All PADs that are required to function under tension, compression, or shear loads shall have the ability to operate satisfactorily both unloaded and loaded to at least 150% of the maximum predicted operating load.

f. All FTS applications using a PAD shall require redundancy. If the use of a single PAD to perform a function is approved, dual initiators shall be used.

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

1. The PAD shall be required to satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) 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 12-m (40-ft) drop onto a steel plate. The device is not required to function after this test.
3. The PAD mechanisms shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at SLC.

h. A PAD shall not fragment upon initiation unless designed to do so (e.g., explosive bolts).

3.24 Explosive Transfer System

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

NOTE	The ETSs are used to transmit the initiation reaction from the initiator to the termination charge. Most ETS harnesses contain flexible confined detonating cord (FCDC), mild detonating cord (MDC), or a mild detonating fuse terminated by end booster caps or manifolds.

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

1. All ETSs shall use only explosives listed in MIL-STD-1316 for in-line use or that are approved by the associated safety evaluation board.
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 ESD, drop, high-temperature exposure, shock, and vibration.

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

d. 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 five times the number of planned cycles or 10 cycles, whichever is higher, 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.

e. An ETS shall satisfy all of its performance requirements 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 satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) drop onto a steel plate.
3. Each ETS component shall satisfy all of its performance requirements when subjected to two times the tensile load that can occur during installation and handling or an axial pull of 445 N (100 lbf), whichever is greater, for not less than one minute.

f. 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 12-m (40-ft) drop onto a steel plate. The device is not required to function after this test.

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

An ETS shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

3.25 Destruct/Terminate Charge

This section applies to any destruct/terminate charge that is part of an FTS.

a. 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.

b. Initiation of a destruct/terminate charge shall result in an FTS action IAW the FTS functional requirements of this document.

c. 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.
2. Ordnance used in a destruct/termination charge shall consist of a secondary explosive.
3. Anomalous conditions include ESD, drop, high-temperature exposure, shock, and vibration.

d. A destruct/terminate charge shall completely sever or penetrate no less than 150% of the thickness of the flight material. A destruct/terminate charge, when initiated to terminate the flight of a vehicle, shall not detonate any vehicle or payload propellant.

1. Choose the destruct/terminate charge margin option below.
   - Option 1, Severance Margin. A destruct/terminate charge shall sever no less than 150% of the thickness of the flight material.
   - Option 2, Penetration Margin. A destruct/terminate charge shall penetrate no less than 150% of the thickness of the flight material. Severance of the entire flight material is not required so long as the depth of penetration is 150% of the flight material thickness.
2. Both options require using a witness plate and target plate(s) for the destruct test to verify that the destruct/terminate charge severs or penetrates to required thickness of the flight material. Details of the witness and target plates are further defined in Subsection 4.34.3.
3. Severance margin shall be designed for the worst-case flight operating temperature.

e. A destruct/terminate charge shall satisfy all of its performance requirements 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 satisfy all of its performance requirements after being subjected to a 1.8-m (6-ft) drop onto a steel plate.
3. Each destruct/terminate charge component shall satisfy all of its performance requirements when subjected to two times the tensile load that can occur during installation and handling or an axial pull of 222 N (50 lbf), whichever is greater, for not less than one minute.

f. 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 12-m (40-ft) drop onto a steel plate. The device is not required to function after this test.

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

A destruct/terminate charge shall be sealed so as to admit a gas leak rate no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

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 satisfy 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 Flight Termination System Shutdown Valves

Liquid propellant shutoff valves used as the primary means of flight termination shall be designed to ensure reliable termination within the required flight performance conditions.

1. Recyclable shutdown valves shall allow repeated opening, 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 (e.g., pyro valves) shall have only two positions, open or closed, and shall not change positions after actuation.

3.27.1 General

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

1. 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.
2. If critical to FTS functionality, supporting hardware such as fluid transfer lines must also meet the valve requirements.

NOTE	Where failure of a fluid transfer line results in a fail-safe condition, the requirements of this section may be reduced or eliminated.

NOTE	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 (i.e., pilot valves). d. Pyrotechnic valves. Theses valves are actuated by an ordnance device input, such as squibs, resulting in direct interruption or venting of fluids. Ordnance devices used in FTS valves shall meet all the requirements specified in the appropriate section of this chapter.

a. All FTS shutdown valves and associated subsystems shall satisfy the applicable requirements of Section 3.9.

b. Valves and associated subsystems shall be designed to satisfy all of their performance requirements when exposed to the worst-case maximum expected operating pressure (MEOP) plus a margin.

1. Pressurized lines shall not leak and shall satisfy all of their performance requirements at operational pressures from 0 to 1.25 times MEOP (i.e., a 25% margin on MEOP).
2. Pressurized lines shall not burst at less than 4 times MEOP (i.e., a 300% margin on MEOP).
3. Valves and valve systems shall be designed to withstand, without leakage, the water hammer effect resulting from a minimum valve closure time during maximum velocity flow plus a margin with a representative upstream pipe length.
4. External leakage shall be low enough to prevent development of an explosive atmosphere, hazards to personnel, or potential FTS failure conditions such as propellant compatibility with FTS components or freezing the valve closed.

c. 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 position outputs shall be provided to GSE and TM.

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

e. Valves shall be marked with sufficient information to allow installation technicians and QA personnel 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 number.
   c. Manufacturer's serial number.
   d. Manufacturer's name or trademark.
   e. Date of manufacture.
   f. Service life.
3. If a valve is designed to be removed/replaced after system-level testing or a one-shot shutdown valve, it must be designed with fittings so that reverse installation or interchange is not possible.

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

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

The following applicable valve specifications shall be included.

1. Operating time at minimum, nominal, and maximum operating voltage.
2. Operating voltage.
3. Operating current.
4. Operating pressure.
5. Flow rate.
6. Proof pressure.
7. Burst pressure.
8. Solenoid temperature rise.
9. Dielectric strength.
10. Actuation cycle life (endurance).
11. Service life.

3.27.2 External Leak

A valve and associated systems shall meet its specified maximum leak rate requirements when exposed to the MEOP plus a margin.

1. A valve and associated systems shall meet its specified maximum leak rate requirements when exposed to 1.25 times MEOP (i.e., a 25% margin on MEOP).
2. The specified external leak rate shall be met with the valve in both the static position and while cycling.
3. External leakage shall not create:
   a. an explosive atmosphere environment;

b. hazards to personnel;
c. failure of FTS due to propellant incompatibility with FTS components;
d. cryogenic freezing that damages FTS components.

a. Closed valves shall be designed to meet leakage performance requirements to the valve output at a continuous 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 into contact with downstream propulsion systems or components that may be vulnerable to performance degradation or may cause personnel safety hazards due to fuel/oxidizer incompatibility over time.

b. Valves shall not create a fratricide condition that could disable the FTS or create a hazardous condition for 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 (i.e., a 300% margin on MEOP).

3.27.3 Operational Environment

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

3.27.4 Electromechanical Valves

Electromechanical valves shall not degrade in performance or create a hazardous condition when subjected to the worst-case input current that could occur during pre-launch and launch environments.

1. An electrically recyclable valve shall not degrade in performance after an extended stall at worst-case system high current for five 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 one hour.

3.27.5 Pressure Cycle Life

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

1. Valves shall withstand five times the worst-case checkout and operational pressure cycles (i.e., a 400% margin on repetitive pressure cycles).
2. Pressure cycles shall be from ambient pressure to 1.25 times MEOP at a pressure rate of change that envelopes flight pressure application (i.e., a 25% margin on MEOP).

3.27.6 Insulation Resistance

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

1. Insulation shall be capable of withstanding a minimum potential of 500 Vdc between the mutually insulated or isolated points. The voltage shall not damage or degrade the valve or solenoid.
2. The insulation resistance between all insulated parts shall be 2 MΩ or more.

3.28 Vibration and Shock Isolators

A vibration or shock isolator shall ensure the environmental survivability of an FTS component during applicable non-operating 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 requirements 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

NOTE	This AFTS component processes the tracking data and 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 Section 3.9.

3.29.2 Processing

a. All 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% 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.

NOTE	This does not include self-test software for 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 one 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 V.

3.29.5 Output Monitors

The monitoring circuits of an AFTU shall provide the data for real-time pre-launch checkout and flight.

The data provided by monitoring circuits of an AFTU shall include the following.

1. The status of all inhibits.
2. Results of processor BIT.
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 Autonomous Flight Termination Unit 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 GSE 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 Autonomous Flight Termination Unit Terminate Decision Criteria

An AFTU shall initiate a termination action prior to a 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. The AFTU terminate logic shall initiate before any powered stage, debris, focused distance overpressure, or toxic agents can violate a Range Safety-protected area.

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. If all required adequate tracking sources are lost, then the AFTU shall initiate a termination command before the vehicle can violate 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 this time.

d. 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:

1. ground launched/non-programming (straight up);
2. rapid turn towards impact limit line;
3. slow turn towards impact limit line;
4. for space launch, inability to make orbit.

e. 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 but rather continue to 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. All data is lost.
   b. The dilution of precision (DOP) figure of merit exceeds specifications.
   c. The GPS is in a "coast" mode.
   d. Filter residuals that indicate errors exceed specification.

   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. All data is lost.
   b. A shared mission/FTS INS that has not been validated by another source after key vehicle events (e.g., a shock event) is an example of an inadequate source test condition.
   c. Any discrepancies, such as unrealistically large jumps in state vector or diverging data with GPS, are also examples of inadequate source test conditions.

   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).

   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. The AFTU shall process data normally and shall NOT initiate a terminate output when all valid tracking sources diverge but none of them violate any terminate criteria. The AFTU shall initiate a terminate output when any adequate tracking source violates a terminate criteria.

g. The AFTU shall process data normally and shall NOT initiate a terminate output 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.

An 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 samples per second. 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 Subsection 3.29.7 item b above.

k. A Monte Carlo or similar statistical analysis shall be performed to ensure that variations in tracking performance and destruct criteria do not result in failure to terminate when a protected area is violated and do not result in an inadvertent termination for nominal vehicle dispersions. The details of this analysis will be determined by Range Safety.

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.

NOTE	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

Flight Termination System 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 of its performance requirements 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

a. 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.

b. For any component that is used for more than one flight, the test procedure shall provide for component reuse qualification, refurbishment, and acceptance.

c. 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 and the mechanism of the failure and shall 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 Test Failures and Anomalies

a. 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.

1. Anomalies are initially treated as failures, but may be accepted as a non-failure/ compliance as determined by Range Safety. This includes minor exceedances beyond allowable tolerances or minor shortcomings on time duration, test levels, etc.
2. 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 one day. Data shall be provided in a timely manner that allows Range Safety sufficient time to review documentation that supports program schedule.

A detailed description with any supporting data shall be provided in writing within two weeks of the date the failure is noted.

c. This requirement 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.

4.5.2 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 sufficient time to review documentation that supports program schedule.

Failure analyses shall be submitted to Range Safety for approval within 30 days of the failure.

4.6 Test Tolerances

a. 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.

b. 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.

Table 4-1 below lists several tests and the tolerances allowable.

Table 4-1. Test Tolerances

Test	Tolerance
Sampling Time Interval	±5%
Temperature	±3°C
Pressure	
Above 1.3×10^{2} Pa (1 Torr)	±10%
1.3×10^{-1} to 1.3×10^{2} Pa (0.001 Torr to 1 Torr)	±25%
Less than 1.3×10^{-1} Pa (0.001 Torr)	±80%
Relative Humidity	±5%
Acceleration	±10%
Vibration Frequency	±2%
Sinusoidal Vibration Amplitude	±10%
Random Vibration Power Spectral Density (m^2/s^3 or g^2/Hz)	
Amplitude at all test frequencies	±1.5 dB
Processing Bandwidths	≤ 5 Hz per band
Sound Pressure Level	
1/3 Octave Band	±3.0 dB
Overall	±1.5 dB
Shock Response Spectrum (SRS)	
Frequency Sampling Bandwidth	≥ 6 samples per octave (1/6 octave sampling)
Sample Rate	≥ 10 times the maximum SRS frequency with a minimum of 100,000 samples per second
SRS magnitude points	−3/+6 dB

Static Load	±5%

4.7 Test Equipment

4.7.1 Environmental Testing

Test equipment shall expose the unit under test to the required environmental test levels. Environmental monitoring devices shall be placed to ensure accurate representation of the actual test environment. Any differences between the test fixtures or cables used during pre-qualification acceptance testing of the qualification units and acceptance testing of the flight units shall undergo an evaluation to ensure that flight hardware is not overstressed.

a. All qualification testing shall use flight-specified hardware (support structure, isolators, connectors, cables, cable clamping scheme, and attaching hardware such as washers, nuts, adapter plates, cable clamps, brackets, and bolts).

b. All cables and explosive transfer lines (ETLs) shall be routed and secured in the flight configuration to the first tie-down point from the connector or end tip. Unless otherwise noted, flight-specified hardware shall be installed per flight installation requirements, including required torque forces or locking features (Loctite®, lockwire, etc.).

c. Samples of cables and ETLs shall be clamped using the maximum and minimum unsupported lengths and arranged to include the minimum bend radius allowed per installation requirements.

d. All dynamic portions of acceptance testing may use flight-equivalent or flight-like cables and cable clamping schemes if the range user can show that the acceptance test configuration does not impose higher loads than the pre-qualification acceptance test configuration.

Vibration and Shock Test Requirements

1. A component's dynamic test input shall be validated by the use of accelerometers at each mounting location of the component input. Each accelerometer location shall meet the tolerance specifications per Table 4-1. Exceptions to this requirement may be acceptable on a case-by-case basis, as approved by Range Safety. (Note: Uniformly responding fixtures may not require the full number of monitoring points.
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 during testing of combined environments (i.e., shock and/or vibration at temperature), sensors used to monitor thermal testing temperature levels shall be placed on the component and in a location to monitor the ambient air temperature.

   a. The air temperature shall be a minimum of the acceptance or qualification thermal cycle temperature levels depending on the type of testing being done.
   b. The component temperature (as measured on the component) shall be a minimum of the workmanship thermal levels.

Vibration and Shock Test Terms and Definitions

Control Accelerometer - An accelerometer used in the control loop with a shaker table for vibration testing or table shock.
Response Accelerometer - An accelerometer not used in the control loop with a shaker table for vibration testing or table shock. Also an accelerometer used to record the results from any kind of shock or acceleration testing.
In-line response - Response measured in the same axis as the unit is being tested.
Cross-talk response - Response measured in the axes perpendicular to the axis being tested. Also referred to as the cross-axis or off-axis response.
Peak - A positive spike in the vibration versus frequency curve.
Notch - A negative spike in the vibration versus frequency curve.
Maxi-max - The absolute peak acceleration response over all time (both during and after the shock).
Maximum positive spectrum - An SRS determined from only the maximum positive response.
Maximum negative spectrum - An SRS determined from only the maximum negative response.
Primary shock - The response correlating to the time that the shock excitation is applied.
Residual shock - The response after the excitation has ended.
Statistical degrees of freedom (sDOF) - A parameter that controls the accuracy of the averaging performed on the random vibration test.

Random Vibration Test Requirements

1. Random Vibration Testing - General

   a. All required accelerometer measurements for fixture evaluation, acceptance testing, and qualification testing shall remain within ±1.5 dB of the specified levels across the entire test frequency band.
   b. Exceptions for spikes (peaks and notches) are allowed provided all of the following criteria are satisfied.

      (1) There shall be no more than four spikes across the entire test frequency band with no more than three in either direction (peak or notch).
      (2) Spikes shall not exceed ±3 dB of the specified levels.
      (3) The spike width at the ±1.5-dB limit shall be less than 10% of the spike center frequency. Figure 4-1 displays an example of these limitations.

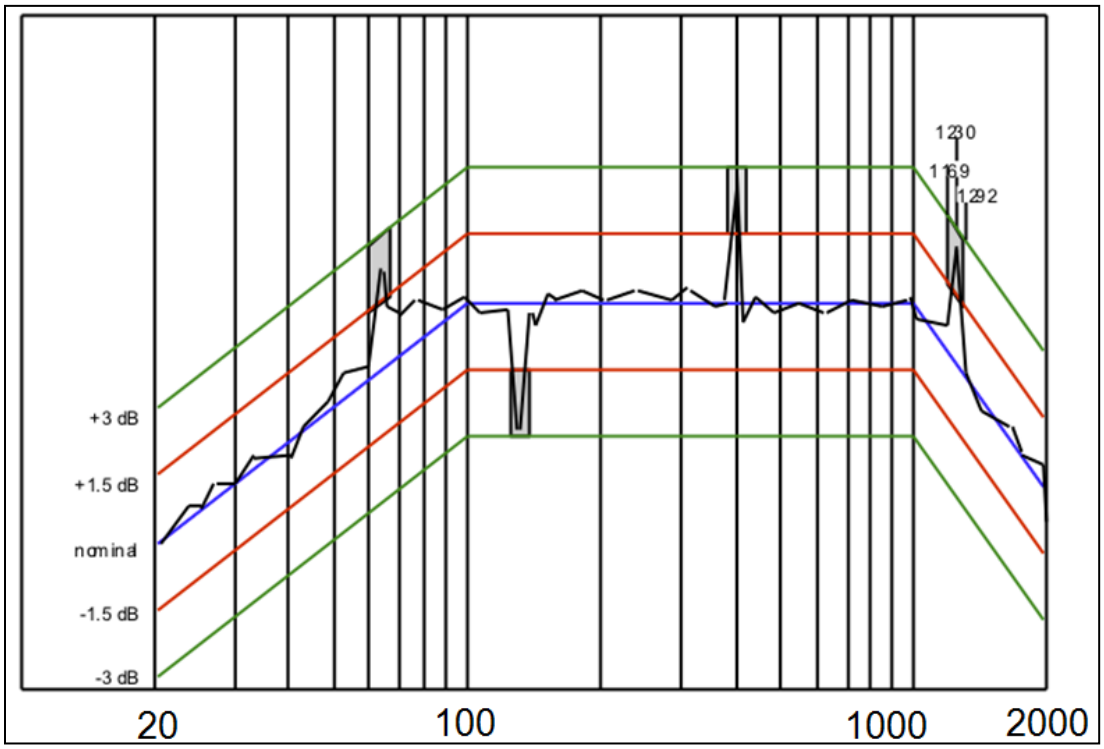

Figure 4-1. Example of Allowable Spikes

c. When located at the required monitoring points, special exceptions for spikes on the control channels when using dual control are allowed provided they meet the criteria of item b above and with the exception that the spikes do not exceed ±6 dB of the specified levels.

NOTE	In Figure 4-1, there are three peaks and one notch that exceed the ±1.5-dB tolerance limits. Each spike is within ±3 dB of the specified levels and each has a maximum width at the tolerance limit that is less than 10% of the center frequency.

d. If dual control averaging is employed, the two in-axis vibration control channels shall be within 3 dB of each other at all frequencies tested.

e. Cross-talk: Vibration responses in each orthogonal off-axis shall not exceed the nominal in-axis level from 20 Hz to 1 kHz and shall not exceed +1.5 dB of the nominal in-axis level from 1 to 2 kHz. Figure 4-2 displays these limits.

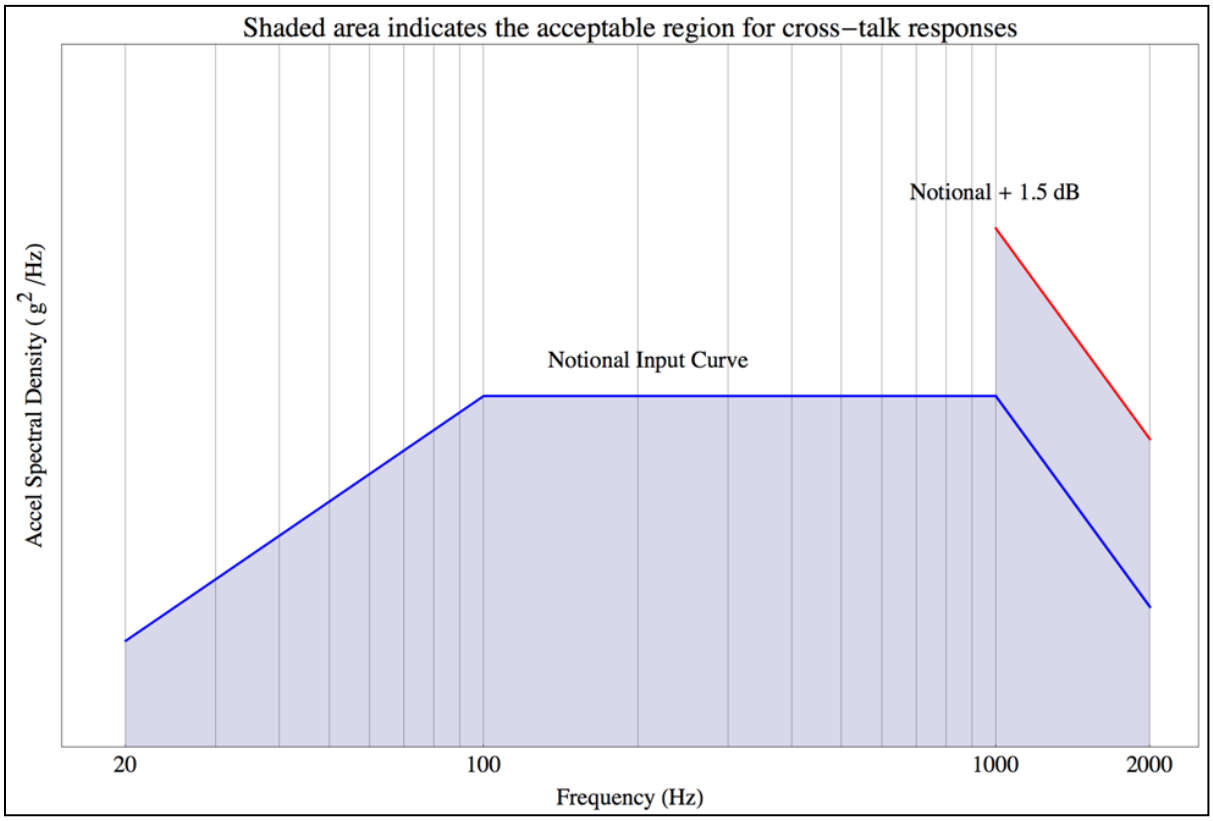

Figure 4-2. Example Cross-Talk Response Acceptable Region

2. Random Vibration Test Fixture Evaluation

a. The dynamic test system (i.e., spectrum controller and shaker system, test fixture, test item, etc.) configuration shall be evaluated to ensure that the random vibration input control requirements are met. Test system parameters including sDOF, frequency resolution, alarm and abort limit criteria, and accelerometer output voltages shall be specified prior to testing.

NOTE	The sDOF specifications have an impact on the averaging accuracy of the test and should be chosen carefully (A typical range for sDOF is 180-220). High sDOF values may not be appropriate for short-duration tests due to excessively long averaging intervals.

b. The unit being used to evaluate the test system (dynamic/mass simulator or actual test unit) shall be subjected to vibration in each test axis IAW the product specification for the time needed to collect the required evaluation data.

c. The unit shall be mounted on the shaker table using the same hardware and torque values intended for acceptance or qualification testing.

d. If the unit is a dynamic/mass simulator, it shall be subjected to vibration at full (0 dB) acceptance or qualification levels depending on the type of equipment testing being performed. If the unit is an actual test unit, it shall be subjected to vibration at −12 dB of the full vibration levels or at a level that yields a total root mean square (RMS) acceleration of 9.8 m/s^2 (1 g), whichever is higher.

e. Sufficient numbers of accelerometers or test runs with different configurations shall be performed so that response data is obtained at representative unit mounting points in all three orthogonal axes.
f. If multiple units are to be tested at the same time on the same fixture, the appropriate input to each unit shall be verified.
g. The test data shall be evaluated to ensure that it meets the criteria above.

Shock Test Requirements

1. Shock Testing - General

a. All required accelerometer measurements for fixture evaluation, acceptance testing, and qualification testing shall remain within −3 to +6 dB of the specified levels across the entire test frequency band.
b. Exceptions for spikes below the lower tolerance limit are allowed provided all of the following criteria are satisfied.

(1) No SRS points are below −6 dB of the nominal.
(2) No more than 20% of the SRS points are below −3 dB of the nominal.
(3) No more than 5% of the SRS points are consecutively below −3 dB of the nominal (i.e., no clustering of out-of-tolerance SRS points).

Example: 1/6 octave sampling from 100 Hz to 10 kHz yields 41 SRS points. Therefore, no more than 8 (41 x 20% = 8.2) total points may be below −3 dB of which no more than 2 (41 x 5% = 2.1) may be consecutive.

NOTE	Between 30% and 50% of all the SRS magnitude points should be greater than the specified nominal.

2. Shock Test Fixture Evaluation

a. An appropriate mass simulator shall be mounted on the fixture using the same hardware and torque values intended for acceptance or qualification testing.
b. Sufficient numbers of accelerometers or test runs with different configurations shall be performed so that response data is obtained at representative unit mounting points in all three orthogonal axes. Note: Accelerometers should be mounted within 2.5 cm (1 in) of the mass simulator mounting locations.
c. Additional accelerometers may be added to the configuration to ensure that levels are sufficient to accurately represent inputs to all components under test at the discretion of the cognizant engineer/Range Safety.
d. For pyro-shock testing, accelerometers shall be mounted at least 16 cm (6.3 in) away from the shock source. Source ordnance shall not be applied to fixture edges.
e. The fixture and the unit under test shall be checked after each shock event to ensure compliance with test and mounting requirements. At a minimum, all mounting hardware torques and the integrity of all accelerometers shall be checked.

3. Accelerometers

a. Accelerometers shall have sufficient accuracy to measure the acceleration levels over

the frequency range specified by the test with adequate margin. Accelerometers shall have sufficiently high resonant frequency to prevent interference with the measured signal.

b. Accelerometers shall be installed and instrumented according to manufacturer guidelines. Note: Accelerometers should be mounted directly into the fixture. If mounting blocks are used, it is recommended that they be bolted and bonded to the fixture (particularly for high levels of acceleration). Glue-only mounting is not recommended (especially for accelerations exceeding 49 km/s^2 [5000 g]), but if used, the bond line should be thin and without fillets.

4. Signal Conditioning

a. Low-pass analog anti-aliasing filters shall be used and placed before the analog-to-digital converter.

(1) The rejection rate shall be at least 24 dB /octave (4 pole filter).
(2) The cutoff frequency shall be in the range specified by:

$$1.5 \text{ x highest SRS frequency} < f_{cutoff} < 0.4 \text{ x sampling rate.}$$

b. Low-noise cabling shall always be used with piezoelectric transducers.
c. A sampling rate of at least 10 times highest SRS frequency shall be used in analog-to-digital conversion.
d. The SRS frequency points shall be calculated for at least 6 points per octave (1/6 octave sampling). Note: The preference is for 12 points or more per octave.
e. A range-approved SRS algorithm, such as Smallwood or Kelly-Richman, shall be used for the SRS computation and shall be documented.
f. The damping ratio (Q) shall be appropriately selected.

5. Data Presentation

a. The maximum positive and negative SRS spectrums from the entire shock event (primary and residual) as well as the SRS frequency points and damping ratio shall be presented. Note: If the positive and negative SRS spectrums diverge more than 4.5 dB for any SRS point, it is recommended that the range user's dynamicist confer with Range Safety prior to breaking the test configuration.
b. The raw accelerometer time history data used in the SRS calculation, the duration of the shock event itself, and the duration used in the SRS calculations shall be provided.
c. The calculated velocity time history data shall be provided to Range Safety in an acceptable format. Note: the velocity time history should be centered on the zero axis and attenuate in a manner similar to the instantaneous acceleration time history.
d. All accelerometer data channels shall be processed to produce acceleration and velocity time history plots.
e. All shock data shall be reviewed by the range user's dynamicist (cognizant engineer/technical expert) for validity and documented. If post-test data manipulation is performed, such as additional filtering, cleaning, de-trending, roving mean removal, DC offset removal, etc., then clear rationale shall be provided along with a description of what was done.

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 to be used for acceptance and qualification 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 satisfies all of 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 up to three complete acceptance tests for flight hardware. Use of a component that has been acceptance tested more than three times requires specific Range Safety approval.

4.9 Test and Analysis Reports

The range user shall provide a written report demonstrating compliance to all component performance and environmental requirements.

As a minimum, the reports shall:

1. describe all component test results and test conditions;
2. describe any analysis performed instead of testing;
3. identify, by serial number or other identification, each test result that applies to each system or component;
4. describe any family performance data to be used for comparison to any subsequent test of a component or system;
5. 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;
6. 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.

When applicable, combined tests (e.g., thermal/vibration or thermal/shock) shall be performed to reflect the environments that will be experienced by the flight component during pre-flight and flight.

NOTE	A determination as to whether analysis or testing is required will be made by Range Safety as part of the tailoring process.

NOTE	The following represent component-level testing categories. 1. 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. 2. 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 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 envelope the maximum predicted and workmanship levels unless otherwise approved by Range Safety. 3. Lot acceptance tests (LATs) are potentially destructive performance tests that are conducted on one-shot FTS components. For this reason, this type of testing will be done on a specified number of randomly selected units. The LATs 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 LAT does not necessarily invalidate the qualification test for that component but will cause rejection of the particular lot for flight termination purposes. 4. 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. 5. Delta-qualification tests are additional functional tests conducted on hardware

	that have previously passed a 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. 6. Age surveillance tests are conducted periodically over the service life of the unit in order to ensure that components have not degraded over time. These tests are typically employed on items with known sensitivity to storage environmental conditions or where information on the storage environment is incomplete. Range Safety will determine the frequency and type of age surveillance testing required. 7. The SLE tests are conducted to extend the service life of an item beyond its current limit. 8. Reuse tests are conducted to recertify an FTS component for another flight. Approval for reuse of an FTS component shall be obtained from the RSO 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 acceptance test procedure (ATP) baseline data and any previous certification test data. 9. 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, an RF compatibility test of the airborne system and range equipment shall also be conducted in the flight configuration.

4.10.2 Analysis Substitution

An analysis used in lieu of testing shall demonstrate at least 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 new components, 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 in that component's test table provided they demonstrate at least one of the following.

(1) The component has already experienced comparable environmental tests.

(2) The component is similar to a design that has experienced comparable environmental tests.

(3) The design has been shown by analysis/demonstration to not be susceptible to the applicable test environment.

c. Any component that a range user uses for any comparison to a new component shall have undergone all the environmental tests that are 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.

NOTE	A subset of performance 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 the low, nominal, and high operating voltages that the component could experience during pre-flight and flight operations.

d. Monitoring and recording shall be performed with 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.

NOTE	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.

NOTE	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 sampled at a minimum rate of 1000

samples per second during testing in dynamic environments.

2. All FTS components that are part of an ordnance firing circuit, such as batteries, SADs, or command receivers, shall have their relevant parameters sampled at a minimum rate of 10,000 samples per second during testing in 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.

NOTE	Status-of-health indications are not necessarily tied to a measurable test and include the following conditions: 1. overheating; 2. loose screws, connectors, or attaching hardware; 3. unit rattles when shaken; 4. bent, worn, or deformed parts; 5. electrical burning smell; 6. 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 that components satisfy 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 environments, and vehicle monitoring system tolerances.

NOTE	Text boxes following each performance requirement may contain margins based on lessons learned from numerous nominal and errant vehicle flights from all MRTFBs.

NOTE	The margins in the text box may be reduced or increased depending on the specific component and vehicle application.

4.10.8 Test Sequence

A component or system shall undergo each test in the order it is presented in the test table. A range user may deviate from the test sequence if he or she 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. Inspect all connector pins and sockets 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 Mass or Weight Measurement

A mass or weight measurement of a component shall verify that the component satisfies its mass or 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:

1. component name;
2. manufacturer identification;
3. date of manufacture;
4. date of explosive loading for components containing explosives;
5. serial number;
6. part number;
7. shelf life;
8. service life;
9. manufacturer's lot date code;
10. 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 ASTM E1742[21] or the equivalent unless otherwise specified in the component specification.
2. N-ray radiographic testing shall conform to the requirements of ASTM E748-02.[22]

4.11.7 Internal Inspection

An internal inspection of a component shall demonstrate that there is no debris and no 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.

NOTE	Destructive disassembly is not usually required unless there is an anomaly.

4.11.8 Leakage

For components with a seal, a leakage test shall demonstrate that the seal satisfies all of its performance requirements. The test shall have a resolution and sample rate sufficient to demonstrate that the component's leak rate is no greater than its specified limit.

Gas leak rate tests shall be performed IAW MIL-STD-202,[23] method 112, procedure III or IV or the equivalent.

4.12 Acceptance Testing and Analysis

4.12.1 General

This section applies to each acceptance test or analysis identified by any table of this chapter. An acceptance test or analysis of a component shall demonstrate that it satisfies all of its performance requirements when exposed to environmental levels, durations, and rates (as appropriate) that envelope the MPE and any applicable workmanship levels.

[21] American Society for Testing and Materials. *Standard Practice for Radiographic Examination*. E 1742-12. West Conshohocken: American Society for Testing and Materials, 2012.
[22] American Society for Testing and Materials. *Standard Practices for Thermal Neutron Radiography of Materials.* West Conshohocken: American Society for Testing and Materials.
[23] Department of Defense. Electronic and Electrical Component Parts. MIL-STD-202G w/Change 2. 28 June 2013. May be superseded by update. Available at http://quicksearch.dla.mil/.

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. Single-use components, such as ordnance or primary batteries, shall undergo the production lot sample acceptance tests identified by any tables of this chapter.

c. If a vehicle uses a previously flown and recovered FTS component, the component shall undergo one or more reuse acceptance tests before flight to demonstrate that the component still satisfies all of its performance requirements 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 written component reuse qualification, refurbishment, and acceptance plans 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 consistent with those used during qualification testing.

4.12.2 Acceptance Thermal Cycle

An acceptance thermal cycle test of a component shall demonstrate that the component satisfies all its performance requirements when exposed to thermal levels, durations, and rates that envelope the MPE and workmanship levels

For high MPE 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 five minutes.

NOTE	Thermal shock may be completed as qualification.

Figure 4-3 displays the acceptance thermal cycle temperatures for non-ordnance components.

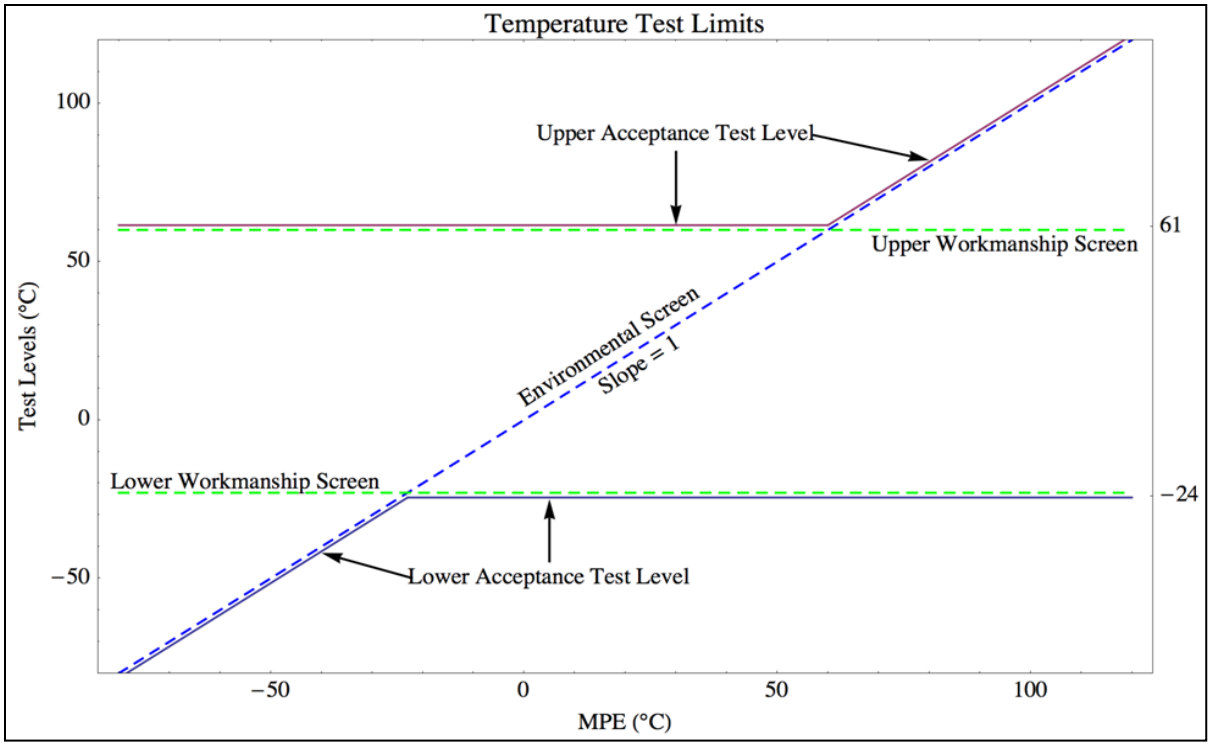

Figure 4-3. Acceptance Thermal Cycle Temperatures - Non-Ordnance

a. Passive Electrical Components. For any passive component that does not contain any active electronic piece-part, such as an RF antenna, coupler, or cable, an acceptance thermal cycle test shall satisfy all of the following.

(1) The test shall subject a component to no less than 1.5 times MPE (rounded up) or eight thermal cycles, whichever is higher. The MPE shall account for all pre-flight processing, delays, recycling, and flight.

(2) The lower acceptance thermal cycle temperature shall be no greater than the lower MPE or a −24°C workmanship level, whichever is lower.

(3) The upper acceptance thermal cycle temperature shall be no less than the upper MPE or a 61°C workmanship level, whichever is higher. This is displayed in Figure 4-3.

(4) The acceptance thermal cycle temperature transition rate shall be no less than the MPE or 3°C per minute, whichever is higher.

(5) Each dwell shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour.

(6) 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.

(7) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and Subsection 4.10.5 during all cycles and thermal transitions.

b. Active Electronic Components. Active electronic components shall be subjected to all of the following thermal cycle test requirements.

(1) Prior to acceptance testing the component shall be powered and subjected to no fewer than 10 burn-in thermal cycles at acceptance levels, rates, and durations.

(2) The test shall subject a component to no less than 1.5 times MPE (rounded up) or eight thermal cycles, whichever is higher. The MPE shall account for all pre-flight processing, delays, recycling, and flight.

(3) The lower acceptance thermal cycle temperature shall be no greater than the lower MPE or a −24°C workmanship level, whichever is lower.

(4) The upper acceptance thermal cycle temperature shall be no less than the upper MPE or a 61°C workmanship level, whichever is higher. This is displayed in Figure 4-3.

(5) The acceptance thermal cycle temperature transition rate shall be no less than the MPE or 3°C per minute, whichever is higher.

(6) Each dwell shall begin with the component turned off until it reaches internal thermal equilibrium. The component shall then be turned on until it again reaches internal thermal equilibrium. The dwell time with the component turned on shall be at least one hour.

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 burn-in thermal cycles, the dynamic environmental tests, and the remaining thermal cycles (usually 8 more) with final electrical performance tests at the hot, cold, and ambient levels of the last thermal cycle. Using this approach, thermal performance functions may be required during the beginning and end of burn in.

(7) 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.

(8) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and Subsection 4.10.5 during environmental exposure.

c. Power Sources. Battery thermal cycle temperature limits are chemistry-dependent and are included in the individual battery test sections.

d. Mechanical Devices. These include electromechanical SADs with internal explosives and mechanical valves. An acceptance thermal cycle test shall satisfy all of the following.

(1) The test shall subject a component to no less than 1.5 times MPE (rounded up) or eight thermal cycles, whichever is higher. The MPE shall account for all pre-flight processing, delays, recycling, and flight.

(2) The lower acceptance thermal cycle temperature shall be no greater than the lower MPE or a −24°C workmanship level, whichever is lower.

(3) The upper acceptance thermal cycle temperature shall be no less than the upper MPE or a 61°C workmanship level, whichever is higher. This is displayed in Figure 4-3.

(4) The acceptance thermal cycle temperature transition rate shall be no less than the MPE or 3°C per minute, whichever is higher.

(5) Each dwell shall last long enough for the component to achieve internal thermal equilibrium and shall last no less than one hour.

(6) 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.

(7) The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and Subsection 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.

e. Ordnance Components. Although ordnance components are not thermal-cycle tested to acceptance levels, the following values are used to calculate qualification levels.

(1) The test shall subject a component to no less than 1.5 times MPE (rounded up) or eight thermal cycles, whichever is higher. The MPE shall account for all pre-flight processing, delays, recycling, and flight.

(2) The lower acceptance thermal cycle temperature shall be no greater than the lower MPE or a −44°C workmanship level, whichever is lower.

(3) The upper acceptance thermal cycle temperature shall be no less than the upper MPE or a 61°C workmanship level, whichever is higher.

(4) The acceptance thermal cycle temperature transition rate shall be no less than the MPE or 3°C per minute, whichever is higher.

4.12.3 Acceptance Thermal Vacuum

An acceptance thermal vacuum test or analysis shall demonstrate that a component satisfies all of its performance requirements when exposed to the acceptance thermal vacuum environment as follows.

a. The thermal vacuum pressure gradient shall be greater than or equal to the MPE rate of change that the component will experience during flight. The pressure gradient shall allow for no less than 10 minutes for reduction of chamber pressure from ambient to the MPE low pressure.

1. With the component in the thermal chamber, reduce the pressure from atmospheric to a

critical pressure (i.e., the pressure that yields the lowest breakdown voltage and hence the highest vulnerability to arcing) of approximately 20 Pa (0.15 Torr). A function test shall be performed. Note: Breakdown voltage versus pressure is typically modeled using Paschen's Law. Note: 20 Pa (0.15 Torr) corresponds to a US Standard Atmosphere 1976[24] altitude of approximately 60 km (196,850 ft) mean sea level (MSL).

2. The time for reduction of chamber pressure from ambient to the critical pressure shall be at least 10 minutes to allow sufficient time in the region of critical pressure.
3. Reduce the pressure from critical pressure to the pressure at the actual flight altitude or 13.3 mPa (0.0001 Torr), whichever is lower.

b. The final vacuum dwell time shall be sufficient to achieve internal component vacuum equilibrium or shall be the maximum predicted flight vacuum time, whichever is higher.

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 vacuum dwell time shall be the maximum predicted vacuum dwell time or 12 hours, whichever is greater.

c. During the final vacuum dwell, the environment shall include no less than the MPE number of thermal cycles.

d. The acceptance thermal vacuum temperature limits shall be the same as the acceptance thermal cycle temperature limits in Subsection 4.12.2.

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 Subsection 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.

[24] National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration, United States Air Force. US Standard Atmosphere, 1976. Available at http://www.dtic.mil/get-tr-doc/pdf?AD=ADA035728.

NOTE	Low voltages are considered to be those less than 50 V.

(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.

NOTE	High voltages are considered to be those greater than 250 V.

(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.

4.12.4 Acceptance Sinusoidal Vibration

An acceptance sinusoidal vibration test shall demonstrate that a component satisfies all of its performance requirements when exposed to the acceptance sinusoidal vibration environment as follows.

a. The acceptance sinusoidal vibration environment shall equal or exceed the MPE sinusoidal vibration levels for the expected sinusoidal frequencies in each of three mutually perpendicular axes

b. For each axis, the sinusoidal vibration test duration shall be the time required to perform as many complete frequency sweeps as needed to meet or exceed the MPE flight sinusoidal duration.

c. A component shall be tested to demonstrate it satisfies all abbreviated performance verification tests required in the component test matrix and Subsection 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 sinusoidal vibration test in the same isolator-mounted configuration or hard-mounted configuration as the component's qualification sinusoidal 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.

4.12.5 Acceptance Random Vibration

An acceptance random vibration test shall demonstrate that a component satisfies all of its performance requirements when exposed to the acceptance random vibration environment as follows.

a. The acceptance random vibration levels shall envelope both the MPE and the workmanship levels given in Table 4-2. Figure 4-4 provides a graph of this data.

Table 4-2. Workmanship Random Vibration Profile

Frequency / Frequency Range (Hz)	Minimum Power Spectral Density
20	0.51 m^2/s^3 (0.0053 g^2/Hz)
20-150	3 dB/Octave Slope
150-600	3.8 m^2/s^3 (0.04 g^2/Hz)
600-2000	−6 dB/Octave Slope
2000	0.35 m^2/s^3 (0.0036 g^2/Hz)
Overall RMS acceleration = 60 m/s^2 (6.1 g)	

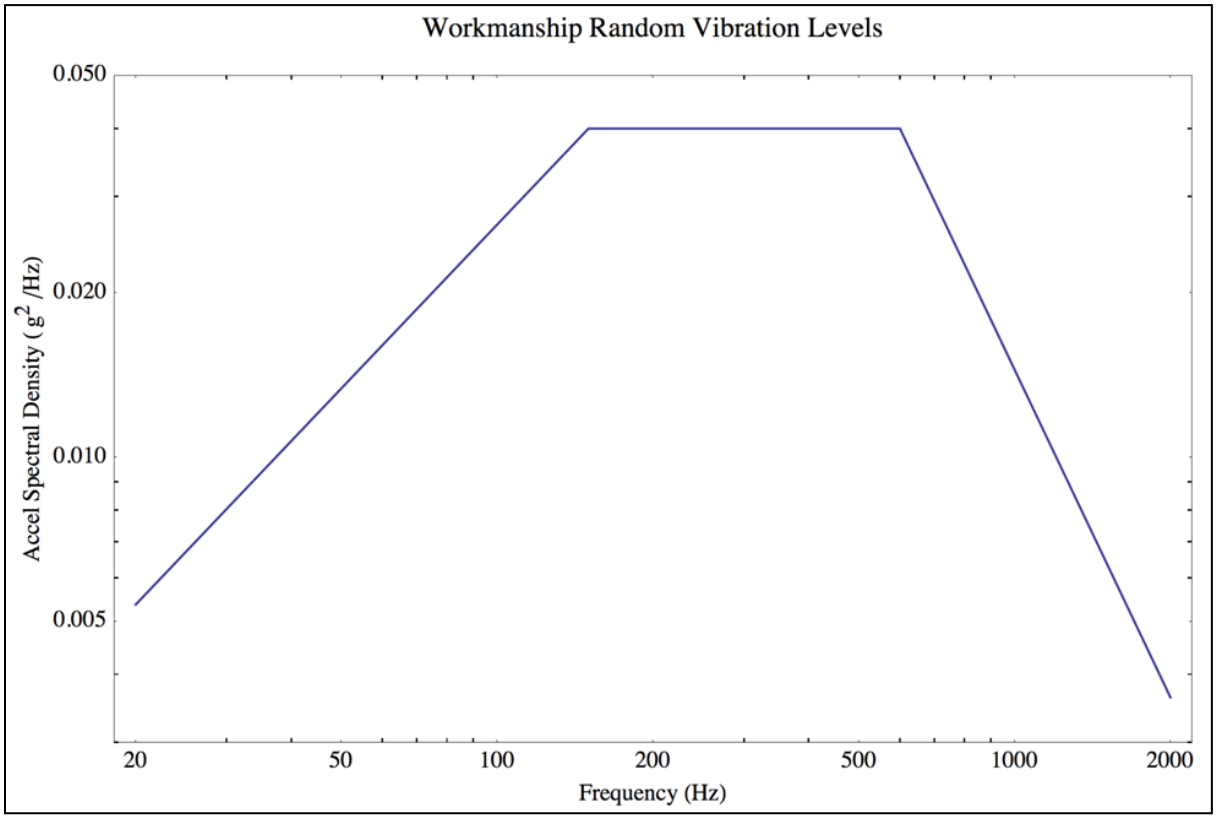

Figure 4-4. Workmanship Random Vibration Profile

b. The acceptance random vibration duration in each axis shall envelope both the MPE and a workmanship duration of one minute.

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 and adds a 1.5-dB margin to account for any isolator attenuation variability. This shall also include any thermal effects and acceleration pre-load performance 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; and
- 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 satisfies all abbreviated performance verification tests required in the component test matrix and Subsection 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 6 dB 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. The relevant parameters shall be sampled at a minimum rate of 1000 samples per second.

4.12.6 Acceptance Acoustic Vibration

a. The acceptance acoustic vibration level shall equal or exceed the MPE acoustic level in each of three mutually perpendicular axes.

The frequency range used for testing shall be 50 Hz to 10 kHz.

b. The acceptance acoustic vibration duration in each axis shall envelope MPE and workmanship durations with a workmanship duration of one minute.

c. A component shall be tested to demonstrate it satisfies all abbreviated performance verification tests required in the component test matrix and Subsection 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 6 dB 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 show that the acceptance random vibration test environment of Subsection 4.12.5 encompasses the acoustic vibration environment.

When using the results from random vibration testing as a baseline, the analysis shall account for the peak vibration and acceleration levels and durations.

4.12.7 Tensile Loads

An acceptance load test of a component shall demonstrate that the component is not damaged and satisfies all of its performance requirements after experiencing the worst-case expected transportation and installation compression and tensile loads that the component could experience before, during, or after installation or a minimum workmanship level, whichever is higher.

1. This section is not applicable to one-shot FTS devices, see section 4.14.11.
2. For optical, RF, and electrical cables and connectors, shall be able to withstand a workmanship level tensile pull of 67 N (15 lbf) and a torque of 0.85 N-m (7.5 in-lbf) or ½ the manufacturer-specified limit, whichever is higher. Torque testing is only applicable to compression connector design.
3. The component and associated fittings shall be capable of withstanding the loads for one minute minimum without damage or degradation in performance.

4.12.8 Thermal Shock

An acceptance thermal shock test of a component shall demonstrate that the component satisfies all its performance requirements when exposed to sudden changes in temperature of the surrounding atmosphere. For skin-mounted components such as antennas, the component shall be exposed to the high-temperature aerodynamic heating profile expected during flight, and then maintained at the expected steady-state temperature predicted after the aerodynamic heating profile.

a. The lower acceptance temperature shall be no greater than the lower MPE.

b. The upper acceptance temperature shall be no less than the upper MPE.

c. The acceptance transition rate shall be no less than the MPE thermal ramp rate.

d. The duration of exposure is the time from liftoff to end of Range Safety's responsibility. The thermal shock profile shall be provided by the customer and approved by Range Safety.

e. The test shall subject a component to one thermal shock profile.

f. The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and Subsection 4.10.5 during environmental exposure.

NOTE	Thermal shock may be completed as qualification.

4.13 General Qualification Testing and Analysis Requirements

4.13.1 General

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 of a component shall demonstrate that it will satisfy all of its performance requirements when exposed to acceptance test levels plus a margin.

4.13.2 Initial Testing

Before a component sample undergoes a qualification environmental test, it shall pass all the required acceptance tests.

4.13.3 Flight-Representative Configuration

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 Loctite® 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.

4.13.4 Re-Qualification Tests

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, 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.

4.13.5 Component Sample

Any component sample that has been subjected to a qualification test environment is not acceptable for flight.

4.13.6 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 no more than 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. Approval from RSO for qualification by similarity is required. Components that are to be qualified by similarity will be identified at the beginning of the program. The RSO will approve or disapprove the similarity analysis at that time. The early identification of potential noncompliant hardware that 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 to which the item was qualified 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.

4.13.7 Multiple-Flight Components

For any FTS component used for more than one flight, the component qualification tests shall demonstrate that the component satisfies all of its performance requirements 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.

4.14 Qualification Non-Operating Environments

4.14.1 General

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 of its performance requirements when subjected to each maximum predicted non-operating environment that the component could experience, including all storage, transportation, and installation environments plus a margin.

4.14.2 Storage Temperature

A storage temperature test or analysis shall demonstrate that a component will satisfy all of its performance requirements after being 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.

NOTE	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 range of 20°C.

NOTE	For items containing chemically active components, such as batteries or ordnance, high storage temperatures generally result in shorter lifetimes. This should be taken into consideration when determining the service life of the item. Relative aging times are typically modeled using the Arrhenius equation.

a. A storage temperature test shall subject the component to the range of temperatures from 10°C lower than the lowest predicted storage temperature to 10°C higher than the highest predicted storage temperature. The rate of change from one thermal extreme to the other shall be no less than the maximum predicted storage 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-battery and non-ordnance components;
   b. −54°C to 71°C for ordnance components.

2. A battery minimum storage temperature range shall not exceed the manufacturer-

recommended values. Note: The minimum and maximum storage temperatures for batteries are primarily determined by battery chemistry.

3. The component shall be tested to the high and low temperatures for a minimum of seven cycles with 12-hour dwells 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.

4.14.3 Artificial Aging

An ordnance component production lot may have its service life increased by satisfactory completion of performance testing on a sample after being subjected to artificial aging by high-temperature storage. The test shall impart environmental stress levels that simulate a component's aging effects.

1. Ordnance devices will have an initial service life of 1 year if no artificial aging is performed prior to testing.
2. Devices using a deflagration-to-detonation interface will have an initial service life of 3 years if each component sample satisfies all of its performance requirements after the ordnance is subjected to artificial aging at 71°C and 40 to 60% relative humidity (RH) for no less than 20 days each.
3. Linear ordnance systems initiated by a high-order interface will have an initial service life of 5 years if each component sample satisfies all of its performance requirements after the ordnance is subjected to artificial aging at 71°C and 40 to 60% RH for no less than 33 days each.
4. Certain linear ordnance systems initiated by a high-order interface may be allowed to have an initial service life of 10 years if each component sample satisfies all of its performance requirements after the ordnance is subjected to artificial aging at 71°C and 90% RH for no less than 66 days each. Candidate devices include linear shaped charges, conical shaped charges, bi-directional wafer charges, and various implementations of detonating cord, such as FCDC, shielded MDC, and Primacord®. Application of the Arrhenius equation by itself does not result in a ten-year service life.

   a. The following design elements must have a demonstrated functionality on similar devices over at least 15 years:

      (1) all ordnance compositions;
      (2) all direct interfaces between different ordnance compositions;
      (3) all materials in direct contact with ordnance compositions;
      (4) all materials that make up the component (including the housing, passivation, coatings, lubrication, and epoxies).

   b. The 10-year service life only applies to the first 10 years of the component's service life. Any SLEs are limited to no more than 5 years.
   c. The component shall be tested to demonstrate that it is sealed so as to admit a gas leak rate

no greater than the equivalent of 10^{-7} W (10^{-7} Pa m^3/s, 10^{-6} atm cm^3/s) of helium at SLC.

d. Ordnance components that use a small ordnance load, such as shock tube, shall not be permitted to use the 10-year initial shelf life.

e. If approved, 10-year service life would only be applicable for a specific ordnance design with consistent production for individual programs as evaluated by individual ranges based on previous ordnance history, local storage conditions, and other factors as applicable.

5. Test durations of 20, 33, and 66 days for 3, 5, and 10 years service life, respectively, are based on an operational storage temperature of 21°C. If the operational storage temperatures are expected to exceed 21°C, the test duration and/or test storage temperature shall be recalculated to account for any additional aging effects.

NOTE	The above artificial aging times were calculated using the Arrhenius equation with the following assumed values: activation energy = 67540 J/mol (0.7 eV/molecule), operational storage temperature = 21°C, and test storage temperature = 71°C. The resulting estimates are conservative insofar as the activation energy used in the calculations was selected to envelope (i.e., fall below) the actual activation energies of any of the commonly encountered energetic materials.

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 SLE for each type of ordnance component.

b. The tables of this chapter identify the number of ordnance component samples that shall undergo any SLE test. Each component sample shall:

(1) be from the same production lot;

(2) consist of identical parts and materials;

(3) be manufactured through identical processes; and

(4) be stored with the flight ordnance component or in an environment that duplicates the storage conditions of the flight ordnance component.

4.14.4 Transportation Random Vibration

A transportation vibration test or analysis shall demonstrate that a component satisfies all of its performance requirements as follows.

a. A transportation vibration test shall subject the component to 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 a minimum of one hour per axis. The test shall subject each axis to at least the vibration profile in Table 4-3. If the component is resonant below 10 Hz, the

test vibration profile shall extend to the lowest resonant frequency.

Table 4-3. Minimum Transportation Random Vibration Profile

Frequency / Frequency Range (Hz)	Minimum Power Spectral Density
10-40	1.4 m^2/s^3 (0.015 g^2/Hz)
40-500	−5.5 dB/Octave Slope
500	0.014 m^2/s^3 (0.00015 g^2/Hz)
Overall RMS acceleration = 9.8 m/s^2 (1 g)	

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.

4.14.5 Transportation Shock

A transportation shock test or analysis shall demonstrate that a component satisfies all of its performance requirements 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.

1. Commercial Packaging

a. The test component shall be packaged in the manner intended for shipment.
b. The test component shall be oriented so that, upon impact, a line from the impacting corner or edge to the center of gravity of the transportation case and the component is perpendicular to the impact surface.
c. Drops should be made from a quick-release hook or drop tester.
d. This test may be conducted at ambient temperature.

2. Launch Vehicle Transport

a. A full functional test shall be performed before and after all shock tests to evaluate performance and to detect any failures.
b. A visual inspection shall be made before and after the test.
c. The visual inspection shall not entail the removal of component covers or any disassembly.
d. The proposed test method shall be validated prior to conducting tests on the flight component.
e. Any test technique that is used shall, as a minimum, provide the following:

(1) a transient with the prescribed shock spectrum can be generated within specified tolerances;
(2) the applied shock transient provides a simultaneous application of the frequency

components as opposed to a serial application.

f. As applicable, the component shall be mounted, including dynamic isolator (if used), as in-flight configuration with flight-type support structure, hardware, cable, ETL, and brackets.
g. The transportation SRS in each direction along each of the three orthogonal axes shall be the maximum predicted level.
h. The minimum number of shocks shall be three times per axis for each direction, positive and negative, for a total of 18 shocks.
i. The shock duration shall simulate the actual event.

4.14.6 Bench Handling Shock

A bench handling shock test shall demonstrate that a component satisfies all of its performance requirements after being subjected to maximum predicted bench handling-induced shock levels plus a margin. The test shall include a drop from the maximum predicted handling height onto a representative surface for each orientation that could occur during servicing.

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 100 mm (4 in) 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.

4.14.7 Handling Drop of Ordnance

A handling drop test shall demonstrate that an ordnance component satisfies all of its performance requirements after experiencing the maximum predicted drop and resulting impact that could occur if dropped by personnel.

The component shall be dropped from 1.8 m (6 ft) onto a representative surface in any orientation that could occur during storage, transportation, or installation.

1. Drop 3 times onto a 13-mm (1/2-in) thick steel plate using the following procedure.
   a. Drop to cause it to impact on the output end. This is drop 1 of 3.
   b. Drop to cause it to impact on its side. This is drop 2 of 3.
   c. Drop to cause it to impact on the connector or input pin end. This is drop 3 of 3.
2. The device shall not fire, dud, or deteriorate in performance as a result of this test.

4.14.8 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 12 m (40 ft) onto a steel plate.

4.14.9 Fungus Resistance

A fungus resistance test or analysis shall demonstrate that a component satisfies all of its performance requirements 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 IAW MIL-STD-810G[25], Method 508.5.

4.14.10 Dust or Fine Sand

For a component that will be exposed to dust or fine sand, a fine-sand test or analysis shall demonstrate that the component satisfies all of its performance requirements 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.

Testing shall be performed IAW MIL-STD-810G, Method 510.5.

4.14.11 Tensile Load

A qualification load test shall demonstrate that a component satisfies all of its performance requirements after being exposed to no less than two times the acceptance test level with the exception of one-shot devices. For one-shot FTS devices, the qualification and lot sample acceptance testing levels are the same.

1. Optical, RF, and electrical cables and connectors shall be able to withstand a tensile pull of 133 N (30 lbf) and a torque of 1.7 N-m (15 in-lbf) or the manufacturer-specified limit, whichever is higher. Torque testing is only applicable to compression connector designs. 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. 2. For one-shot FTS devices, the levels below shall be used to ensure that flight hardware will not be damaged during inadvertent or accidental load conditions.

[25] Department of Defense. Environmental Engineering Considerations and Laboratory Tests. MIL-STD-810G. 13 October 2008. May be superseded by update. Available at http://www.atec.army.mil/publications/Mil-Std-810G/Mil-Std-810G.pdf.

a. For an ETS and its associated fittings, a pull of no less than 445 N (100 lbf) 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 222 N (50 lbf).
c. For an LVI wire, EBW, EFI, and LID pigtails, a pull of no less than 80 N (18 lbf) or the manufacturer-specified limit, whichever is higher. Any LVIs contained in a SAD may undergo additional testing once the LVI is installed in the rotor in lieu of the 80-N pull requirement. Testing helps ensure the LVIs were not damaged during installation. These tests include X-ray, N-ray, thermal time constant, and bridgewire resistance.
d. For an electrical pin of an initiator that is installed or removed in the field, no less than an 80-N (18 lbf) force in axial tension and compression modes.

3. The component and associated fittings shall be capable of withstanding tensile loads for one minute minimum without damage or degradation in performance.

4.15 Qualification Operating Environments

4.15.1 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, flight/launch countdown, and flight plus a margin IAW Subsection 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 pre-flight/launch and flight. The detailed requirements for combined tests will be determined during tailoring.

All performance verification tests required by the component test matrix shall be performed before and after each operating environmental test.

4.15.2 Qualification Thermal Cycle

A qualification thermal cycle test shall demonstrate that a component satisfies all of its performance requirements when subjected to acceptance thermal cycle environments plus a margin. Figure 4-5 and Figure 4-6 contain the upper and lower temperature limits for qualification thermal cycle requirements (excluding ordnance).

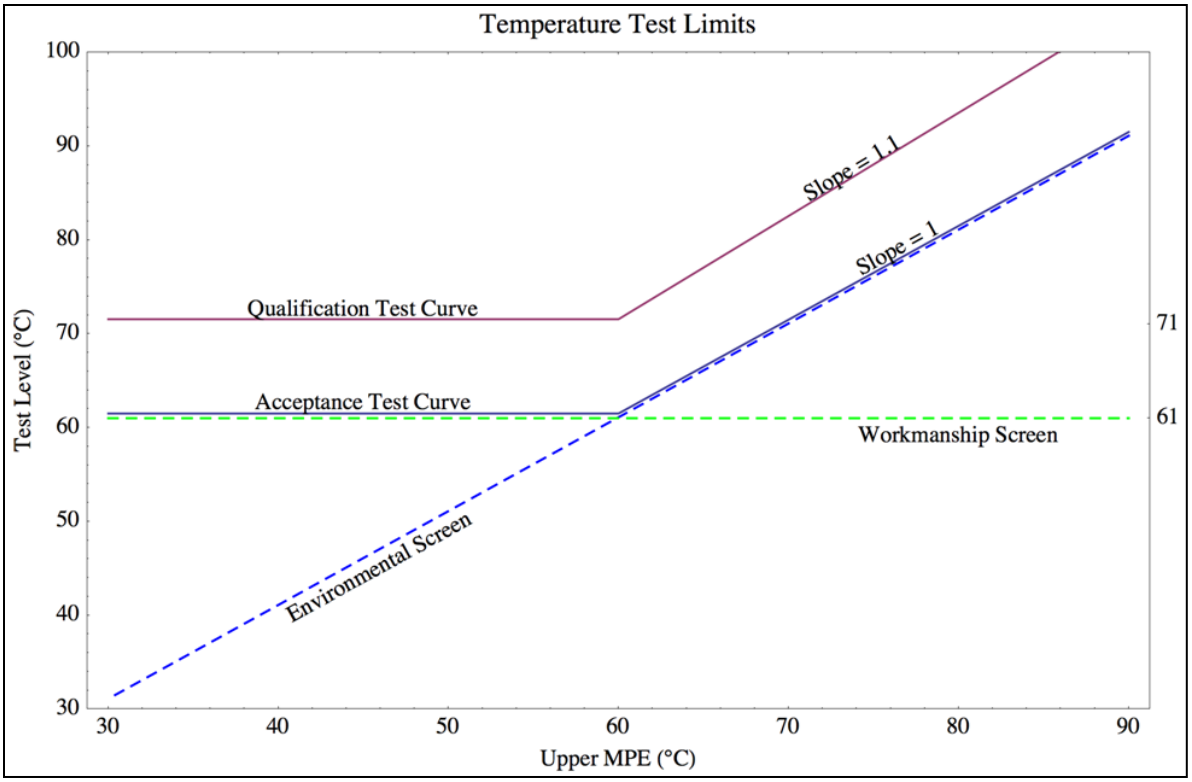

Figure 4-5. Qualification Thermal Cycle Temperature Requirements - Non-Ordnance, Upper Maximum Predicted Environment

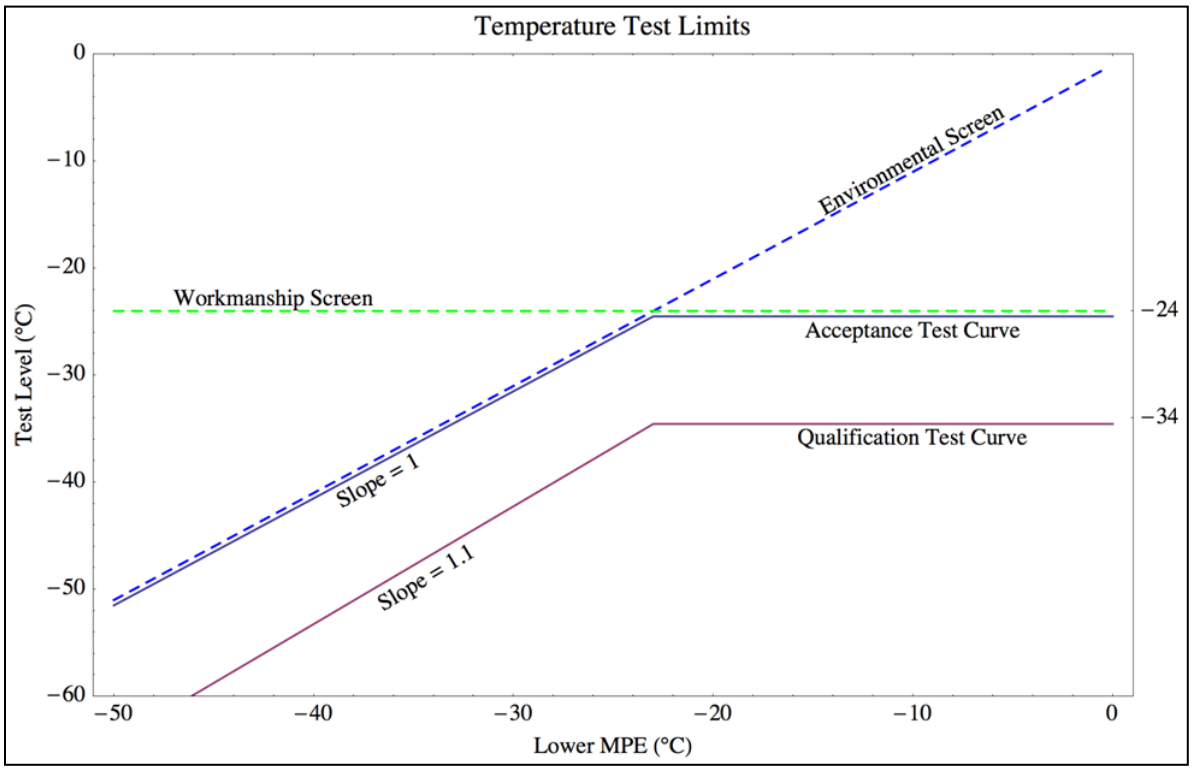

Figure 4-6. Qualification Thermal Cycle Temperature Requirements - Non-Ordnance, Lower Maximum Predicted Environment

For high 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 MPE 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 five minutes.

a. Passive Electrical Components. For any passive component that does not contain an active electrical piece-part (such as an RF antenna, RF coupler, or cable), a qualification thermal cycle test shall satisfy all of the following.

(1) Qualification thermal cycle temperature limits shall be at least the acceptance thermal cycle temperature limits in Subsection 4.12.2 plus a margin of 10°C. If an MPE is outside the workmanship range, an additional 10% of the difference between the MPE and the workmanship level shall be added. Figure 4-5 and Figure 4-6 display these test limits.

(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 higher. Exclude burn-in cycles when calculating number of qualification cycles. 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 the maximum predicted rate or 3°C per minute, whichever is higher.

(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 Subsection 4.10.5 during environmental exposure.

b. Active Electronic Components. For 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) Qualification thermal cycle temperature limits shall be at least the acceptance thermal cycle temperature limits in Subsection 4.12.2 plus a margin of 10°C. If an MPE is outside the workmanship range, an additional 10% of the difference between the MPE and the workmanship level shall be added. Figure 4-5 and Figure 4-6 display these test limits.

(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 higher. 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 the maximum predicted rate or 3°C per minute, whichever is higher.

(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 Subsection 4.10.5 during environmental exposure.

c. Power Sources. Battery thermal cycle temperature limits are chemistry-dependent and are included in the individual battery test sections.

d. Mechanical Components. These devices include electromechanical SADs with an internal explosive and mechanical valves. An acceptance thermal cycle test shall satisfy all of the following.

(1) Qualification thermal cycle temperature limits shall be at least the acceptance thermal cycle temperature limits in Subsection 4.12.2 plus a margin of 10°C. If an MPE is outside the workmanship range, an additional 10% of the difference between the MPE and the workmanship level shall be added. Figure 4-5 and Figure 4-6 display these test limits.

(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 higher. 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 the maximum predicted rate or 3°C per minute, whichever is higher.

(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 Subsection 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.

e. Ordnance Components. Ordnance components shall satisfy all of the following.

(1) Qualification thermal cycle temperature limits shall be at least the acceptance thermal cycle temperature limits in Subsection 4.12.2 plus a margin of 10°C. If an MPE is outside the workmanship range, an additional 10% of the difference between the MPE and the workmanship level shall be added.

(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 a SAD, 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 a rate of not less than the maximum predicted rate or 3°C per minute, whichever is higher.

4.15.3 Qualification Thermal Vacuum

A qualification thermal vacuum test or analysis shall demonstrate that a component satisfies all of its performance requirements, including structural integrity, when subjected to the MPE thermal vacuum environment plus a margin as follows.

a. The thermal vacuum pressure gradient shall equal or exceed the MPE rate of change that the component will experience during flight. The pressure gradient shall allow for no less than 10 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 (i.e., the pressure that yields the lowest breakdown voltage and hence the highest vulnerability to arcing) of approximately 20 Pa (0.15 Torr). A performance test shall be performed. Note: Breakdown voltage versus pressure is typically modeled using Paschen's Law. Note: 20 Pa (0.15 Torr) corresponds to a US Standard Atmosphere 1976 altitude of approximately 60 km (196,850 ft) MSL.
2. The time for reduction of the chamber pressure from ambient to the critical pressure shall be at least 10 minutes to allow sufficient time in the region of critical pressure.
3. Reduce the pressure from critical pressure to the pressure at the actual flight altitude or 13.3 mPa (0.0001 Torr), whichever is lower.

b. The final vacuum dwell time shall be sufficient to achieve internal component vacuum equilibrium or shall be the maximum predicted flight vacuum time, whichever is higher, 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 vacuum dwell time shall be the maximum predicted vacuum dwell time or 12 hours, whichever is greater.

c. The thermal vacuum qualification number of thermal cycles shall be no less than three times the acceptance number of thermal cycles.

A minimum of three thermal cycles shall be used.

d. The qualification thermal vacuum temperature limits shall be the same as the qualification thermal cycle temperature limits in Subsection 4.15.2.

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 Subsection 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.

NOTE	Low voltages are considered to be those less than 50 V.

(2) Any high-voltage 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.

NOTE	High voltages are considered to be those greater than 250 V.

(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 Qualification Humidity

A qualification humidity test or analysis shall demonstrate that a component satisfies all of its performance requirements when subjected to the MPE humidity environment that it 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 RH environment.

b. The test or analysis shall demonstrate the ability of each internal part of a component to withstand the maximum predicted RH 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 10 thermal cycles while the component is exposed to a RH of no less than 95%.

(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 Subsection 4.10.5 during environmental exposure.

Cycle 1:

1. Gradually increase the internal chamber temperature to 61°C and the RH to 95±5% over a two-hour period.
2. Maintain temperature and humidity for six hours.
3. Maintain 85% or greater RH and reduce the internal chamber temperature in eight hours to 30°C and 95±5% humidity.
4. Maintain these conditions for eight hours.

Cycles 2 through 4: Repeat cycle 1.
Cycle 5: Repeat Cycle 1 and perform a performance verification test.
Cycles 6 through 9: Repeat cycle 1.
Cycle 10:

5. Repeat cycle 1 and perform a performance verification test.
6. Decrease the internal chamber temperature to 23°C and 50% RH by blowing air through the chamber for six hours. The volume of air that is used per minute shall be between one

and three times the test chamber volume. A suitable container may be used in place of the test chamber for drying the component.
7. Visually inspect the component for physical damage or deterioration.
8. Perform a performance verification test.

4.15.5 Salt Fog

For a component that will be exposed to salt fog, a salt fog test or analysis shall demonstrate that the component satisfies all of its performance requirements when subjected to the effects of an atmosphere containing moisture and salt at MPE concentration levels 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 it to 5% salt fog at 35°C for a period of two days.
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 two days.
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 V.

4.15.6 Temperature/Humidity/Altitude

A temperature, humidity, and altitude test or analysis shall demonstrate that a component satisfies all of its performance requirements when subjected to the MPE temperature, humidity, and altitude environments plus a margin as follows.

A component shall satisfy all of its performance requirements, including structural integrity, corona, and internal component electrical/optical degradation.

NOTE	This test is used 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 Subsection 4.10.5 during environmental exposure.

c. The test shall subject a component to no less than four thermal/humidity/altitude cycles.

1. Place the component in a test chamber and adjust the pressure to one standard atmosphere.
2. Low Temperature Step. Reduce the chamber temperature to the lower qualification temperature within two hours.
3. Altitude (Low Pressure) Step.

   a. Reduce the chamber pressure at a rate equivalent to an increase of 300 meters/minute to 450 meters/minute (approximately 1000 feet/minute to 1500 feet/minute) to the equivalent of the highest mission altitude or 15.24 km (50,000 ft) MSL, whichever is higher, while maintaining the low temperature.

   b. When the altitude of the component has stabilized, conduct a performance test on the component. Figure 4-7 displays a graph of the target lapse rate during the low-pressure chamber test.

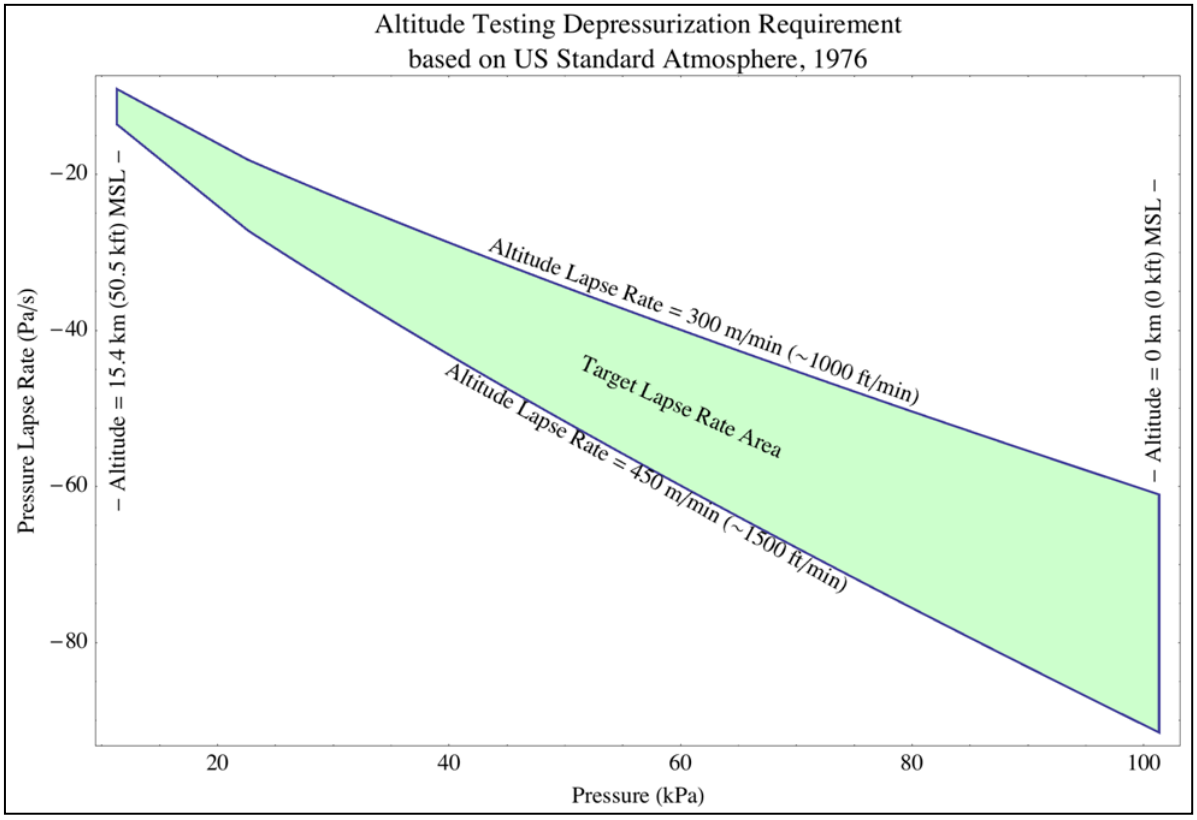

Figure 4-7. Pressure Lapse Rate for the Altitude (Low Pressure) Step

4. Humidity Step

   a. Within 30 minutes, raise the chamber pressure to one standard atmosphere and the temperature to ambient; then, raise the chamber humidity to 95% RH.

   b. Maintain the temperature and humidity conditions for 2½ hours.

5. High Temperature Step
   a. During the next 30 minutes, increase the temperature to the upper qualification temperature and maintain the humidity at 95% RH.
   b. Maintain the temperature and humidity conditions for 6 hours.
   c. When the chamber and component stabilize, conduct another performance test.
6. Ambient Temperature Step
   a. During the next 8 hours, reduce the chamber temperature to ambient at a uniform rate while maintaining the humidity at 95% RH.
   b. Maintain ambient temperature and humidity at 95% RH for 2 hours.
   c. When the chamber and component stabilize, conduct another performance test.
7. Repeat the temperature/humidity/altitude test cycle described in steps 2-6 for three additional cycles for a total of four cycles. Figure 4-8 displays the changes to temperature and pressure described in the steps of one test cycle.

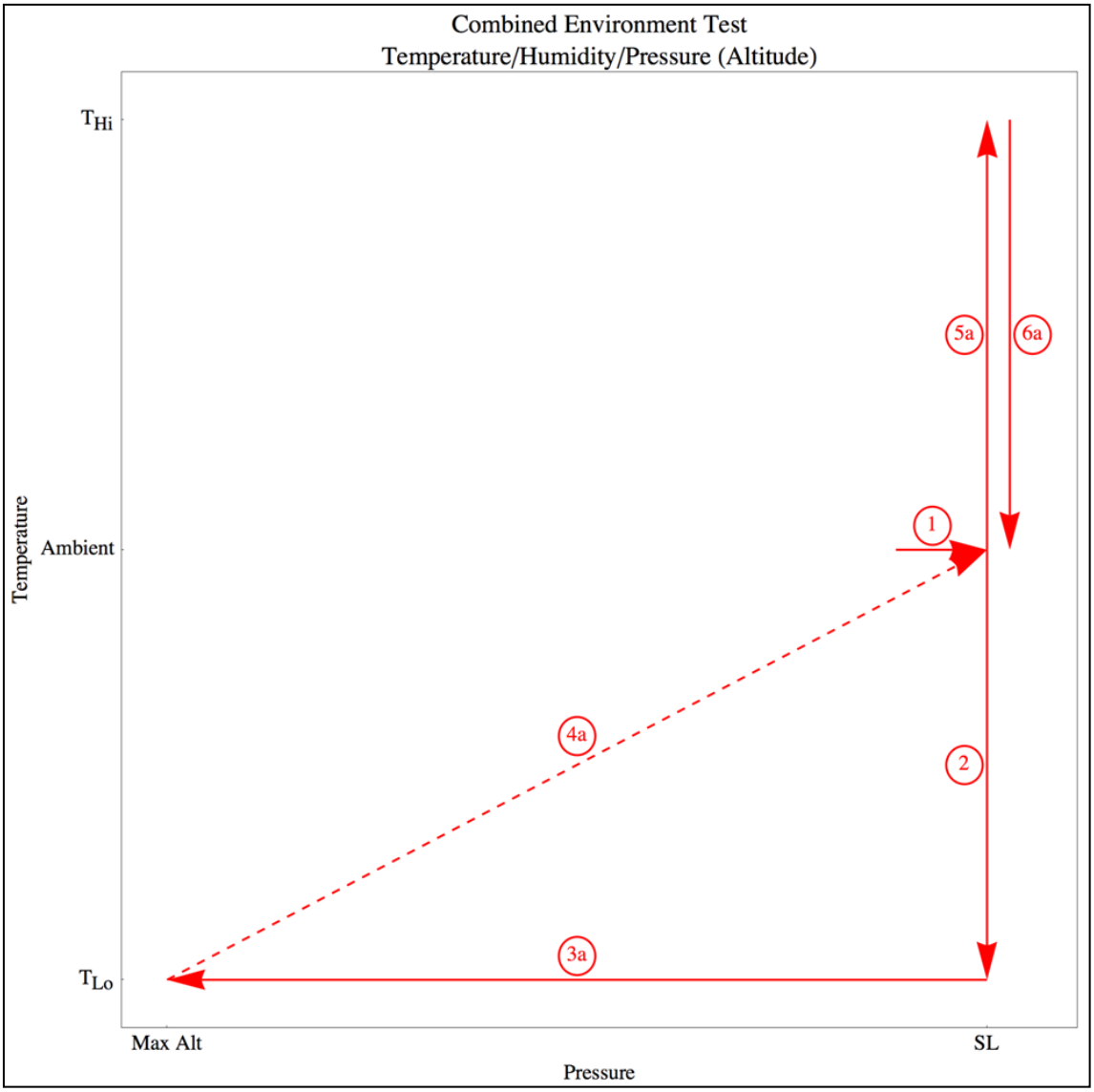

Figure 4-8. Temperature/Humidity/Altitude Test Profile

4.15.7 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 MPE flight 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 testing shall be performed at qualification hot and/or cold temperatures if the component will be exposed to the combined dynamic/thermal environment.

b. A component shall be tested to demonstrate it satisfies all abbreviated performance verification tests required in the component test matrix and Subsection 4.10.5 during environmental exposure.

c. The qualification acceleration test environment shall be two times 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 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. The relevant parameters shall be sampled at a minimum rate of 1000 samples per second.

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 five minutes per axis in each direction.

4.15.8 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 acceptance sinusoidal vibration environment plus a margin. 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 qualification hot and/or cold temperature if the component will be exposed to the combined dynamic/thermal environment.

b. A component shall be tested to demonstrate it satisfies all abbreviated performance verification tests required in the component test matrix and Subsection 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 6 dB greater than the maximum predicted sinusoidal vibration environment for no less than three times the maximum predicted duration.

e. The sinusoidal sweep frequencies shall range from the lowest predicted frequency to highest predicted frequency plus a margin.

The minimum test frequency shall be 50% of the lowest sinusoidal frequency predicted. The maximum test frequency shall be 150% of the highest sinusoidal frequency predicted.

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.

4.15.9 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 random 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.

Random vibration shall be performed at qualification hot and/or cold temperatures if the component will be exposed to the combined dynamic/thermal environment.

b. A component shall be tested to demonstrate it satisfies all abbreviated performance verification tests IAW Subsection 4.10.5 during environmental exposure.

c. The minimum qualification random vibration environment shall satisfy 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 kHz.

1. This section 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. Figure 4-9 illustrates a potential conflict between the minimum qualification test level and maximum acceptance test level tolerances.

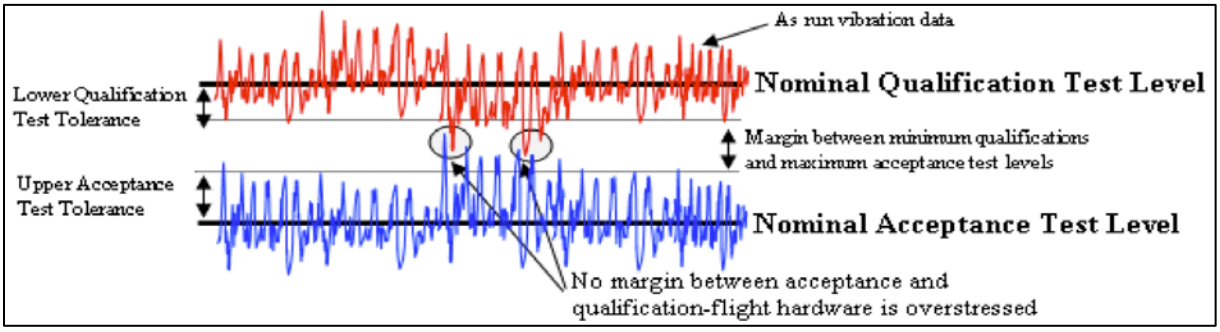

Figure 4-9. Sample of Conflict Between Qualification and Acceptance Test Margins

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 +1.5-dB 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 acceptance levels.

(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 kHz.

1. This section applies to components that are not subjected to vibration acceptance testing. These tests are usually reserved for components such as ordnance and Ag-Zn 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 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 levels in Table 4-4.

Table 4-4. Minimum Qualification Random Vibration Profile	
Frequency / Frequency Range (Hz)	**Minimum Power Spectral Density**
20	2.0 m^2/s^3 (0.021 g^2/Hz)
20-150	3 dB/Octave slope
150-600	15.4 m^2/s^3 (0.16 g^2/Hz)
600-2000	−6 dB/Octave slope
2000	1.3 m^2/s^3 (0.014 g^2/Hz)
Overall RMS acceleration = 120 m/s^2 (12.2 g)	

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. Perform 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 4-4. 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 Hz to 2 kHz.

e. The duration used for qualification testing shall be the acceptance test duration 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 three 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. Perform a single test that envelopes 3 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 3 times the MPE
      (2) The duration for the second test shall be 3 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 three 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.

NOTE	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 4-10).

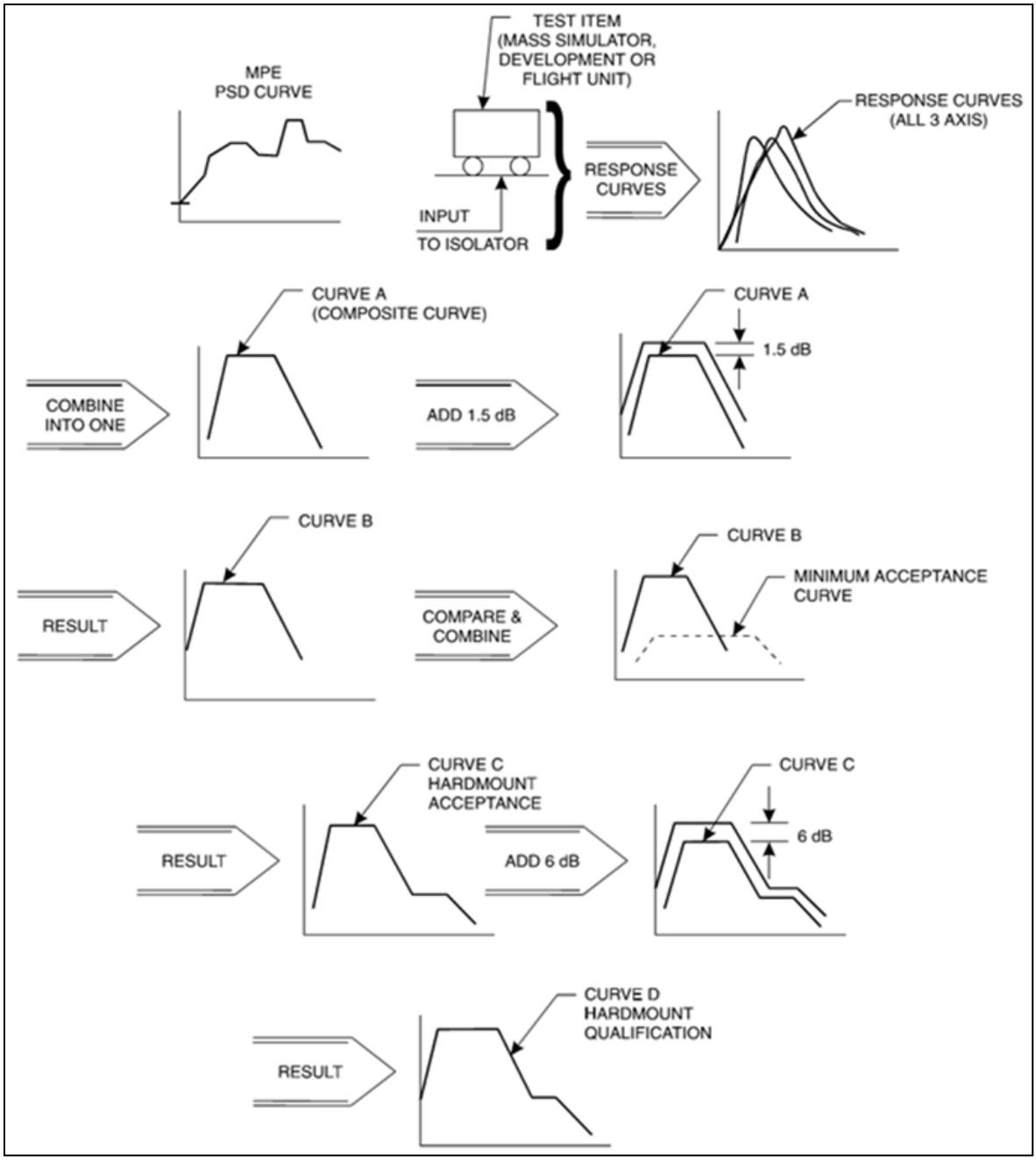

Figure 4-10. Procedure for Hardmount Qualification of Components on Vibration Isolators

(1) The entire flight-configured isolated system shall demonstrate it satisfies 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 ETLs) 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. that no added displacements can cause failures in attaching hardware and induce new vibration modes into the component.

(2) The component shall demonstrate that it satisfies all its performance requirements when subjected to the isolated input qualification test environment.

The isolated input qualification random vibration level shall be tested using one of the following methods.

1. Characterize the component qualification test level input through the isolators and test the flight hardware hard-mounted (without isolators)
2. 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 number (1) above.

(3) The component shall satisfy all its performance requirements when subjected to the minimum qualification level in Table 4-4.

NOTE	The minimum qualification level input is directly into the component and not through the isolated system.

NOTE	This test is typically performed hardmount since the isolator system often attenuates the test level below the required minimum workmanship levels.

4.15.10 Qualification Acoustic Vibration

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 MPE 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.

NOTE	Acoustic levels are specified in terms of sound pressure level (Lp) in dB relative to 20 µPa.

b. A component shall be tested to demonstrate it satisfies all abbreviated performance verification tests required in the component test matrix and Subsection 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 10 kHz.

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. The relevant parameters shall be sampled at a minimum rate of 1000 samples per second.

f. An acoustic vibration analysis may be used in lieu of testing. The analysis shall demonstrate that the qualification random vibration test environment of Subsection 4.15.9 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.

4.15.11 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 MPE flight 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.

The algorithms, inputs, constants, and assumptions used to calculate the SRS during shock testing shall match those used to derive the specified SRS.

b. The test item shall be configured per the vehicle installation drawing/specification.

1. The test item shall be mounted in a manner that is consistent with that of the mass simulator used during fixture evaluation.
2. Mount points shall allow the input frequencies to resonate through a test item in a manner that is similar to that which would occur during flight.
3. Shock testing shall be performed at qualification hot and/or cold temperatures if the component will be exposed to the combined dynamic/thermal environment.

c. The minimum qualification shock environment shall be 3 dB above the MPE plus test tolerances for all frequencies from 100 Hz to 10 kHz.

For a shock test with a 3-dB lower test tolerance, the qualification test environment shall be 6 dB above the MPE.

d. The test shall subject the component simultaneously to a shock transient at all the required frequencies.

e. The test shall subject each component to three shocks in each direction (positive and negative) along each of the three orthogonal axes.

For single-axis and direction shock simulators, a minimum of 18 shocks consisting of 3 shocks in each direction, positive and negative, for each of three mutually perpendicular axes are required (3 x 2 x 3 = 18).

NOTE	Only 3 shocks may be required for shock simulators that can satisfy all acceleration levels with 1 shock event in all three axes in both directions.

f. The selected method for generating the shock environment shall be capable of meeting the required SRS with a transient that has the duration, time-to-peak, and decay rate comparable to that of the expected in-flight shock used to derive the SRS.

The test shock event (primary and residual) shall be analyzed to derive the maximum positive and negative SRS (not maxi-max). The duration of the shock event used in the SRS calculation is the time between the instant of shock arrival at the measurement point and the instant that the waveform has decayed to the pre-shock averaged noise floor.

g. 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.

h. A component shall be tested to demonstrate it meets the applicable abbreviated performance verification tests required in the component test matrix and Subsection 4.10.5 during environmental exposure.

For multi-stage vehicles, a component shall satisfy all of its performance requirements when exposed to the qualification minimum breakup shock levels described in Table 4-5 below.

Table 4-5. Minimum Breakup Qualification Shock Profile

Frequency (Hz)	Minimum Peak Acceleration
100	980 m/s^2 (100 g)
2000	12.75 km/s^2 (1300 g)
10,000	12.75 km/s^2 (1300 g)

Note: These are the corner points for the shock response profile.
Note: Q (Resonant Amplification Factor) = 10.

4.15.12 Electromagnetic Interference and Electromagnetic Compatibility

The EMI and electromagnetic compatibility (EMC) tests shall demonstrate that a component satisfies all of its performance requirements when subjected to radiated or conducted emissions from all vehicle systems and external ground transmitter sources. In addition, the test shall demonstrate that the component does not radiate or conduct EMI that would degrade the performance of any other FTS component.

1. All FTS components shall be tested to the requirements of MIL-STD-461. 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. The MIL-STD-461 tests, frequencies, limits, and levels shall envelope electromagnetic operating environments or the default test environments, whichever is higher.

4.15.13 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.

NOTE	An analysis may be used to satisfy this requirement if it can be shown that: 1. the component will never be subjected to an explosive atmosphere; 2. the unit cannot produce sufficient heat, arcing, or other ignition sources that could ignite an explosive atmosphere.

4.15.14 Thermal Shock

A qualification thermal shock test shall demonstrate that a component satisfies all of its performance requirements when subjected to acceptance thermal shock environments plus a margin.

a. The qualification thermal shock temperature range limits shall be at least the acceptance thermal cycle temperature limits in Subsection 4.12.8 plus a margin of 10°C.

b. The qualification transition rate shall be no less than the acceptance thermal ramp rate.

c. The duration of exposure is the time from liftoff to end of Range Safety responsibility. The thermal shock profile shall be provided by the customer and approved by Range Safety.

d. The test shall subject a component to three thermal shock profiles.

e. The test shall continuously monitor and record the applicable abbreviated performance verification tests required in the component test matrix and Subsection 4.10.5 during environmental exposure.

f. The test shall demonstrate all performance verification required by the component test matrix after all cycles are complete.

g. The component shall not be damaged and shall be capable of meeting the performance requirements of its specification.

4.16 Radio Frequency Receiving System

This section applies to an RF receiving system, which 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 4-6 contains acceptance tests and associated requirements and Table 4-7 contains qualification tests and requirements for RF receiving systems.

Table 4-6. Radio Frequency Receiving System Acceptance Test Requirements

Test	Section	Quantity Tested		
		Cable	Coupler	Antenna
Component Examination	4.11			
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	4.16.6	-	-	100%
Abbreviated Performance Verification	4.10.5			
VSWR[1,2]	4.16.2	-	-	100%
Environment Tests - Operating	4.12.1			
Thermal Cycle	4.12.2	100%	100%	100%
Thermal Vacuum	4.12.3	-	100%	100%
Sinusoidal Vibration	4.12.4	-	100%	100%
Random Vibration	4.12.5	-	100%	100%
Acoustic Vibration	4.12.6	-	100%	100%
Tensile Load	4.12.7	100%	-	-

[1]This test shall be performed during the hot and cold dwells of the first and last cycles of the thermal cycle and thermal vacuum tests.
[2]This test shall be performed during random vibration and acoustic vibration testing.

Table 4-7. Radio Frequency Receiving System Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3		
		Cable	Coupler	Antenna
Acceptance Tests	Table 4-6	X	X	X
Antenna Pattern	4.16.5	X	X	X
Performance Verification	4.10.4			
VSWR	4.16.2	X	X	X
Insertion Loss[2,3]	4.16.3	X	X	-
Isolation[2]	4.16.4	-	X	X
Abbreviated Antenna Pattern	4.16.6	-	-	X
Abbreviated Performance Verification	4.10.5			
VSWR[2,3]	4.16.2	-	-	X
Environment Tests - Non-Operating	4.14.1			
Storage Temperature	4.14.2	X	X	X
Transportation Vibration	4.14.4	X	X	X
Transportation Shock	4.14.5	X	X	X
Bench Handling Shock	4.14.6	X	X	X
Fungus Resistance	4.14.9	1	1	1
Fine Sand	4.14.10	1	1	1
Environment Tests - Operating[4]	4.15.1			
Thermal Cycle	4.15.2	X	X	X
Thermal Vacuum	4.15.3	X	-	X
Humidity	4.15.4	X	X	X
Salt Fog	4.15.5	X	X	X
Temperature/Humidity/Altitude	4.15.6	X	X	X
Acceleration	4.15.7	X	X	X
Sinusoidal Vibration	4.15.8	X	X	X
Random Vibration	4.15.9	X	X	X
Acoustic Vibration	4.15.10	X	X	X
Shock	4.15.11	X	X	X
Tensile Load	4.14.11	X	X	X
Internal Inspection	4.11.7	-	X	X

[1]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.
[2]This test shall be performed during thermal cycle, thermal vacuum, humidity, salt fog, and temperature/altitude/humidity testing.
[3]This test shall be performed during acceleration, shock, acoustic vibration, sinusoidal vibration, and random vibration testing.
[4]These tests shall be performed with flight RF cables attached in the flight-representative configuration.

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 splitter, combiners, hybrids, coaxial cables, or other passive devices are used to connect the antenna to the RF receiving system, these shall then be considered as part of the RF receiving 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.
3. The 3-dB bandwidth of the RF receiving system shall be greater than 360 kHz.

4.16.2 Voltage Standing Wave Ratio

The component shall be tested to demonstrate that it does not exceed the maximum specified VSWR across the assigned operating frequency band. The VSWR shall be continuously monitored to detect any variation in amplitude.

1. Antenna VSWR testing shall be performed on a ground plane that allows for repeatable performance.
2. Unless otherwise specified, RF receiving system components shall be designed for a nominal 50 Ω impedance and shall yield an overall VSWR of 2:1 or less across the specified passband in all operating environments.
3. During testing, the VSWR shall be sampled at a minimum rate of 10,000 samples per second.

NOTE	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 information of interest is any relative changes in performance, such as chatter or fluctuations.

4.16.3 Insertion Loss

The component shall be tested to demonstrate that it does not exceed the maximum specified insertion loss across the assigned operating frequency band.

The insertion loss shall be less than 4 dB from the output port of any antenna to the input port of any FTR.

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 minimum 50% power margin

4.16.5 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 vehicle and demonstrate that the system is capable of meeting the required performance specifications.

b. All test conditions shall emulate flight conditions, including ground transmitter polarization, using a simulated vehicle and a flight-configured RF command destruct system.

c. The test shall measure the radiation gain for 360° around the vehicle using angle increments that are small enough to identify any deep pattern null. Each antenna pattern gain measurement angle increment shall not exceed 2°.

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.

NOTE	Antenna pattern test requirements and formats can be found in RCC 253-93.[26]

4.16.6 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 is 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 Subsection 4.16.5.

[26] Range Commanders Council. Missile Antenna Pattern Coordinate System and Data Formats. RCC 253-93. August 1993. May be superseded by update. Available at http://www.wsmr.army.mil/RCCsite/Pages/Publications.aspx.

4.17 Flight Termination Receiver - Analog/Tone-Based

After the initial adjustment, the FTR shall perform IAW the latest released requirements of RCC 313,[27] the procurement specification, and of this document without subsequent adjustment. Table 4-8 contains requirements for acceptance testing and Table 4-9 contains requirements for qualification testing of FTRs.

Table 4-8. Flight Termination Receiver Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Inspection	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification[1]	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 Monitor Circuits	4.17.5	100%
Self-Test	4.17.6	100%
Circuit Protection	4.17.7	
Low Voltage	4.17.7.b	100%
Power Dropout	4.17.7.c	100%
Watchdog Circuit	4.17.7.d	100%
Fail-Safe	4.17.10	100%
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 Command Circuits[2]	4.17.4.a	100%
	4.17.4.b	100%
Output Monitor Circuits[2]	4.17.5	100%
Thermal Performance[3,4]	4.17.13	100%
Environment Tests – Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration	4.12.4	100%
Random Vibration	4.12.5	100%
Acoustic Vibration	4.12.6	100%
In-Band Interference	4.17.11.q	100%
Leakage	4.11.8	100%

[1]These tests shall also be performed as part of the pre-flight tests in Chapter 5.

[27] Range Commanders Council. Test Standards for Flight Termination Receivers and Decoders. RCC 313-01. May 2001. May be superseded by update. Available at http://www.wsmr.army.mil/RCCsite/Pages/Publications.aspx.

[2]This test shall be performed during sinusoidal, random, and acoustic vibration testing.
[3]This test shall be performed during thermal cycle and thermal vacuum testing.
[4]This test shall be performed during the hot and cold dwells of the first and last thermal cycles. A component shall be continuously monitored for input current, SSTO, and intended and inadvertent command output during all thermal cycles and transitions. If thermal cycles are added after random vibration then additional thermal performance testing will be required.

Table 4-9. Flight Termination Receiver Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Acceptance Tests	Table 4-8	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 Monitor Circuits	4.17.5	X
Self-Test	4.17.6	X
Circuit Protection	4.17.7	X
Overvoltage	4.17.7.a	X
Low Voltage	4.17.7.b	X
Power Dropout	4.17.7.c	X
Watchdog Circuit	4.17.7.d	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[2,3]	4.17.2	X
Output Command Circuits[2]	4.17.4.a	X
	4.17.4.b	X
Output Monitor Circuits[2,3]	4.17.5	X
Thermal Performance[4,5]	4.17.13	X
Environment Tests – Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Environment Tests - Operating	4.15.1	
Thermal Cycle	4.15.2	X
Thermal Vacuum	4.15.3	X
Humidity	4.15.4	X

Salt Fog	4.15.5	X
Temperature/Humidity/Altitude	4.15.6	X
Acceleration	4.15.7	X
Sinusoidal Vibration	4.15.8	X
Random Vibration	4.15.9	X
Acoustic Vibration	4.15.10	X
Shock	4.15.11	X
EMI/EMC	4.15.12	2
Explosive Atmosphere	4.15.13	1
Repetitive Function	4.17.8	1
Circuit Protection	4.17.7	
Overvoltage	4.17.7.a	2
Output Monitor Circuit Protection	4.17.7.e	2
Leakage	4.11.8	X
Internal Inspection	4.11.7	2
Memory	4.17.9	1

[1]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.
[2]This test shall be performed during acceleration testing and sinusoidal, random, and acoustic vibration testing.
[3]The FTR 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]This test shall be performed during the hot and cold dwells of the first, middle, and last thermal cycles. A component shall be continuously monitored for input current, SSTO, and intended and inadvertent command output during all thermal cycles.
[5]This test shall be performed during thermal vacuum, temperature/humidity/altitude, thermal cycle, humidity, and salt fog operating environments.

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 of its performance requirements.

Isolation resistance shall be 2 MΩ or more.

4.17.2 Input Current

Input current of the FTR shall be monitored to demonstrate that it satisfies all its performance requirements.

The FTR input current shall be sampled at a minimum rate of 10,000 samples per second 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.

NOTE	These requirements address non-RF commands that may exist on some FTRs that have additional functions, such as fail-safe, power transfer, and disable.

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 three 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 pre-launch 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 V in amplitude into a 10-kΩ load for more than 200 µs during the voltage transient and shall meet its performance requirements after the application of the voltage transient.
2. The leakage current from the Terminate output with no Terminate command applied shall be no more than 50 µA unless otherwise agreed to by Range Safety.

d. The FTR shall be tested to demonstrate that it satisfies all of its performance specifications for response time, from receipt of a completed command sequence to initiation of command output.

An FTR shall generate a command output between 4 ms and 25 ms after receipt of the

completed command signal when tested at the specified threshold sensitivity.

4.17.5 Output Monitor Circuits

Output monitor circuits shall be tested to verify that all the required monitor signals meet their specified performance requirements.

1. All output monitors shall receive the required stimulus necessary to demonstrate they meet their performance requirements.
2. During environmental testing, output monitors shall be continuously sampled.

NOTE	Output monitors include the SSTO, fail-safe indicators, and tone monitors.

4.17.6 Self Test

If the FTR has self-test capabilities, it shall be tested to demonstrate that 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 of its performance requirements when subjected to abnormal conditions. The demonstration shall include all of the following.

a. Overvoltage. The FTR shall be tested to demonstrate that it satisfies all of its performance requirements after application of the OCV of the unit's power source to the power input port in both forward and reverse polarity.

The FTR shall function nominally after being subjected to the application of up to ± the OCV of the power source or ±45 Vdc, whichever is higher, to the power input port for a period not less than five minutes.

b. Low Voltage. The FTR shall be tested to demonstrate that it will not be damaged or produce an inadvertent output command when voltages below the specified operational level are applied to the power input port.

The FTR shall be tested from 0 V to the minimum specified voltage and back to 0 V without damage or producing a spurious output regardless of the voltage transition rate. The FTR shall function nominally after this test.

c. Power 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 satisfy all performance requirements after a 50-ms power dropout.

d. Watchdog Circuit. All watchdog circuits shall be tested to verify they meet their performance specifications.

e. Output Monitor Circuit Protection. The FTR shall be tested to 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 OCV of the vehicle FTS power supply or ±45 Vdc, whichever is higher.
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

The FTR shall be tested to demonstrate that it satisfies all of its performance requirements when subjected to the required number of output commands plus a margin into a flight load.

The FTR shall be tested for five times the number of command outputs into a representative flight load without degradation, including acceptance, pre-launch, and potential rework and re-acceptance test.

NOTE	Typical number of command outputs into a representative flight load is 200.

4.17.9 Memory

The FTR shall be tested to demonstrate that data stored in memory is not degraded and it is able to satisfy 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 DC power being applied.

4.17.10 Fail-Safe

The FTR shall be tested to demonstrate that its fail-safe circuits meet their performance requirements as indicated below.

a. The fail-safe system shall demonstrate it will satisfy all input and output fail-safe combinations when it experiences either loss of command link, low voltage, or any 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, that path 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 fail-safe inputs and outputs shall be tested to demonstrate that they meet their threshold levels. The following are conditions of fail-safe inputs and outputs that are tested.

(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 fail-safe timing circuits shall be tested to demonstrate they meet their performance requirements. The following are conditions of fail-safe timing circuits that are tested.

(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 Radio Frequency Processing

The FTR shall be tested to 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 pre-flight and flight environments.

For this testing, the antenna port shall be connected to a signal source with a 50-Ω impedance.

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

NOTE	Flight signal degradation causes include locally induced RF noise sources, vehicle plume, multi-path propagation, noise floor, and abnormal vehicle flight.

NOTE	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. Voltage Standing Wave Ratio. The FTR shall be tested to demonstrate it meets its RF port impedance and VSWR performance requirements.

1. The FTR shall be tested to demonstrate that it has an RF port impedance of 50 Ω.

2. The FTR shall be tested to demonstrate that it has an RF port VSWR of 2:1 or less over the specified 60-dB passband.

b. Dynamic Stability. The FTR shall be tested to demonstrate that it meets its performance requirements after being subjected to an RF input short circuit, open circuit, or changes in input VSWR.

c. Radio Frequency Input Characteristics.

(1) Measured Threshold Sensitivity. The FTR shall be tested to demonstrate that the measured threshold sensitivity is repeatable and in-family.

The FTR shall be tested to demonstrate that the measured threshold sensitivity is greater than −116 dBm.

(2) Guaranteed (Specified) Sensitivity. The FTR shall be tested to demonstrate that it meets its performance requirements with the RF input at the guaranteed sensitivity level.

NOTE	The guaranteed (specified) sensitivity of the FTR will be between −116 dBm and −107 dBm.

(3) Radio Frequency Dynamic Range. The FTR shall be tested to demonstrate that it meets its performance requirements 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.

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.

NOTE	An RF level of +13 dBm (+10 dBm maximum expected operational input + 3 dB margin) will meet the maximum RF level requirement for most vehicle applications.

d. Signal Strength Monitor. The FTR shall be tested to demonstrate that the signal strength monitor circuit meets the following requirements.

(1) The monitor circuit shall be tested to demonstrate it accurately monitors and outputs the strength of the RF input signal during flight.

(2) The output of the monitor circuit (the SSTO) shall be directly related and proportional to the strength of the RF input signal from the FTR threshold SSTO to SSTO saturation.

(3) The SSTO quiescent 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 FTR shall be tested to demonstrate that the response time of the SSTO circuitry is 4 ms or less.

(6) The FTR shall be tested to demonstrate that the slope of the signal strength monitor circuit output does not change polarity.

1. The FTR shall be tested to demonstrate that the SSTO, while operating into a 10-kΩ and flight-representative TM load, meets the following requirements.
   a. The SSTO output for a quiescent input condition shall be 0.5 ± 0.25 Vdc.
   b. An input RF signal at the measured threshold sensitivity level shall result in an SSTO greater than 0.1 Vdc above that for a quiescent input.
   c. The SSTO output level shall reach 4.5 Vdc with an RF input between −60 dBm and −50 dBm.
   d. The maximum SSTO voltage shall not exceed 5 Vdc under all conditions.
   e. The slope of the SSTO voltage versus signal strength curve shall not change polarity (i.e., it will be monotonic) when the RF input is varied from the measured threshold to circuit saturation. The SSTO shall drop no more than 50 mV from circuit saturation to the upper limit of the dynamic range.
2. The SSTO voltage shall not be used as a command output monitor.

NOTE	The SSTO is expected to produce approximately 1 Vdc change in voltage for each 13-dB change in RF input signal from threshold to saturation.

e. Operational Band. The FTR shall be tested to demonstrate that it meets its performance requirements when receiving a valid command signal modulated on a carrier centered anywhere within the required operational band plus a margin.

1. The FTR shall be tested to demonstrate that the minimum operational band edges are more than 45 kHz above and below the assigned center frequency.
2. The IF peak-to-valley ratio of the receiver shall be tested to demonstrate that for a carrier input at the guaranteed threshold sensitivity level, the received signal strength as indicated by the SSTO does not vary by more than 3 dB across the operational band.

f. Decoder Channel Frequency Modulation Deviation. The FTR shall be tested to demonstrate that it meets its performance requirements when receiving an RF carrier modulated with FM tones at the specified minimum and maximum deviations plus a margin.

1. The FTR shall be tested to demonstrate that it meets its performance requirements when the input RF carrier is modulated with FM tones that are deviated over the range of ±27 kHz to ±33 kHz per tone.
2. The FTR shall be tested to demonstrate that each tone decoder FM deviation threshold is between ±9 kHz and ±18 kHz.

NOTE	Current analog FTS range command transmitters will produce a nominal FM tone deviation of ±30 kHz per tone.

g. Decoder Channel Band Edges. 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 Decoders:
   a. The decoder channel band edges shall be more than 1% above and below the assigned center frequency at 2 dB above the threshold deviation.
   b. The decoder channel band edges shall be less than 4% above and below the assigned center frequency at 14 dB above the threshold deviation when tested at the box level.
   c. The decoder channel band edges shall be less than 4% above and below the assigned center frequency at 20 dB above the threshold deviation when tested at the board level.
2. High-Alphabet Tone Decoders:
   a. The decoder channel band edges shall be more than 40 Hz (~0.25%) above and below the assigned center frequency at 2 dB above the threshold deviation.
   b. The decoder channel band edges shall be less than 600 Hz (~4%) above and below the assigned center frequency at 20 dB above the threshold deviation.

h. Adjacent Tone Decoder Channel Rejection. The FTR shall be tested to demonstrate that it meets its performance requirements when subjected to the specified over-modulation of adjacent tones plus a margin.

A tone decoder for a particular tone that is actively decoding that tone shall not drop the tone due to the presence of any combination of other tones frequency-modulated with deviations set at ±50 kHz per tone.

i. Tone Balance (High-Alphabet). The FTR shall be tested to demonstrate that it will reliably decode a valid command at the worst-case ground transmitter tone amplitude imbalance between tones plus a margin within the same command sequence or message.

j. Message Timing (High-Alphabet). An FTR shall be tested to demonstrate that it meets its performance requirements when subjected to specified command timing errors.

k. Acquisition and Reacquisition Time. The FTR shall be tested to demonstrate that the acquisition and reacquisition times meet the performance requirements.

l. Command Response Time. The FTR shall be tested to demonstrate that after appropriate signal acquisition and synchronization the command response time meets the performance requirements.

Standard FTRs (not High-Alphabet) shall be tested to demonstrate that the command response time from the time the RF signal is applied to the input to the output of the appropriate command is between 4 ms and 25 ms.

m. Message Format (High-Alphabet FTR). The FTR shall be tested to demonstrate that it will process the specified command format and messages.

The FTR shall be tested to demonstrate that it will process the command format and messages as specified in the RCC 319-14 Supplement.

n. Check Channel. The FTR shall be tested to demonstrate it will decode the check channel tone (standard FTR) or pilot tone (high-alphabet FTR) and provide a TM output. The test shall also demonstrate that the presence or absence of this tone signal does not affect any other FTR command processing or output capability.

o. Termination Sequence. The FTR shall be tested to demonstrate that it will provide the required command output IAW the design specification. The FTR shall be tested to demonstrate that it will generate a Terminate command only if preceded by an Arm command.

p. Out-of-Band Signal 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 pre-launch and launch operations plus a margin.

The FTR shall be tested to demonstrate it can reliably process commands when subjected to any interfering frequency from 10 MHz to 1 GHz at a power level 60 dB above the guaranteed sensitivity signal level. Test frequencies shall be generated in increments no greater than 1 kHz.

NOTE	The SSTO may be used 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 Band Edges. The FTR shall have an IF at 3 dB with band edges more than 90 kHz above and below the assigned center frequency and at 60 dB with band edges less than 180 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned center frequency.
2. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious Frequency Rejection. The FTR shall provide at least 60 dB of rejection of signals from 10 MHz to 1 GHz, excluding the 60-dB band at the assigned center frequency referenced to response at center frequency. Test frequencies shall be generated in increments no greater than 1 kHz.
4. Range Transmissions Rejection. The FTR shall be tested for rejection of interference from all intended and unintended range transmitting sources. At a minimum, the frequency bands in Table 4-10 shall be tested.

Table 4-10. Out-of-Band Signal Rejection Test Frequencies for Flight Termination Receivers

Frequency Band (GHz)	Designation	Current Range Use
1.435 - 1.525	Middle L-Band	Telemetry
1.755 - 1.85	Upper L-Band	Telemetry
2.2 - 2.4	S-Band	Telemetry
4.4 - 4.95	Lower C-Band	Telemetry / Video
5.09 - 5.15	Middle C-Band	Telemetry
5.4 - 5.9	Upper C-Band	Tracking Radar / Telemetry / UAV Command Links
9.2 - 9.6	X-Band	Airborne Intercept Radar

NOTE: Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

q. In-Band Interference. Where there are in-band interfering sources during pre-launch 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. The specific requirement for an interfering modulated signal will be determined on a case-by-case basis.

NOTE: This data is used to determine whether interfering sources must be deconflicted or if a different FTS frequency is required.

For capture ratio, the FTR shall be tested to demonstrate that it processes all commands when an interfering signal of less than 80% of the intended signal power 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.

4.17.12 Inadvertent Command Output

The FTR shall be tested to demonstrate that it will not produce an inadvertent command when exposed to the following conditions.

a. 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 two seconds between power cycles.

b. 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 VSWR.

NOTE	Only RF input short circuit and open circuit testing need to be performed during acceptance testing.

c. Tone Decoder Noise Rejection. The FTR shall be tested at the specified FM noise guard deviation to demonstrate it will not trigger any tone channel outputs.

Each tone decoder shall be tested to demonstrate that it will not produce an output for a tone frequency-modulated with a deviation of less than ±9 kHz.

d. Adjacent Tone 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.

A tone decoder for a particular tone shall be tested to demonstrate that is will not respond to any combination of other tones frequency-modulated with deviations set at ±50 kHz per tone.

e. 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 will produce a Terminate command only if preceded by an Arm command.

f. Out-of-Band Signal Rejection. The FTR shall be tested to demonstrate it will not respond to any specified in-band or 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 pre-launch 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 can reliably process commands when subjected to any interfering frequency from 10 MHz to 1 GHz at a power level 60 dB above the guaranteed sensitivity signal level. Test frequencies shall be generated in increments no greater than 1 kHz.
2. Special attention should be given to other command termination frequencies used on a range.

(2) The interfering frequencies used 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 Band Edges. The FTR shall have an IF at 3 dB with band edges more than 90 kHz above and below the assigned center frequency and at 60 dB with band edges

less than 180 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned center frequency.

2. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious-Response Rejection. The FTR shall provide at least 60 dB of rejection of signals from 10 MHz to 1 GHz, excluding the 60-dB band at the assigned center frequency referenced to response at center frequency. Test frequencies shall be generated in increments no greater than 1 kHz.
4. Range Transmissions Rejection. The FTR shall be tested for rejection of all intended and unintended interfering transmitting sources.

NOTE	Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

g. In-Band Interference. The FTR shall be tested to demonstrate that it will not produce an inadvertent output when subjected to specified in-band noise.

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 if a different FTS frequency is required.

(1) Frequency Modulation White Noise Rejection.

The FTR shall be tested to demonstrate that it will not produce any inadvertent command or monitor outputs when it is subjected to an RF input signal with the following characteristics:

1. carrier at the assigned center frequency;
2. the RF power set at −95 dBm (−107 dBm + 12 dB);
3. frequency modulated by white noise containing all frequencies between 1 Hz and 600 kHz;
4. at a deviation 12 dB higher than the highest measure deviation threshold of any of the individual RCC tones.

(2) Amplitude Modulation Rejection. The FTR shall be tested to demonstrate that it will not produce an inadvertent output 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% AM. Qualification testing shall be performed at 100% AM.
2. Acceptance testing of AM rejection at 50% and 100% shall verify that the FTR can reject an amplitude-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 with RF power set at −90.1 dBm with 50% AM modulation by the assigned RCC tone frequencies;
   b. an RF input signal at the assigned frequency with RF power set at −85.4 dBm with 50% AM modulation by white noise containing all frequencies between 1 Hz and 600 kHz;

c. an RF input signal at the assigned RF center frequency with RF power set at −67 dBm with 100% peak AM modulation by white noise containing all frequencies between 1 Hz and 3.5 kHz or 7 kHz.

NOTE	This requirement addresses an AM signal modulated on top of the range-transmitted FM signal.

4.17.13 Thermal Performance Tests

A thermal performance test shall demonstrate that the FTR satisfies its performance specifications when subjected to operating and workmanship thermal environments. An FTR shall undergo a thermal performance test during thermal cycle and thermal vacuum testing. The FTR shall be subjected to performance testing at low and high operating voltage while it is at the high and low temperatures. Performance tests at high and low temperatures shall include the tests listed in Table 4-11.

Table 4-11. Thermal Performance Tests for Flight Termination Receivers

#	Test	Section	#	Test	Section
1.	Input Current	4.17.2	7.	RF Threshold Sensitivity	4.17.11.c(1)
2.	Command and Control	4.17.3	8.	RF Dynamic Range	4.17.11.c.(3)
3.	Output Command Circuits	4.17.4	9.	SSTO	4.17.11.d
4.	Output Monitors	4.17.5	10.	Operational Bandwidth	4.17.11.e
5.	Self-Test	4.17.6	11.	Decoder Channel Deviation	4.17.11.f
6.	Fail-Safe	4.17.10	12.	Decoder Channel Bandwidth	4.17.11.g
			13.	Check Channel	4.17.11.n

4.18 Enhanced Flight Termination Receiver

After final acceptance testing, the FTR shall perform IAW the latest released requirements of RCC 325,[28] the procurement specification, and of this document, without subsequent adjustment. Table 4-12 lists acceptance tests and requirements and Table 4-13 lists qualification tests and requirements for EFTRs.

Table 4-12. Enhanced Flight Termination Receiver Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Inspection	4.11.2	100%

[28] Range Commanders Council. Test Standards for Enhanced Flight Termination Receivers (EFTRs). RCC 325-11. December 2011. May be superseded by update. Available at https://wsdmext.wsmr.army.mil/site/rccpri/Publications/Forms/AllItems.aspx.

Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification[1]	4.10.4	100%
Continuity and isolation	4.18.1	100%
Input Current	4.18.2	100%
Command and Control	4.18.3	100%
Output Command Circuits	4.18.4	100%
Output Monitor Circuits	4.18.5	100%
Self-Test	4.18.6	100%
Circuit Protection	4.18.7	
Low Voltage	4.18.7.b	100%
Power Dropout	4.18.7.c	100%
Watchdog Circuit	4.18.7.d	100%
Fail-Safe	4.18.10	100%
RF Processing	4.18.11	100%
Inadvertent Command Output	4.18.12	100%
Abbreviated Performance Verification	4.10.5	
Input Current[2]	4.18.2	100%
Output Command Circuits[2]	4.18.4.a	100%
	4.18.4.b	100%
Output Monitor Circuits[2]	4.18.5	100%
Thermal Performance[3,4]	4.18.13	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration	4.12.4	100%
Random Vibration	4.12.5	100%
Acoustic Vibration	4.12.6	100%
In-band Interference	4.18.11.o	100%
Leakage	4.11.8	100%

[1]This test shall also be performed as part of the pre-flight tests in Chapter 5.
[2]This test shall be performed during sinusoidal, random, and acoustic vibration testing.
[3]This test shall be performed during thermal cycle and thermal vacuum testing.
[4]This test shall be performed during the hot and cold dwells of the first and last thermal cycles. A component shall be continuously monitored for input current, SSTO, monitor command, and inadvertent command output during all thermal cycles and transitions.

Table 4-13. Enhanced Flight Termination Receiver Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Acceptance Tests	Table 4-12	X
Performance Verification	4.10.4	

Continuity and isolation	4.18.1	X
Input Current	4.18.2	X
Command and Control	4.18.3	X
Output Command Circuits	4.18.4	X
Output Monitor Circuits	4.18.5	X
Self-Test	4.18.6	X
Circuit Protection	4.18.7	X
Overvoltage	4.18.7.a	X
Low Voltage	4.18.7.b	X
Power Dropout	4.18.7.c	X
Watchdog Circuit	4.18.7.d	X
Fail-Safe	4.18.10	X
Tone-based RF Processing	4.18.11	X
Inadvertent Command Output	4.18.12	X
Abbreviated Performance Verification	4.10.5	
Input Current[2,3]	4.18.2	X
Output Command Circuits[2]	4.18.4.a	X
	4.18.4.b	X
Output Monitor Circuits[2,3]	4.18.5	X
Thermal Performance[4,5]	4.18.13	X
Environment Tests – Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Environment Tests – Operating	4.15.1	
Thermal Cycle	4.15.2	X
Thermal Vacuum	4.15.3	X
Humidity	4.15.4	X
Salt Fog	4.15.5	X
Temperature/Humidity/Altitude	4.15.6	X
Acceleration	4.15.7	X
Sinusoidal Vibration	4.15.8	X
Random Vibration	4.15.9	X
Acoustic Vibration	4.15.10	X
Shock	4.15.11	X
EMI/EMC	4.15.12	2
Explosive Atmosphere	4.15.13	1
Repetitive Function	4.18.8	1
Circuit Protection	4.18.7	
Overvoltage	4.18.7.a	2
Output Monitor Circuit Protection	4.18.7.e	2

Leakage	4.11.8	X
Internal Inspection	4.11.7	2
Memory	4.18.9	1

[1]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.
[2]This test shall be performed during acceleration testing and sinusoidal, random, and acoustic vibration testing.
[3]The FTR 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]This test shall be performed during the hot and cold dwells of the first, middle, and last thermal cycles. A component shall be continuously monitored for input current, SSTO, monitor tone, and inadvertent command output during all thermal cycles.
[5]This test shall be performed during thermal vacuum, temperature/humidity/altitude, thermal cycle, humidity, and salt fog operating environments.

4.18.1 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 of its performance requirements.

Isolation resistance shall be 2 MΩ or more.

4.18.2 Input Current

Input current of the FTR shall be monitored to demonstrate that it satisfies all its performance requirements.

The receiver input current shall be sampled at a minimum rate of 10,000 samples per second during dynamic environmental testing.

4.18.3 Command and Control

The 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 three seconds, and then powered up. The unit shall power up in the safe state.

4.18.4 Output Command Circuits

The 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 its 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 pre-launch 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 V in amplitude into a 10-kΩ load for more than 200 µs during the voltage transient and shall meet its performance requirements after the application of the voltage transient.
2. The leakage current from the Terminate output with no Terminate command applied shall be no more than 50 µA unless otherwise agreed to by Range Safety.

d. The FTR shall be tested to demonstrate that it satisfies all of its performance specifications for response time, from receipt of command sequence to initiation of command output.

An FTR shall generate a command output between 4 ms and 25 ms after receipt of the completed command signal when tested at the specified threshold sensitivity.

4.18.5 Output Monitor Circuits

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.

NOTE	Output monitors include SSTO, fail-safe indicators, receiver status TM output (RSTO), command valid TM output (CVTO), and check channel TM output (CCTO).

a. Receiver Status Telemetry Output. The FTR shall be tested to demonstrate that it will generate an RSTO that operates IAW the design specification.

(1) The FTR shall be tested to demonstrate that it will generate an RSTO response within 1 ms of the respective change of state.

(2) The FTR shall be tested to demonstrate that it will generate the RSTO voltage levels listed in Table 4-14 into a 10-kΩ load for a given receiver state.

Table 4-14. Receiver Status Telemetry Output Voltage Levels

Receiver State	DC Voltage
Receiver Failure	0.1 ± 0.1
Self Test Running	0.5 ± 0.1
Self Test Passed	1.0 ± 0.1
Bit Sync Locked	1.5 ± 0.1
Frame Sync Locked	2.0 ± 0.1
Range ID Valid	2.5 ± 0.1
TX ID Valid	3.0 ± 0.1
Vehicle ID Valid	3.5 ± 0.1
Command Valid	4.0 ± 0.1
Command Accepted	4.5 ± 0.1

b. Command Valid Telemetry Output

(1) The FTR shall be tested to demonstrate that it will generate a CVTO that operates IAW the design specification.

(2) Testing shall also demonstrate that it will generate a CVTO of 5 ± 1 Vdc into a 10-kΩ load for 19.9 ms each time the receiver receives an authenticated valid message.

c. Check Channel Telemetry Output

(1) The FTR shall be tested to demonstrate that it will generate a CCTO that operates IAW the design specification.

(2) Testing shall also demonstrate that it will check for the presence of the check channel bit in the command message and, if present, it shall reset the loss of communications timer (see (1) of item a, Subsection 3.5.2) and generate a CCTO of 5 ± 1 Vdc into a 10-kΩ load for 20 ms.

d. User-Defined Data Port

(1) The FTR shall be tested to demonstrate that it will generate a user-defined data port (UDDP) that operates IAW the design specification.

(2) Testing shall also demonstrate that it will generate a UDDP output with the following characteristics. The UDDP shall be an output-only digital communications port at RS-232C levels at 19.2 kbps with 8 data bits, 1 start bit, 1 stop bit, and no parity bits (10 bits total). The 8 data bits shall comprise 2 leading 0 bits followed by the user-defined 6-bit command with the most significant bit sent first.

4.18.6 Self Test

The FTR shall be tested to demonstrate that it can perform self tests, detect errors, and output the results.

4.18.7 Circuit Protection

A circuit protection test shall demonstrate that the FTR satisfies all of its performance requirements when subjected to abnormal conditions. The demonstration shall include all of the following.

a. Overvoltage. The FTR shall demonstrate that it satisfies all of its performance requirements after application of the OCV of the unit's power source to the power input port in both forward and reverse polarity.

The FTR shall function nominally after being subjected to the application of up to ± the OCV of the power source or ±45 Vdc, whichever is higher, to the power input port for a period not less than five minutes.

b. Low Voltage. The FTR shall not be damaged or produce an inadvertent output command when voltages below the specified operational level are applied to the power input port.

The FTR shall be tested from 0 V to the minimum specified voltage and back to 0 V without damage or producing a spurious output regardless of the voltage transition rate. The FTR shall function nominally after this test.

c. Power 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 satisfy all performance requirements after a 50-ms dropout.

d. Watchdog Circuit. All watchdog circuits shall be tested to verify they meet their performance specifications.

e. Output Monitor Circuit Protection. The FTR shall be tested to 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 OCV of the vehicle FTS power supply or ±45 Vdc, whichever is higher. 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.

4.18.8 Repetitive Function

This test shall demonstrate that the FTR satisfies all of its performance requirements when subjected to the required number of output commands plus a margin into a flight load.

The FTR shall be tested for five times the number of command outputs into a representative flight load without degradation, including acceptance, pre-launch and potential rework, and re-acceptance test.

NOTE	The typical number of command outputs into a representative flight load is 200.

4.18.9 Memory

The FTR shall demonstrate that data stored in memory is not degraded and it is able to satisfy all performance requirements after remaining in the powered-off condition for the maximum specified time.

Data loaded into the FTR shall remain in memory for no less than 180 days without primary DC power being applied.

4.18.10 Fail-Safe

The FTR shall be tested to demonstrate that its fail-safe circuits meet their performance requirements as indicated below.

a. The fail-safe system shall demonstrate it will satisfy all input and output fail-safe combinations when it experiences either loss of command link, low voltage, or any 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, that path 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 fail-safe inputs and outputs shall be tested to demonstrate that they meet their threshold levels. The following are conditions for fail-safe inputs and outputs that are tested.

(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 fail-safe timing circuits shall be tested to demonstrate they meet their performance requirements. The following are conditions for fail-safe timing circuits that are tested.

(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

4.18.11 Radio Frequency Processing

The FTR shall be tested to 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 EFTR shall satisfy all of the following for all pre-flight and flight environments.

For this testing, the antenna port shall be connected to a signal source with a 50-Ω impedance.

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

NOTE	Flight signal degradation causes include locally induced RF noise sources, vehicle plume, multi-path propagation, noise floor, and abnormal vehicle flight.

NOTE	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. Voltage Standing Wave Ratio. The FTR shall be tested to demonstrate it meets its RF port impedance and VSWR performance requirements.

1. The FTR shall be tested to demonstrate that it has an RF port impedance of 50 Ω.
2. The FTR shall be tested to demonstrate that it has an RF port VSWR of 2:1 or less over the specified 60-dB passband.

b. 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 VSWR.

c. Radio Frequency Input Characteristics.

(1) Measured Threshold Sensitivity. The FTR shall be tested to demonstrate that the measured threshold sensitivity is repeatable and in-family.

The FTR shall be tested to demonstrate that the measured threshold sensitivity is greater than −116 dBm.

NOTE	The measured threshold sensitivity is the lowest RF power level that yields a message error rate no greater than 1 in 10,000 messages.

(2) Guaranteed (Specified) Sensitivity. The FTR shall be tested to demonstrate it satisfies all performance requirements with the RF input at the guaranteed sensitivity level.

NOTE	The guaranteed (specified) sensitivity of the FTR will be between −116 dBm and −107 dBm.

(3) Radio Frequency 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.

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.

NOTE	An RF level of +13 dBm (+10 dBm maximum expected operational input + 3 dB margin) will meet the maximum RF level requirement for most vehicle applications.

d. Signal Strength Monitor. The FTR signal strength monitor circuit shall be tested to demonstrate the following.

(1) The monitor circuit shall be tested to demonstrate it accurately monitors and outputs the strength of the RF input signal during flight.

(2) The output of the monitor circuit (the SSTO) 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 FTR shall be tested to demonstrate that the response time of the SSTO circuitry is 4 ms or less.

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

1. The FTR shall be tested to demonstrate that the SSTO, while operating into a 10-kΩ and flight-representative TM load, meets the following requirements.

   a. The SSTO output for a quiescent input condition shall be 0.5 ± 0.25 Vdc.
   b. An input RF signal at the measured threshold sensitivity level shall result in an SSTO greater than 0.1 Vdc above that for a quiescent input.

c. The SSTO output level shall reach 4.5 Vdc with an RF input between −60 dBm and −50 dBm.
d. The maximum SSTO voltage shall not exceed 5 Vdc under all conditions.
e. The slope of the SSTO voltage versus signal strength curve shall not change polarity (i.e., it will be monotonic) when the RF input is varied from the measured threshold to circuit saturation. The SSTO shall drop no more than 50 mV from circuit saturation to the upper limit of the dynamic range.

2. The SSTO voltage shall not be used as a command output monitor.

NOTE	The SSTO is expected to produce approximately 1 Vdc change in voltage for each 13-dB change in RF input signal from threshold to saturation.

e. Operational Band. The FTR shall be tested to demonstrate that it meets its performance requirements when receiving a valid command signal modulated on a carrier centered anywhere within the required operational band plus a margin.

1. The FTR shall be tested to demonstrate that the operational bandwidth plus margin is greater than 70 kHz.
2. The IF peak-to-valley ratio of the receiver shall be tested to demonstrate that for a carrier input at the guaranteed threshold sensitivity level, the received signal strength as indicated by the SSTO does not vary by more than 3 dB across the operational band.

f. Command Signal Frequency Modulation Deviation. The FTR shall be tested to demonstrate that it meets its performance requirements when receiving an RF carrier modulated with FM command signals at the specified minimum and maximum deviations plus a margin.

The FTR shall be tested to demonstrate that it meets its performance requirements when the input RF carrier is modulated with FM command signals that are deviated over the range of ±45 kHz to ±55 kHz.

NOTE	Current EFTS range command transmitters will produce a nominal FM command signal deviation of ±50 kHz.

g. Inverted Modulation. The FTR shall be tested to demonstrate that it will detect and compensate for signals that are inverted at the transmitter (i.e., a positive voltage generating a negative frequency offset and a negative voltage generating a positive frequency offset).

h. Message Timing. The FTR shall be tested to demonstrate that it meets its performance requirements when subjected to specified command timing errors.

i. Acquisition and Reacquisition Time. Upon initial RF reception, the FTR shall acquire and synchronize the command signal and generate the first command and TM outputs within the specified time and reliability at any RF input power level within the dynamic range.

The time from initial RF reception of an appropriately modulated EFTS command signal to output of the first command and TM outputs by the FTR shall be within 60 ms (3 times nominal frame length of 20 ms) for at least 95% of the samples and within 100 ms for all samples.

j. Command Response Time. The FTR shall be tested to demonstrate that after appropriate signal acquisition and synchronization, it will generate all appropriate command and TM outputs within the specified time after receipt of a complete command or command message.

k. Message Format. The FTR shall be tested to demonstrate that it will process the specified command format and messages.

The FTR shall be tested to demonstrate that it will process the command format and messages as specified in the EFTS Command Link Interface Requirements Document.

l. Message Error Rate. The FTR shall be tested to demonstrate that it will receive and process messages that are within the specified signal variation limits with an error rate no greater than 1 in 10,000 messages.

m. Termination Sequence. The FTR shall be tested to demonstrate that it will provide the required command output IAW the design specification. The FTR shall be tested to demonstrate that it will generate a Terminate command only if preceded by an Arm command.

n. Out-of-Band Signal 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 commands when subjected to out-of-band interfering frequencies that the FTR could experience during pre-launch and launch operations plus a margin.

The FTR shall be tested to demonstrate it can reliably process commands when subjected to any interfering frequency from 10 MHz to 1 GHz at a power level 60 dB above the guaranteed sensitivity signal level. Test frequencies shall be generated in increments no greater than 1 kHz.

NOTE	The SSTO may be used 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 Band Edges: The FTR shall have an IF at 55 dB with band edges less than 180 kHz above and below the assigned center frequency and at 60 dB with band edges less than 275 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned center frequency.
2. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.
3. Spurious-Response/Rejection. The receiver shall provide at least 60 dB of rejection of

CW signals from 10 MHz to 1 GHz (excluding the frequency band $F_0 \pm 275$ kHz). In addition it will provide 55 dB of rejection of CW signals within the frequency band $F_0 \pm 275$ kHz (excluding the frequency band $F_0 \pm 180$ kHz). The rejection levels shall be referenced to the response at the assigned center frequency of the receiver. Test frequencies shall be generated in increments no greater than 1 kHz.

4. Range Transmission Rejection. The FTR shall be tested for rejection of interference from all intended and unintended range transmitting sources. At a minimum, the frequency bands in Table 4-15 shall be tested.

Table 4-15. Out-of-Band Rejection Test Frequencies for Enhanced Flight Termination Receivers

Frequency Band (GHz)	Designation	Current Range Use
1.435 – 1.525	Middle L-Band	Telemetry
1.755 – 1.85	Upper L-Band	Telemetry
2.2 – 2.4	S-Band	Telemetry
4.4 – 4.95	Lower C-Band	Telemetry / Video
5.09 – 5.15	Middle C-Band	Telemetry
5.4 – 5.9	Upper C-Band	Tracking Radar / Telemetry / UAV Command Links
9.2 – 9.6	X-Band	Airborne Intercept Radar

NOTE Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

o. In-band Interference. Where there are in-band interfering sources during pre-launch 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. The specific requirement for an interfering modulated signal will be determined on a case-by-case basis.
3. For noise immunity. The FTR shall be tested to demonstrate that it is capable of processing all command inputs subjected to an interfering RF input signal with a carrier at the assigned center frequency and RF power set at −17 dBm (−107 dBm + 90 dB) that is modulated by a signal with the following characteristics:

   a. modulation - BPSK;
   b. processor clock frequency - 5 Mbps;
   c. bit sequence - pseudo-random bit sequence generated with a 15-bit generator ($2^{15}-1$ bit sequence);
   d. burst repetition rate - 100 Hz.

NOTE This data is used to determine whether interfering sources must be deconflicted or if a different FTS frequency is required.

For capture ratio, the FTR shall be tested to demonstrate that it processes all commands when an interfering signal of less than 80% of the intended signal power 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.

4.18.12 Inadvertent Command Output

The FTR shall be tested to demonstrate that it will not produce an inadvertent command when exposed to the following conditions.

a. 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 two seconds between power cycles.

b. 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 VSWR.

Only RF input short circuit and open circuit testing need to be tested for acceptance.

c. Out-of-Band Signal Rejection. The FTR shall be tested to demonstrate it will not respond to any specified 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 pre-launch and flight. For these tests, the modulating signal shall be a command or tones that can be processed by the FTR.

The FTR shall be tested to demonstrate it provides 60 dB of rejection for any out-of-band interfering frequency from 10 MHz to 1 GHz. Test frequencies shall be generated in increments no greater than 1 kHz.

NOTE	Special attention should be given to other command termination frequencies used on a range.

(2) The interfering frequencies used 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 Band Edges. The FTR shall have an IF at 55 dB with band edges less than 180 kHz above and below the assigned center frequency and at 60 dB with band edges less than 275 kHz above and below the assigned center frequency. Both bands shall be centered within 0.005% of the assigned center frequency.
2. Image Rejection. The FTR shall provide at least 60 dB of RF rejection at the image frequency.

3. Spurious-Response/Rejection. The receiver shall provide at least 60 dB of rejection of CW signals from 10 MHz to 1 GHz (excluding the frequency band $F_0 \pm 275$ kHz). In addition it will provide 55 dB of rejection of CW signals within the frequency band $F_0 \pm 275$ kHz (excluding the frequency band $F_0 \pm 180$ kHz). The rejection levels shall be referenced to the response at the assigned center frequency of the receiver. Test frequencies shall be generated in increments no greater than 1 kHz.
4. The FTR shall be tested for rejection of interference from all intended and unintended range transmitting sources.

NOTE	Ranges typically have transmitting sources in the L-band, S-band, C-band, and X-band frequencies (i.e., sources in the frequency range of 1 GHz to 12 GHz).

d. In-Band Interference. Where there are in-band interfering sources during pre-launch and flight, the FTR shall be tested to characterize any inadvertent output that occurs because of the interfering signal.

1. Testing shall be performed to simulate the worst-case interfering signal characteristic.
2. For noise immunity, the FTR shall be tested to demonstrate that it will not produce an inadvertent output when it is subjected to an interfering RF input signal with a carrier at the assigned center frequency and RF power set at −17 dBm (−107 dBm + 90 dB) that is modulated by a signal with the following characteristics:

   a. modulation - BPSK;
   b. processor clock frequency - 5 Mbps;
   c. bit sequence - pseudo-random bit sequence generated with a 15-bit generator ($2^{15}-1$ bit sequence);
   d. burst repetition rate - 100 Hz.

NOTE	This data is used to determine whether interfering sources must be deconflicted or if a different FTS frequency is required.

4.18.13 Thermal Performance

A thermal performance test shall demonstrate that the FTR satisfies its performance specifications when subjected to operating and workmanship thermal environments. An 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 it is at the high and low temperatures. Performance tests at high and low temperatures shall include the tests listed in Table 4-16.

Table 4-16. Thermal Performance Tests for Enhanced Flight Termination Systems

#	Test	Paragraph	#	Test	Paragraph
1.	Input Current	4.18.2	6.	Fail-Safe	4.18.10
2.	Command and Control	4.18.3	7.	RF Threshold Sensitivity	4.18.11.c.(1)

3.	Output Command Circuits	4.18.4	8.	RF Dynamic Range	4.18.11.c.(3)
4.	Output Monitors	4.18.5	9.	SSTO	4.18.11.d
5.	Self-Test	4.18.6	10.	Operational Bandwidth	4.18.11.e

4.19 Autonomous Flight Termination Unit

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 324. Table 4-17 lists acceptance tests and requirements and Table 4-18 lists qualification tests and requirements for AFTUs.

Table 4-17. Autonomous Flight Termination Unit Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Inspection	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification[1]	4.10.4	
Continuity and Isolation	4.19.8	100%
Input Current[2]	4.19.7	100%
Terminate Decision Criteria	4.19.2	100%
Abbreviated Terminate Criteria[2]	4.19.9	100%
Output Firing Circuit[2]	4.19.3	100%
Command and Control[2]	4.19.4	100%
Output Monitors[2]	4.19.5	100%
Circuit Protection	4.19.10	
Low Voltage	4.19.10.b	100%
Dropout	4.19.10.c	100%
Watchdog Circuit	4.19.10.d	100%
Self Test[2]	4.19.6	100%
Abbreviated Performance Verification[2,3]	4.10.5	
Output Monitors	4.19.5	100%
Input Current	4.19.7	100%
Abbreviated Terminate Criteria	4.19.9	100%
Environment Tests – Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration[3]	4.12.4	100%
Random Vibration[3]	4.12.5	100%
Acoustic Vibration[3]	4.12.6	100%
Leakage	4.11.8	100%

[1]This test shall also be performed as part of the pre-flight tests in Chapter 5.
[2]This test shall be performed during the hot and cold dwells of the first and last cycles of the thermal cycle and thermal vacuum tests. Input current and command output shall be continuously monitored during all other thermal cycles and transitions.
[3]Abbreviated performance verification tests shall be performed during dynamic operating environments.

Table 4-18. Autonomous Flight Termination Unit Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Acceptance Tests	Table 4-17	X
Performance Verification[2]	4.10.4	
Continuity and Isolation	4.19.8	X
Input Current[3]	4.19.7	X
Terminate Decision Criteria	4.19.2	X
Abbreviated Terminate Criteria[3]	4.19.9	X
Output Firing Circuit[3]	4.19.3	X
Command and Control[3]	4.19.4	X
Output Monitors[3]	4.19.5	X
Circuit Protection	4.19.10	
Low Voltage	4.19.10.b	X
Dropout	4.19.10.c	X
Watchdog Circuit	4.19.10.d	X
Self Test[3]	4.19.6	X
Abbreviated Performance Verification[4]	4.10.5	
Output Monitors	4.19.5	X
Input Current	4.19.7	X
Abbreviated Terminate Criteria	4.19.9	X
Environment Tests – Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Environment Tests – Operating	4.15.1	
Thermal Cycle[3]	4.15.2	X
Thermal Vacuum[3]	4.15.3	X
Humidity[3]	4.15.4	X
Salt Fog	4.15.5	2
Temperature/Humidity/Altitude[3]	4.15.6	X
Acceleration[4]	4.15.7	X

Sinusoidal Vibration[4]	4.15.8	X
Random Vibration[4]	4.15.9	X
Acoustic Vibration[4]	4.15.10	X
Shock[5]	4.15.11	X
EMI/EMC	4.15.12	2
Explosive Atmosphere	4.15.13	2
Memory	4.19.12	X
Repetitive Functioning	4.19.11	X
Circuit Protection	4.19.10	1
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

[1]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.
[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]This test shall be performed 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.
[4]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
[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.

4.19.1 General

The 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 IAW the acceptance and qualification test matrices and accompanying requirements of this section.

a. Input into the AFTU shall use tracking-source inputs that duplicate the flight interface, including processing delays, sample rate, measurement data, and message structure.

b. All tracking source inputs used for testing shall be capable of independently simulating nominal and errant vehicle trajectories.

4.19.2 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:

1. ground launched/non-programming (straight up);
2. rapid turn towards impact limit line;
3. slow turn towards impact limit line;
4. 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. 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 but rather continue to 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. All data is lost.
   b. The DOP exceeds specification.
   c. The GPS is in a coast mode.
   d. Filter residuals that indicate errors exceed specification.

   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. All data is lost.
   b. The 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, are examples of inadequate source test conditions.

   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).

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. The AFTU shall NOT initiate a terminate output but rather continue to 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. The AFTU shall NOT initiate a terminate output but rather continue to 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.

The 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° 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 both AFTU processors cease functioning. The AFTU shall initiate a terminate command in a timeframe that meets performance requirements.

1. The AFTU shall output a terminate command only when both of the following 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.

4.19.3 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 it delivers the required energy at its 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 V in amplitude for more than 200 µs into a 10-kΩ load during the voltage transient and shall meet its performance requirements after the application of the voltage transient.

4.19.4 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 one 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-V signal is applied for five 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.

4.19.5 Output Monitors

Output monitor circuits shall be tested to verify that all the required monitor signals meet their specified performance requirements.

4.19.6 Self Test

The AFTU shall demonstrate it can perform self tests, detect errors, and output the results.

4.19.7 Input Current

Input current of the AFTU shall be monitored to demonstrate that it satisfies all its performance requirements.

Input current to the AFTU's input power and arm power shall be sampled at a minimum rate of 10,000 samples per second during dynamic environmental testing.

4.19.8 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 of its performance requirements.

Isolation resistance shall be 2 MΩ or more.

4.19.9 Abbreviated Terminate Criteria

An abbreviated functional test shall exercise an 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 of its performance requirements.

The AFTU shall use an abbreviated test routine that exercises terminate and non-terminate scenarios in Subsection 4.19.2. This same routine shall be used for qualification and acceptance testing.

4.19.10 Circuit Protection

A circuit protection test shall demonstrate that any circuit protection allows an AFTU to satisfy all of its performance requirements 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. Overvoltage. The AFTU shall demonstrate that it satisfies 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 ± the OCV of the power source or ±45 Vdc, whichever is higher, to the power input port for a period not less than five 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 V to the maximum specified voltage and back to 0 V without damage or producing a spurious output regardless of the rate of transition between the voltage present. 2. The AFTU shall satisfy all performance requirements after power is removed for greater than one 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 satisfy all performance requirements after a 50-ms dropout.

d. Watchdog Circuit. All watchdog circuits shall be tested to verify they meet their performance specifications.

e. Monitor Protection. The AFTU shall be tested to 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.

4.19.11 Repetitive Function

This test shall demonstrate that the AFTU satisfies all of its performance requirements 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.

4.19.12 Memory

An AFTU shall demonstrate that data stored in memory is not degraded and it is able to satisfy 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 DC power being applied.

4.20 Flight Termination System Shutdown Valves

This section lists acceptance and qualification tests for electro-mechanical valves, pneumatically actuated valves, and electro-pneumatic valves. Table 4-19 and Table 4-20 list test requirements for electro-mechanical valve tests. Table 4-21 and Table 4-22 list test requirements for pneumatic valves. Table 4-23 and Table 4-24 list test requirements for electro-pneumatic valves.

Table 4-19. Electro-Mechanical Valve Acceptance Test Requirements[1]

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Examination[2]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[2]	4.11.5	100%
Performance Verification[2]	4.10.4	
Continuity and Isolation	4.20.2	100%
Actuation Resistance (Solenoid coil)	4.20.3	100%
Insulation Resistance (Solenoid coil to case)	4.20.4	100%
Actuation Test	4.20.7	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle[3,4]	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration[5,6]	4.12.4	100%
Random Vibration[5,6]	4.12.5	100%
Acoustic Vibration[5,6]	4.12.6	100%
External Leak/Proof Test	4.20.5	100%
Performance Verification	4.10.4	
Actuation Test	4.20.7	100%
Continuity and Isolation	4.20.2	100%
Actuation Resistance (Solenoid coil)	4.20.3	100%
Insulation Resistance (Solenoid coil to case)	4.20.4	100%
Component Examination	4.11	
Visual Examination	4.11.2	100%
X-ray	4.11.6	100%

[1]The tests required by this table apply to all valve subassemblies, including the actuation assembly.
[2]This test shall also be performed as part of pre-flight testing at the launch site.
[3]Perform the valve actuation test IAW Subsection 4.20.7 during the hot and cold dwells of the first and last thermal cycles.
[4]Perform the valve cycle test IAW Subsection 4.20.12 during the hot dwells of thermal cycles 4-7.
[5]Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

a. The valve shall meet its leak specification in the closed position for the first half of the vibration test.
b. Open the valve and verify pressure on valve output port.
c. The second half of the vibration test shall verify no transfer of the valve back to the closed position and verify no out-of-specification loss of pressure.
d. Perform the valve actuation test IAW Subsection 4.20.7 prior to the end of the vibration test for each axis.

[6]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.

Table 4-20. Electro-Mechanical Valve Qualification Test Requirements[1]

Test	Section	Quantity Tested[2] X=3
Acceptance Tests	Table 4-19	X
Environment Tests - Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	X
Fine Sand	4.14.10	X
Environment Tests – Operating	4.15.1	
Thermal Cycle[3]	4.15.2	X
Thermal Vacuum[3]	4.15.3	X
Humidity[3,4]	4.15.4	X
Salt Fog[3]	4.15.5	X
Temperature/Humidity/Altitude[3]	4.15.6	X
Acceleration[5]	4.15.7	X
Sinusoidal Vibration[5]	4.15.8	X
Random Vibration[5]	4.15.9	X
Acoustic Vibration[5]	4.15.10	X
Shock[6]	4.15.11	X
EMI/EMC	4.15.12	X
Explosive Atmosphere	4.15.13	2
Actuation Cycle Life	4.20.13	X
External Leak Test	4.20.5	X
Pressure Cycle Life	4.20.11	X
Performance Verification	4.10.4	
Actuation Test	4.20.7	X
Component Examination	4.11	
Visual Examination	4.11.2	X
System Tests[7]	4.20.9	2
System Functional Margin[7]	4.20.6	X
Extended Stall	4.20.10	1
Burst Test	4.20.14	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]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.
[3]Perform the valve actuation test IAW Subsection 4.20.7.
[4]This test may be performed at system level during engine firings if the minimum humidity level required for operational use is enveloped during testing.
[5]Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

1. The valve shall meet its leak specification in the closed position for the first half of the vibration test.
2. Open the valve and verify pressure on valve output port.
3. The second half of the vibration test shall verify no transfer of the valve back to the closed position and verify no out-of-specification loss of pressure.
4. Perform the valve actuation test IAW Subsection 4.20.7 prior to the end of the vibration test for each axis.

[6]Two thirds of all shock tests on each component shall be performed in a closed position with the MEOP applied to the inlet. The 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 IAW Subsection 4.20.7 after shock testing is completed.
[7]Only one of these tests will be required. Range Safety will 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 4-21. Pneumatically Actuated Valve Acceptance Test Requirements[1]

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Examination[2]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[2]	4.11.5	100%
Performance Verification[2]	4.10.4	
Actuation Test	4.20.7	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle[3,4]	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration[5,6]	4.12.4	100%
Random Vibration[5,6]	4.12.5	100%
Acoustic Vibration[5,6]	4.12.6	100%
External Leak/Proof Test	4.20.5	100%
Performance Verification	4.10.4	
Actuation Test	4.20.7	100%
Component Examination	4.11	
Visual Examination	4.11.2	100%
X-ray	4.11.6	100%

[1]The tests required by this table apply to all valve subassemblies, including the actuation assembly.
[2]This test shall also be performed as part of pre-flight testing at the launch site.
[3]Perform the valve actuation test IAW Subsection 4.20.7 during the hot and cold dwells of the first and last thermal cycles.
[4]Perform the valve cycle test IAW Subsection 4.20.12 during the hot dwells of thermal cycles 4-7.
[5]Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

1. The valve shall meet its leak specification in the closed position for the first half of the vibration test.
2. Open the valve and verify pressure on valve output port.
3. The second half of the vibration test shall verify no transfer of the valve back to the closed position and verify no out-of-specification loss of pressure.
4. Perform the valve actuation test IAW Subsection 4.20.7 prior to the end of the vibration test for each axis.

[6]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.

Table 4-22. Pneumatically Actuated Valve Qualification Test Requirements[1]

Test	Section	Quantity Tested[2] X=3
Acceptance Tests	Table 4-19	X
Environment Tests - Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	X
Fine Sand	4.14.10	X
Environment Tests - Operating	4.15.1	
Thermal Cycle[3]	4.15.2	X
Thermal Vacuum[3]	4.15.3	X
Humidity[3,4]	4.15.4	X
Salt Fog[3]	4.15.5	X
Temperature/Humidity/Altitude[3]	4.15.6	X
Acceleration[5]	4.15.7	X
Sinusoidal Vibration[5]	4.15.8	X
Random Vibration[5]	4.15.9	X
Acoustic Vibration[5]	4.15.10	X
Shock[6]	4.15.11	X
EMI/EMC	4.15.12	2
Explosive Atmosphere	4.15.13	2
Actuation Cycle Life	4.20.13	X
External Leak Test	4.20.5	X
Pressure Cycle Life	4.20.11	X
Performance Verification	4.10.4	
Actuation Test	4.20.7	X
Component Examination	4.11	
Visual Examination	4.11.2	X
System Tests[7]	4.20.9	2
System Functional Margin[7]	4.20.6	X

Burst Test	4.20.14	2

[1]The tests required by this table apply to fully assembled valves, including the actuation assembly, pilot valves, flight brackets, connectors, and plumbing.
[2]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.
[3]Perform the valve actuation test IAW Subsection 4.20.7.
[4]This test may be performed at system level during engine firings if the minimum humidity level required for operational use is enveloped during testing.
[5]Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

1. The valve shall meet its leak specification in the closed position for the first half of the vibration test.
2. Open the valve and verify pressure on valve output port.
3. The second half of the vibration test shall verify no transfer of the valve back to the closed position and verify no out-of-specification loss of pressure.
4. Perform the valve actuation test IAW Subsection 4.20.7 prior to the end of the vibration test for each axis.

[6]2/3 of all shock tests on each component shall be performed in a closed position with the MEOP applied to the inlet. The 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 the valve actuation test IAW Subsection 4.20.7 after shock testing is completed.
[7]Only one of these tests will be required. Range Safety will 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 4-23. Electro-Pneumatic (Pilot) Valve Acceptance Test Requirements[1]

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Examination[2]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[2]	4.11.5	100%
Performance Verification[2]	4.10.4	
Continuity and Isolation	4.20.2	100%
Actuation Resistance	4.20.3	100%
Insulation Resistance	4.20.4	100%
Actuation Test	4.20.8	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle[3,4]	4.12.2	100%
Thermal Vacuum[3]	4.12.3	100%
Sinusoidal Vibration[5]	4.12.4	100%
Random Vibration[5]	4.12.5	100%

Acoustic Vibration[5]	4.12.6	100%
External Leak/Proof Test	4.20.5	100%
Performance Verification	4.10.4	
Actuation Test	4.20.8	100%
Continuity and Isolation	4.20.2	100%
Actuation Resistance	4.20.3	100%
Insulation Resistance	4.20.4	100%
Component Examination	4.11	
Visual Examination	4.11.2	100%
X-ray	4.11.6	100%

[1]The tests required by this table apply to all valve subassemblies, including the actuation assembly.
[2]This test shall also be performed as part of pre-flight testing at the launch site.
[3]Perform the electro-pneumatic functional test IAW Subsection 4.20.8 during the hot and cold dwells of the first and last thermal cycles.
[4]Perform the valve cycle test IAW Subsection 4.20.12 during the hot dwells of thermal cycles 4-7.
[5]Perform the valve actuation test IAW Subsection 4.20.8 prior to the end of the vibration test for each axis. Valve testing during vibration shall verify valve functionality in its intended FTS configuration.

Table 4-24. Electro-Pneumatic (Pilot) Valve Qualification Test Requirements[1]

Test	Section	Quantity Tested[2] X=3
Acceptance Tests	Table 4-19	X
Environment Tests – Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	X
Fine Sand	4.14.10	X
Environment Tests - Operating	4.15.1	
Thermal Cycle[3]	4.15.2	X
Thermal Vacuum[3]	4.15.3	X
Humidity[3]	4.15.4	X
Salt Fog[3]	4.15.5	X
Temperature/Humidity/Altitude[3]	4.15.6	X
Acceleration[4]	4.15.7	X
Sinusoidal Vibration[4]	4.15.8	X
Random Vibration[4]	4.15.9	X
Acoustic Vibration[4]	4.15.10	X
Shock[5]	4.15.11	X
EMI/EMC	4.15.12	X
Explosive Atmosphere	4.15.13	X
Actuation Cycle Life	4.20.13	X

External Leak Test	4.20.5	X
Pressure Cycle Life	4.20.11	X
Performance Verification	4.10.4	
Actuation Test	4.20.8	X
Component Examination	4.11	
Visual Examination	4.11.2	X
System Tests[6]	4.20.9	2
System Functional Margin[6]	4.20.6	X
Extended Stall	4.20.10	2
Burst Test	4.20.14	2

[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]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.
[3]Perform the electro-pneumatic functional test IAW Subsection 4.20.8.
[4]Perform the valve actuation test IAW Subsection 4.20.8 prior to the end of the vibration test for each axis. Valve testing during vibration shall verify valve functionality in its intended FTS configuration.
[5]The test shall demonstrate that the component will maintain a pressure output during shock testing. Verify the unit meets performance requirements after shock testing. Perform the pneumatic functional test IAW Subsection 4.20.8 immediately after the test.
[6]Only one of these tests will be required. Range Safety will determine which one of these tests shall be performed on a case-by-case basis.

4.20.1 General

This section applies to any shutdown valves and associated hardware that are part of the primary means of providing flight termination, including the mechanism for actuation, whether electrical, mechanical, 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 of its performance requirements when subjected to each non-operating and operating environment.

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.

NOTE

The types of valves described in this section are as follows.

1. Electromechanical valves. These valves are actuated by an electrical input resulting in direct interruption or venting of fluids.
2. Pneumatically actuated valves. These valves are actuated by a pressure input resulting in direct interruption or venting of fluids.
3. 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 (i.e., pilot valves). 4. Pyrotechnic valves. These valves are actuated by an ordnance device input, such as squibs, resulting in direct interruption or venting of fluids. Ordnance devices used in FTS valves shall meet all the requirements specified in the appropriate section of this chapter.

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 less than 1.5 times MEOP.
2. Pressure lines shall not burst at less than 4 times MEOP.

4.20.2 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 or more.

4.20.3 Actuation Resistance

The test shall demonstrate that the motor or solenoid drive motor circuit meets performance specification.

4.20.4 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 materials 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%.
3. The insulation resistance between all insulated parts shall be 2 MΩ or more.

4.20.5 External Leak/Proof Test

A valve shall be tested to demonstrate that it meets leak rate requirements when exposed to the 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 MEOP. Maximum allowable leakage rate shall conform to Class II of ANSI/FCI 70-2,[29] in which no greater than 0.5% of full flow may leak at 1.25 times MEOP.
2. External leakage shall be sufficient to prevent explosive atmosphere, hazards to personnel,

[29] Fluid Controls Institute. Control Valve Seat Leakage. ANSI/FCI 70-2-2013. January 2013. May be superseded by update. Available for purchase at http://www.techstreet.com/fci/products/1851249#jumps.

or potential FTS failure conditions, such as propellant compatibility with FTS components or freezing the valve closed.
3. This test shall be performed while cycling the valve at least five times.
4. This test also serves as a proof pressure test.
5. This test may be run with helium or other inert gas.

4.20.6 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 the 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 the MEOP.

1. The maximum leak rate for a closed valve shall be in specification and family at 1.25 times MEOP (i.e., a 25% margin on 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 vehicle.
2. If the valve flow control mechanism is visible, visual inspection may be used to verify that the valve is open before and after open position throughput testing is accomplished.
3. Where applicable, these tests shall include pilot valves.

4.20.7 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 satisfy all performance requirements, including response time and valve input current, where applicable.

Leak testing shall be performed with a gaseous medium at the MEOP in a no-flow configuration.

4.20.8 Electro-Pneumatic Valve Actuation

A valve shall be tested to demonstrate it can produce a pneumatic output that satisfies all of its performance requirements at high and low input operating voltages. The valve shall satisfy 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 sufficient resolution and sample rate that the data can be used for performance evaluation.

4.20.9 System Tests

Valves shall be tested in a flight configuration, including actuation assembly, electrical wiring, flight brackets, connectors, and plumbing.

NOTE	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 pre-launch and launch environments at the planned launch range.

4.20.10 Extended Stall

An electromechanical or pneumatic valve shall be tested to demonstrate it will not degrade in performance or 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 five 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 one hour.
3. For electro-pneumatic valves, only the five-minute extended-stall test is required.

4.20.11 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 pre-launch and launch plus a margin. The valve shall undergo a valve actuation test IAW Subsection 4.20.7 after the test.

1. Testing shall be performed to demonstrate that the valve satisfies 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 times MEOP at a pressure rate of change that envelopes flight pressure application.

4.20.12 Pre-Test Conditioning and Workmanship Actuation 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 IAW 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 during the hot dwells of each of the four thermal cycles specified in the test table.

4.20.13 Actuation Cycle Life

A valve shall be actuation-cycle-life tested to the maximum expected number of shutdown cycles for acceptance, ground checkout, and flight plus a margin. A valve actuation test shall be performed IAW Subsection 4.20.7 (use Subsection 4.20.8 for electro-pneumatic valves) after the actuation cycle life test.

1. This test may be performed unpressurized.
2. For electro-pneumatic valves, this test shall be performed with input pressure ports at the MEOP.
3. Valves shall be actuation-cycle-life tested for a minimum of five times the maximum expected number of shutdown cycles or 500 cycles, whichever is higher.
4. During the last test cycle, the valve shall hold actuation pressure at the MEOP for one hour to satisfy its performance requirements.

4.20.14 Burst Test

The valve shall be tested to demonstrate it 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 a pressure of 1.5 times MEOP.
2. Pneumatic valves shall be tested to demonstrate they will not burst when subjected to a pressure of 1.25 times MEOP.

4.21 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 of its performance requirements 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 4-25 and Table 4-26 identify acceptance and qualification test requirements for miscellaneous components.

Table 4-25. Miscellaneous Component Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification[1,2]	4.10.4	100%
Abbreviated Performance Verification[3]	4.10.5	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration	4.12.4	100%
Random Vibration	4.12.5	100%
Acoustic Vibration	4.12.6	100%
Leakage	4.11.8	100%
Visual Examination	4.11.2	100%

[1]The detailed performance verification test requirements need to be determined during the design and tailoring process.
[2]This test shall also be performed as part of the pre-flight tests in Chapter 5.
[3]The abbreviated performance verification test requirements need to be determined during the design and tailoring process.

Table 4-26. Miscellaneous Component Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Acceptance Tests	Table 4-25	X
Performance Verification[2]	4.10.4	X
Environment Tests - Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Abbreviated Performance Verification[3]	4.10.5	X
Environment Tests - Operating	4.15.1	
Thermal Cycle	4.15.2	X
Thermal Vacuum	4.15.3	X
Humidity	4.15.4	X
Salt Fog	4.15.5	X
Temperature/Humidity/Altitude	4.15.6	X
Acceleration	4.15.7	X
Sinusoidal Vibration	4.15.8	X

Random Vibration	4.15.9	X
Acoustic Vibration	4.15.10	X
Shock	4.15.11	X
EMI/EMC	4.15.12	X
Explosive Atmosphere	4.15.13	1
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

[1]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 component tested shall be one of the original three sample components.
[2]The detailed performance verification test requirements need to be determined during the design and tailoring process.
[3]The abbreviated performance verification test requirements need to be determined during the design and tailoring process.

4.22 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. Test requirements for electrical connectors and harnesses are listed in Table 4-27.

Table 4-27. Electrical Connector and Harness Test Requirements

Test	Section	Quantity Tested	
		Acceptance	Qualification[1] X=3
Component Examination	4.11		
Visual Examination	4.11.2	100%	-
Dimensional Measurement	4.11.3	100%	-
Tensile Load	4.12.7	100%	-
Performance Verification Tests	4.10.4	100%	-
Dielectric Strength	4.22.2	100%	-
Insulation Resistance	4.22.4	100%	-
Continuity & Isolation Resistance	4.22.3	100%	-
Environment Tests – Operating	4.15.1		
Thermal Cycling[4]	4.15.2	-	X
Humidity[2]	4.15.4	-	X
Salt Fog[2]	4.15.5	-	X
Temperature/Humidity/Altitude[2]	4.15.6	-	X
Acceleration[3]	4.15.7	-	X
Sinusoidal Vibration[3]	4.15.8	-	X
Random Vibration[3]	4.15.9	-	X
Shock[3]	4.15.11	-	X
Tensile Load	4.14.11	-	X
Performance Verification Tests	4.10.4	-	X
Dielectric Strength	4.22.2	-	X

Insulation Resistance	4.22.4	-	X
Continuity & Isolation Resistance	4.22.3	-	X

[1]The same three sample components shall undergo each test designated with an X.
[2]Immediately following this test environment, a continuity and isolation resistance test per Paragraph 4.22.3 shall be performed.
[3]This test shall continuously monitor connector and cable continuity parameters using a minimum sample rate of 1000 samples per second.
[4]Qualification-level environmental testing for harnesses is typically accomplished when an associated FTS component is qualification tested. Full-length electrical harnesses are typically not qualification tested so long as the harness length to the first (qualification-like) mounting point is qualification tested, in addition to the connector end. This table provides for qualification testing of electrical connectors/harnesses not otherwise tested. All RF cables are addressed in Table 4-6 and Table 4-7.

4.22.1 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 of its performance requirements when subjected to each non-operating and operating environment.

4.22.2 Dielectric Withstanding Voltage

The test shall measure the DWV between mutually insulated portions of the harness or connector to demonstrate that the harness or connector satisfies all of its performance requirements at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomenon.

1. This test shall be performed at a minimum of 150% of the operating voltage or 500 Vdc, whichever is higher. Measurements shall be taken between mutually insulated points or between insulated points and ground immediately after a one-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%.

4.22.3 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 of its performance requirements.

Continuity resistance shall be 0.05 Ω or less and isolation resistance shall be 2 MΩ or more.

4.22.4 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 150% of the operating voltage or 500 Vdc, whichever is higher. Measurements shall be taken between mutually insulated points or between insulated points and ground immediately after a one-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%.
4. The insulation resistance between all insulated parts shall be 2 MΩ or more.

4.23 Remotely Activated Silver-Zinc Batteries

This section describes remotely activated Ag-Zn batteries. Acceptance tests are in Table 4-28 and qualification tests are in Table 4-29.

Table 4-28. Remotely Activated Silver-Zinc Battery Lot Acceptance Test Requirements[1]

Test	Section	Quantity Tested[2,3]
Acceptance Tests - LVI Lot[4]	Table 4-49	-
Component Examination[5]	4.11	
Visual Inspection[6]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[6]	4.11.5	100%
X-ray	4.11.6	100%
Battery Case and Mount Weld[7]	4.23.10	100%
Performance Verification[5]	4.10.4	
Continuity and Isolation[6]	4.23.5	100%
Dielectric Strength	4.23.4	100%
Monitoring Capability[6]	4.23.7	100%
Heater Circuit Verification[6]	4.23.11	100%
Activation Circuit (LVI) Resistance[6]	4.23.12	100%
Pin-to-Case Voltage Isolation	4.23.6	100%
Electrostatic Discharge	4.29.10	100%
Battery Venting	4.23.3	Lot Sample or 100%
Environment Tests - Non-Operating[5]	4.14.1	
Thermal Cycle[8]	4.15.2.e	Lot Sample
Performance Verification[9]	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
Environment Tests – Operating[2,10,11,12]	4.15.1	
Acceleration	4.15.7	Lot Sample
Sinusoidal Vibration	4.15.8	Lot Sample
Random Vibration	4.15.9	Lot Sample
Shock	4.15.11	Lot Sample
Battery Case Integrity	4.23.2	Lot Sample

Component Examination[5]	4.11	
X-ray[11]	4.11.6	Lot Sample
Battery Case and Mount Weld[7]	4.23.10	Lot Sample
Discharge and Pulse Capacity	4.23.9	Lot Sample

[1]Batteries shall have an initial service life of three to five years depending on supporting data as determined by Range Safety. Any SLEs will require a tailored retest of the lot acceptance table.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of 2 units or 1 unit for each combined operating environmental axis and thermal extreme (e.g., 3 axes x 2 thermal extremes = 6 units), whichever is higher.

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 environmental tests 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 three individual axes of acceleration, vibration, and shock.
2. Two batteries may be tested if batteries have sufficient life to perform ALL operating tests in the activated state.

[3]Failure of a single battery to meet lot sample test requirement shall result in rejection of the production lot. High failure rates for 100% screening tests of non-lot sample units may also result in rejection of the lot.
[4]Operating environment testing during LATs is only required for LVIs that will be exposed to operating environments prior to functioning.
[5]This test shall be performed prior to activation.
[6]This test shall also be performed at the launch site just before installation.
[7]This test is only required for a battery case or mount that contains a weld.
[8]This test shall be performed using the ordnance thermal cycle requirements.
[9]This test shall be performed during all operating tests for an activated battery.
[10]Thermal and operating tests shall be performed concurrently with the battery at both the upper and lower qualification thermal cycle temperature limits for each activated battery operating test. Combining thermal and operating environments for unactivated batteries shall be required if it reflects the operational flight environment. The electrical performance tests shall be IAW Paragraph 4.22.3.
[11]This test shall be performed prior to and after all operating tests in an activated state.
[12]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.

Table 4-29. Remotely Activated Silver-Zinc Battery Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Component Examination[2]	4.11	
Visual Inspection	4.11.2	X
Dimension Measurement	4.11.3	X
Weight Measurement	4.11.4	X
Identification Check	4.11.5	X
Battery Case and Mount Weld[3]	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	4.29.17	X
LVI Electrostatic Discharge	4.29.10	X
Battery Venting	4.23.3	Lot Sample or 100%
Environment Tests – Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Thermal Cycle[4]	4.15.2.e	X
Thermal Vacuum[4]	4.15.3	X
Fungus Resistance	4.14.9	1
Performance Verification[5]	4.10.4	
Heater Circuit Verification	4.23.11	X
Monitoring Capability	4.23.7	X
Thermal/Electrical Performance[6,7]	4.23.8	X
Pin-to-Case Voltage Isolation	4.23.6	X
Environment Tests – Operating[8,9]	4.15.1	
Salt Fog	4.15.5	X
Temperature/Humidity/Altitude	4.15.6	X
Acceleration[10,11]	4.15.7	X
Sinusoidal Vibration[10,11]	4.15.8	X
Random Vibration[10,11]	4.15.9	X
Acoustic Vibration[10,11]	4.15.10	X
Shock[10,11]	4.15.11	X
Explosive Atmosphere	4.15.13	X
EMI/EMC[12]	4.15.12	X

Battery Case Integrity	4.23.2	X
Battery Case and Mount Weld[3]	4.23.10	X
Discharge and Pulse Capacity	4.23.9	X

[1]A lot sample shall be 10% of the lot (rounded up) or two units, whichever is higher.
[2]This test shall be performed prior to activation.
[3]This test is only required for a battery case or mount that contains a weld.
[4]Thermal cycle testing shall be performed using the ordnance thermal cycle requirements.
[5]This test shall be performed after battery activation.
[6]This test shall be performed prior to and after all operating tests in an activated state.
[7]This test shall be performed using the ordnance thermal cycle requirements.
[8]Thermal and operating tests shall be performed concurrently with the battery at both the upper and lower qualification thermal cycle temperature limits 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 IAW Subsection 4.23.8 at each thermal extreme.
[9]Qualification testing requires 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 three individual axes of acceleration, vibration, and shock. 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.

[10]Apply expected steady-state current load for the duration of the test and monitor at 10 samples per second for dropouts.
[11]The order in which each axis is tested shall be changed for each component to ensure that every axis is performed last on different units.
[12]This test is only required if the battery contains EMI-producing devices such as Hall-effect current monitoring circuits or battery heaters/thermostats.

4.23.1 General

a. After a battery design is qualified for use by an FTS, acceptance tests are performed on production batteries that will be used in the FTS.

b. It is not possible to accurately determine the ability of these reserve batteries to perform acceptably without destructive testing. Because of this, the sample sizes are shown in the test tables and can also be adjusted to accommodate vehicle-dependent variation in the operating environments. The FTS battery requirement specification shall be agreed upon by the range representative during tailoring.

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 IAW 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.

Short-Life Batteries

1. 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.
2. 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 all the remaining operating tests shall be completed.
3. These tests shall be repeated until each required operating environment has been tested with three batteries in an activated state.
4. This methodology significantly increases the samples and amount of testing.

e. 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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second. Any dropout constitutes a test failure.

f. 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 ±10°C.

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 gas leak rate shall satisfy all of its performance requirements 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 of its performance requirements.

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 of its performance requirements. The test shall demonstrate that each device sample vents within ±10% of the manufacturer-specified average vent pressure.

4.23.4 Dielectric Strength

The test shall measure the DWV between mutually insulated portions of the connector to demonstrate that the internal wiring satisfies all its performance specifications at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomenon.

1. Dielectric strength testing shall be performed at a minimum of 150% of the operating voltage or 500 Vdc, whichever is higher. Measurements shall be taken between mutually insulated points or between insulated points and ground immediately after a one-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 of its performance requirements and is in-family.

Isolation resistance shall be 2 MΩ or more at 500 Vdc.

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 that has a resolution that will detect any leakage current of 0.1 mA or greater.

1. This measurement shall use a voltmeter with an internal resistance of 2 MΩ or more.
2. The test shall measure voltage across a circuit using a 150-kΩ 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 a battery's voltage, current, and temperature satisfies all of its performance requirements.

4.23.8 Electrical Performance

An electrical performance test shall demonstrate that a battery satisfies all of its performance requirements while the battery is subjected to the electrical load profile and other requirements described below.

a. The test shall demonstrate that the cell or battery 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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second.

c. The battery shall undergo this test after it 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) The test shall apply steady-state current load for the duration of the test.

(3) The test shall perform design pulse load and pulse width at the beginning and end of each operating test and verify that the battery satisfies 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 an Ag-Zn cell or battery 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 each of the upper and lower qualification thermal cycle temperature limits.

b. The battery shall be tested IAW Subsection 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. Each battery shall be discharged using a C/2 discharge rate to the cutoff voltage.
2. The cutoff voltage shall be the lowest specified voltage of the electronic components or

the manufacturer cutoff voltage, whichever is higher. For example, receivers are tested to a minimum of 24 Vdc.

3. The battery and/or cell voltage and current shall be monitored during the test.
4. At a minimum, the capacity demonstrated during this test and during the operational environmental tests shall be at least the manufacturer-warranted rating and be equal to or greater than 150% of the capacity that is required for actual use.

4.23.10 Battery Case and Mount Weld

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, which shall meet the requirements of Paragraph 4.11.6, or pull testing.

4.23.11 Heater Circuit Verification

A heater circuit verification test shall demonstrate that any battery heater, including its control circuitry, satisfies all of its performance requirements. At a minimum, heater circuit resistance shall be measured.

4.23.12 Activation Circuit Low-Voltage Initiator Resistance

An ordnance-initiated battery activation circuit shall be tested to ensure it meets its required performance specifications.

4.24 Thermal Batteries

Table 4-30 lists thermal battery acceptance tests and Table 4-31 lists thermal battery qualification tests.

Table 4-30. Thermal Battery Lot Acceptance Test Requirements[1]

Test	Section	Quantity Tested[2,3]
Acceptance Tests – LVI Lot[4]	Table 4-49	-
Component Examination[5]	4.11	
Visual Inspection[6,7]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[7]	4.11.5	100%
X-ray	4.11.6	100%
Battery Case and Mount Weld[8]	4.24.7	100%
Performance Verification[5]	4.10.4	
Continuity and Isolation[7]	4.24.4	100%
Dielectric Strength	4.24.3	100%
Cell Stack Polarity	4.24.9	100%
Monitoring Capability[7]	4.24.5	100%
Activation Circuit (LVI) Resistance[7]	4.24.8	100%
Pin-to-Case Voltage Isolation	4.24.11	100%
Electrostatic Discharge	4.29.10	100%
Environment Tests - Non-Operating[5]	4.14.1	
Thermal Cycle[9]	4.15.2.e	Lot Sample

Performance Verification[6]	4.10.4	
Thermal/Electrical Performance[9]	4.24.6	Lot Sample
Environment Tests – Operating[2,10,11]	4.15.1	
Acceleration	4.15.7	Lot Sample
Sinusoidal Vibration	4.15.8	Lot Sample
Random Vibration	4.15.9	Lot Sample
Shock	4.15.11	Lot Sample
Battery Case Integrity	4.24.2	Lot Sample
Component Examination	4.11	
X-ray[6]	4.11.6	Lot Sample
Battery Case and Mount Weld[8]	4.24.7	Lot Sample

[1]Batteries shall have an initial service life of three to five years depending on supporting data as determined by Range Safety. Any SLEs will require a tailored retest of the lot acceptance table.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of 6 units or 1 unit for each combined operating environmental axis and thermal extreme (e.g., 3 axes x 2 thermal extremes = 6 units), whichever is higher.

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. If batteries do not have sufficient life to perform all operating tests in the activated state, a minimum of 18 units shall be tested. This allows for use of activated batteries at hot and cold temperatures and for testing in three individual axes for acceleration, vibration, and shock.
2. If batteries have sufficient life to perform all operating tests in the activated state, a minimum of 6 units shall be tested.

[3]Failure of a single battery to meet lot sample test requirement shall result in rejection of the production lot. High failure rates for 100% screening tests of non-lot sample units may also result in rejection of the lot.
[4]Operating environments during lot acceptance testing are only required for LVIs that will be exposed to operating environments prior to functioning.
[5]This test shall be performed prior to activation.
[6]Visual inspection includes verifying that the activation indicator indicates that the battery is in the proper state.
[7]This test shall also be performed at the launch site just before installation.
[8]This test is only required for a battery case or mount that contains a weld.
[9]This test shall be performed using the ordnance thermal cycle requirements.
[10]Thermal and operating tests shall be performed concurrently with the battery at both the upper and lower qualification thermal cycle temperature limits 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 IAW Subsection 4.24.6 at each thermal extreme.
[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.

Table 4-31. Thermal Battery Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Component Examination[2]	4.11	
Visual Inspection	4.11.2	X
Dimension Measurement	4.11.3	X
Weight Measurement	4.11.4	X
Identification Check	4.11.5	X
Battery Case or Mount Weld[3]	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	X
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 Verification	4.29.17	X
LVI Electrostatic Discharge	4.29.10	X
Battery Venting	4.23.3	Lot Sample or 100%
Environment Tests – Non-Operating[2]	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Thermal Cycle[4]	4.15.2.e	X
Thermal Vacuum[4]	4.15.3	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Performance Verification[5]	4.10.4	
Thermal/Electrical Performance[4,6]	4.24.6	X
Pin-to-Case Voltage Isolation	4.24.11	X
Environment Tests – Operating[7]	4.15.1	
Salt Fog	4.15.5	X
Temperature/Humidity/Altitude	4.15.6	X
Acceleration[8,9]	4.15.7	X
Sinusoidal Vibration[8,9]	4.15.8	X
Random Vibration[8,9]	4.15.9	X

Acoustic Vibration[8,9]	4.15.10	X
Shock[8,9]	4.15.11	X
Explosive Atmosphere	4.15.13	X
EMI/EMC[10]	4.15.12	X
Battery Case Integrity	4.24.2	X
Battery Case or Mount Weld[3]	4.24.7	X
Discharge and Pulse Capacity	4.24.10	X

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 6 units or 1 unit for each combined operating environmental axis and thermal extreme (e.g., 3 axes x 2 thermal extremes = 6 units), whichever is higher.

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. If batteries DO NOT have sufficient life to perform ALL operating tests in the activated state, a minimum of 18 units shall be tested. This allows for use of activated batteries at hot and cold temperatures and for testing in three individual axes for acceleration, vibration, and shock.
2. If batteries have sufficient life to perform ALL operating tests in the activated state, a minimum of 6 units shall be tested.

[2]This test shall be performed prior to activation.
[3]This test is only required for a battery case or mount that contains a weld.
[4]This test shall be performed using the ordnance thermal cycle requirements.
[5]This test shall be performed after activation.
[6]This test shall be performed prior to and after all operating tests in an activated state.
[7]Thermal and operating tests shall be performed concurrently with the battery at both the upper and lower qualification thermal cycle temperature limits 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 IAW Subsection 4.24.6 at each thermal extreme.
[8]Apply expected steady-state current load for the duration of the test and monitor at a minimum of 10 samples per second for dropouts.
[9]The order in which each axis is tested shall be changed for each component to ensure that every axis is performed last on different units.
[10]This test is only required if the battery contains EMI-producing devices, such as Hall-effect current monitoring circuits or battery heaters/thermostats.

4.24.1 General

a. After a battery design is qualified for use by an FTS, acceptance tests are performed on production batteries that will be used in the FTS.

b. It is not possible to accurately determine the ability of these reserve batteries to perform acceptably without destructive testing. Because of this, the sample sizes are shown in the test tables and can also be adjusted to accommodate vehicle-dependent variation in the operating environments. The FTS battery requirement specification shall be agreed upon by the range representative during tailoring.

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 IAW 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

1. 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.
2. 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 all the remaining operating tests shall be completed.
3. These tests shall be repeated until each required operating environment has been tested with three batteries in an activated state.
4. 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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second. 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 ±10°C.

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 gas leak rate shall satisfy all of its performance requirements in Paragraph 4.11.8.

4.24.3 Dielectric Strength

The test shall measure the DWV between mutually insulated portions of the connector to demonstrate that the internal wiring satisfies all its performance specifications at its rated voltage and withstands any momentary over-potential due to switching, surge, or any other similar phenomenon.

1. Dielectric strength testing shall be performed at a minimum of 150% of the operating voltage or 500 Vdc, whichever is higher. Measurements shall be taken between mutually insulated points or between insulated points and ground immediately after a one-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 of its performance requirements and are in-family.

Isolation resistance shall be 2 MΩ or more at 500 Vdc.

4.24.5 Monitoring Capability

A monitoring capability test shall demonstrate that any internal battery monitoring capability used to measure a battery's voltage, current, and temperature satisfies all of its performance requirements.

4.24.6 Electrical Performance

An electrical performance test shall demonstrate that a battery satisfies all of its performance requirements while it is subjected to the electrical load profile and other requirements described below.

a. The test shall demonstrate that the cell or battery 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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second.

c. Load Testing

   (1) The test shall apply a 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 Case and Mount Weld

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, which shall meet the requirements of Paragraph 4.11.6, or pull testing.

4.24.8 Activation Circuit Low-Voltage Initiator 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. The voltage produced on each battery section and any cell stack taps present shall be tested using a voltmeter with high-input impedance. 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 an Ag-Zn cell or battery 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 each of the upper and lower qualification thermal cycle temperature limits.

b. The battery shall be tested IAW Paragraph 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. Each battery shall be discharged using a C/2 discharge rate to the cutoff voltage.
2. The cutoff voltage shall be the lowest specified voltage of the electronic components or the manufacturer cutoff voltage, whichever is higher. For example, receivers are tested to a minimum of 24 Vdc.
3. The battery and/or cell voltage and current shall be monitored during the test.
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% 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 high-input impedance and a resolution that detects any leakage current of 0.1 mA or greater shall be used.

1. This measurement shall use a voltmeter with internal resistance of 2 MΩ or more.
2. The test shall measure voltage across a circuit using a 150-kΩ resistor from pin to case.

4.25 Manually Activated Silver-Zinc Batteries

The following tables detail tests for manually activated Ag-Zn batteries. Table 4-32 lists acceptance tests. Table 4-33 lists qualification tests. Table 4-34 lists age surveillance tests.

Table 4-32. Manually Activated Silver-Zinc Coupon Cell and Battery Acceptance Test Requirements

Test	Section	Quantity Tested	
		X=1 Cell per Battery[1]	Batteries
Cell Capacity	4.25.2	X	-
Insulation Resistance	4.25.3	-	100%
Cell Proof Pressure	4.25.19.a	X	-
Electrolyte	4.25.20	-	100%
Battery Case and Mount Weld[2]	4.25.21	-	100%
Component Examination	4.11		
Visual Examination[3,4]	4.11.2	X	100%
Dimension Measurement[3]	4.11.3	X	100%
Weight Measurement[3,5]	4.11.4	X	100%
Identification Check[3]	4.11.5	X	100%
Internal Inspection	4.11.7	-	100%
Pre-Activation[3]	4.25.7	-	100%
Continuity and Isolation[3]	4.25.4	-	100%
Performance Verification	4.10.4		
Monitoring Capability[3]	4.25.8	-	100%
Heater Circuit Verification[3]	4.25.9	-	100%
Acceptance - Coupon Cell[3]	4.25.18	X	-
Activation[2]	4.25.10	X	100%
No-load Voltage[3]	4.25.5	X	100%
Pin-to-Case Isolation[3]	4.25.6	-	100%
Electrical Performance[3]	4.25.11	X	100%
Battery Case Proof Pressure[3]	4.25.19.b	-	100%

[1]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.
[2]This test is only required for a battery case or mount that contains a weld.

[3]A battery shall undergo this test at the launch site just before installation.
[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 that the required amount of electrolyte has been added for activation.

Table 4-33. Manually Activated Silver-Zinc Cell and Battery Qualification Test Requirements

Test	Paragraph	Quantity Tested[1]	
		Cells X=12	Batteries X=3
Acceptance Tests - Coupon Cell and Battery	Table 4-32	-	X[2]
Insulation Resistance	4.25.3	-	X
Cell Proof Pressure	4.25.19.a	X	-
Electrolyte	4.25.20	X	X
Battery Case and Mount Weld[3]	4.25.21	-	X
Component Examination	4.11		
Visual Examination	4.11.2	X	X
Dimension Measurement	4.11.3	X	X
Weight Measurement[4]	4.11.4	X	X
Identification Check	4.11.5	X	X
Internal Inspection	4.11.7	-	X
Pre-Activation	4.25.7	X	X
Continuity and Isolation	4.25.4	-	X
Environment Tests – Non-Operating	4.14.1		
Storage Temperature	4.14.2	X	X
Transportation Vibration	4.14.4	-	X
Transportation Shock	4.14.5	-	X
Bench Handling Shock	4.14.6	-	X
Fungus Resistance	4.14.9	-	X
Fine Sand	4.14.10	-	X
Performance Verification	4.10.4		
Monitoring Capability	4.25.8	-	X
Heater Circuit Verification	4.25.9	-	X
Activation	4.25.10	X	X
No-load Voltage	4.25.5	X	X
Pin-to-Case Isolation	4.25.6	-	X
Electrical Performance	4.25.11	X	X
Battery Case Proof Pressure	4.25.19.b	-	X
Activated Stand Time	4.25.12	X	X
Overcharge[5]	4.25.13	-	X
Charge-Discharge Cycles[5]	4.25.14	X	X
Environment Tests – Operating	4.15.1		
Thermal Cycle[6,7,8]	4.25.15	X	X

Thermal Vacuum[6,7,8,9]	4.15.3	-	X
Humidity[7]	4.15.4	-	X
Salt Fog	4.15.5	-	X
Temperature/Humidity/Altitude[8,10]	4.15.6	X	X
Acceleration[6,7,8,9]	4.15.7	-	X
Sinusoidal Vibration[6,7,8,9]	4.15.8	-	X
Random Vibration[6,7,8,9]	4.15.9	-	X
Acoustic Vibration[6,7,8,9]	4.15.10	-	X
Shock[7,8,9]	4.15.11	-	X
EMI/EMC[7]	4.15.12	-	1
Explosive Atmosphere[7]	4.15.13	-	1
Performance Verification	4.10.4		
Monitoring Capability	4.25.8	X	X
Heater Circuit Verification	4.25.9	-	X
Discharge and Pulse Capacity[7]	4.25.16	X	X
Pin-to-case Isolation	4.25.6	X	X
Battery Case Proof Pressure[7]	4.25.19.b	-	X
Internal Inspection[7]	4.25.17	X	X

[1]The same 3 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 battery tests designated with a quantity of less than 3, each battery tested shall be one of the original 3 sample batteries.
[2]For each of the 3 battery samples, no less than 1 cell that is representative of the cells that make up the battery shall undergo this test. These cells, no less than 3, are in addition to the 12 cells in the cell test column.
[3]This test is only required for a battery case or mount that contains a weld.
[4]Weight measurements shall include pre- and post-activation weights to validate that the required amount of electrolyte has been added for activation.
[5]This test only applies if normal operation of the battery includes charging.
[6]A cell or battery shall undergo the electrical performance test of Subsection 4.25.11 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.
[7]Each cell or battery sample shall undergo this test at the end of the wet stand time after the last operating charge.
[8]A pin-to-case isolation test of Paragraph 4.25.6 is required before and after these specific operational environmental tests.
[9]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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second. Any dropout constitutes a test failure.
[10]If this test is performed in its entirety, the humidity test and three cycles of the thermal cycle test required in this table will not have to be performed.

Table 4-34. Manually Activated Silver-Zinc Cell Age Surveillance Test Requirements

Test	Section	Quantity Tested[1] X=2 Cells/Year
Cell Proof Pressure	4.25.19.a	X
Electrolyte	4.25.20	X
Component Examination	4.11	
Visual Examination	4.11.2	X
Dimension Measurement	4.11.3	X
Weight Measurement	4.11.4	X
Identification Check	4.11.5	X
Performance Verification	4.10.4	
Monitoring Capability	4.25.8	X
Activation	4.25.10	X
No-Load Voltage	4.25.5	X
Electrical Performance	4.25.11	X
Environment Tests – Operating	4.15.1	X
Activated Stand Time	4.25.12	X
Charge-Discharge Cycles[2]	4.25.14	X
Thermal Cycle[3,4]	4.25.15	X
Discharge and Pulse Capacity[4]	4.25.16	X
Cell Proof Pressure[4]	4.25.19.a	X
Internal Inspection[4]	4.25.17	X

[1]Two Ag-Zn cells from the production lot used for qualification testing shall undergo each test designated with an X each year of the specified service 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 Subsection 4.25.11 under ambient conditions before the cell undergoes this operating environment test and again while it 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.

4.25.1 General

Any Ag-Zn battery shall satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all of its performance requirements when subjected to each non-operating and operating environment.

4.25.2 Cell Capacity

a. Single Electrical Cycle. For a sample Ag-Zn 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 Subsection 4.25.10.

(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 Subsection 4.25.11 using the qualification electrical load profile described in (2) of item g in Subsection 4.25.11

(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 an Ag-Zn 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 Subsection 4.25.10.

(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 Subsection 4.25.11 using the qualification electrical load profile described in (2) of item g in Subsection 4.25.11.

(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.

4.25.3 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 materials 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. Measurement error at the required insulation resistance value shall not exceed 10%.
3. The insulation resistance between all insulated parts shall be 2 MΩ or more.
4. Testing shall be performed prior to connecting any battery harness to the cells.
5. This measurement should not be considered the equivalent of DWV tests.

4.25.4 Continuity and Isolation

The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all of its performance requirements.

1. Continuity resistance shall be 0.05 Ω or less and isolation resistance shall be 2 MΩ or more.

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.

4.25.5 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 vehicle.

4.25.6 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 a resolution that detects any leakage current of 0.1 mA or greater.

1. This measurement shall use a voltmeter with an internal resistance of 2 MΩ or more.
2. The test shall measure voltage across a circuit using a 150-kΩ resistor from pin to case.

4.25.7 Pre-Activation

A pre-activation test shall demonstrate that a cell or battery 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 cell or battery pressure relief device satisfies all of its performance requirements.

b. The test shall exercise all pressure relief devices that can function repeatedly without degradation.

c. The test shall demonstrate that each pressure relief device opens within ±10% of its performance specification.

4.25.8 Monitoring Capability

A monitoring capability test shall demonstrate that each device that monitors an Ag-Zn battery's voltage, current, or temperature satisfies all of its performance requirements.

4.25.9 Heater Circuit Verification

A heater circuit verification test shall demonstrate that any battery heater, including its control circuitry, satisfies all of its performance requirements.

4.25.10 Activation

The key points of the activation procedure are as follows.

a. The activation of a cell or battery 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) 1 of the 3 required qualification battery samples and 6 of the 12 required individual qualification cell samples shall undergo activation with no less than the manufacturer-specified maximum amount of electrolyte.

(2) 1 of the 3 required qualification battery samples and 6 of the 12 required individual qualification cell samples shall undergo activation with no greater than the manufacturer-specified minimum amount of electrolyte.

4.25.11 Electrical Performance

An electrical performance test shall demonstrate that a cell or battery satisfies all of its performance requirements and is in-family while the battery is subjected to the electrical load profile and other requirements described below.

a. The test shall demonstrate that the cell or battery 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 cell's or battery'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 shall be sampled at a minimum rate of 10,000 samples per second.

c. The test shall measure a cell's or battery's no-load voltage before and after the application of any load to the cell or battery.

d. An Ag-Zn cell or battery shall undergo this test after the cell or battery is activated and after the manufacturer-specified soak period.

e. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum acceptance voltage of each electronic component that the battery powers while the cell or battery is subjected to the steady-state portion of the load profile.

f. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the cell or battery 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 three minutes 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

ms, whichever is higher. 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.

(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 three minutes followed by a current pulse. The pulse width shall be no less than 3 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 ms, whichever is higher. 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.

4.25.12 Activated Stand Time

An activated stand time test shall demonstrate that an Ag-Zn cell or battery satisfies all of its performance requirements after it is activated and subjected to the environments that the cell or battery 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 pre-flight cell or battery conditioning environments, including the vehicle installation environment.

b. The test environment shall simulate the worst-case temperature exposure and any thermal cycle (such as due to any freezer storage and any diurnal cycling) on the vehicle.

c. The test shall measure the cell's or battery's OCV 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 cell or battery at the end of the activated stand time to demonstrate whether the cell or battery is in a peroxide or monoxide chemical state that satisfies its performance specifications before undergoing any other operating environment test.

4.25.13 Overcharge

An overcharge test only applies to a cell or battery that undergoes charging during normal operations. The test shall demonstrate that the cell or battery satisfies all of its performance requirements when subjected to an overcharge of no less than the manufacturer-specified overcharge limit using the nominal charging rate.

4.25.14 Charge-Discharge Cycles

This test only applies to a cell or battery that undergoes charging during normal operations. The test shall satisfy all of the following.

a. The test shall subject the cell or battery sample to the maximum predicted number of charge-discharge cycles that the cell or battery will experience during normal operations.

b. After activation, each cell or battery 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 item b through item e of Subsection 4.25.15.

d. For a battery, after the three thermal cycles for each charge-discharge cycle, it shall undergo a pin-to-case isolation test that satisfies Subsection 4.25.6.

e. Each cell or battery shall undergo a discharge of its nameplate capacity before each charge.

f. The cell or battery shall undergo any further operating environment tests only after the final charge.

4.25.15 Thermal Cycle

A thermal cycle test shall demonstrate that an Ag-Zn cell or battery satisfies all of its performance requirements when subjected to pre-flight thermal cycle environments and flight thermal cycle environments. This shall include all of the following.

a. The test shall subject the cell or battery to no less than 1.5 times MPE (rounded up) or eight thermal cycles, whichever is higher. The MPE shall account for all pre-flight processing, delays, recycling, and flight.

b. The thermal cycle environment shall satisfy all of the following.

   (1) Each thermal cycle shall range from 5.5°C above the maximum predicted temperature range to 5.5°C below. If the vehicle's TM system does not provide the battery's temperature before and during flight as described in item 9 in Subsection 3.8.2, 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 cell or battery to achieve internal thermal equilibrium and shall last no less than one hour.

   (3) When heating and cooling the cell or battery, the temperature rate of change shall average the maximum predicted rate or 1°C per minute, whichever is higher.

c. Each cell or battery shall undergo the electrical performance test of Subsection 4.25.11 when the cell or battery is at ambient temperature before beginning the first thermal cycle and after completing the last cycle.

d. Each cell or battery shall undergo the electrical performance test of Subsection 4.25.11 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 cell's or battery's OCV, during all thermal cycle dwell times and transitions with a resolution and sample rate that will detect any performance degradation.

4.25.16 Discharge and Pulse Capacity

A discharge and pulse capacity test shall demonstrate that an Ag-Zn cell or battery 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 cell or battery 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 cell's or battery's minimum performance specification.

c. After satisfying item a and item b above, the test shall measure the cell's or battery'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 three minutes followed by a current pulse.

   (2) The pulse width shall be no less than 3 times the ordnance initiator qualification pulse width or a minimum workmanship screening pulse width of 200 ms, whichever is higher.

   (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 cell's or battery'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 its performance parameters and the voltage of each cell within the battery. During the current pulse portion of the load profile, the voltage shall be sampled at a minimum rate of 10,000 samples per second.

e. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum acceptance voltage of each electronic component that the battery powers while the cell or battery is subjected to the steady-state portion of the load profile.

f. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum qualification voltage of each electronic component that the battery powers while the cell or battery is subjected to the pulse portion of the load profile.

g. After satisfying item a through item f above, the cell or battery shall undergo a complete discharge and the test shall demonstrate that the total silver plate capacity is in-family.

1. Each battery shall be discharged using a C/2 discharge rate to the cutoff voltage.
2. The cutoff voltage shall be the lowest specified voltage of the electronic components or the manufacturer cutoff voltage, whichever is higher. For example, receivers are tested to a minimum of 24 Vdc.
3. The battery and/or cell voltage and current shall be monitored.
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% of the capacity that is required for actual use.

4.25.17 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. The following internal inspection shall satisfy Subsection 4.11.7.

1. The battery shall undergo 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. The battery shall undergo an examination to verify the integrity of all cell and wiring interconnects
3. The battery shall undergo 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. Each cell shall be tested for leaks.
6. One cell from each corner and two cells from the middle of the qualification battery shall undergo destructive physical analysis (DPA), which 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 DPA.

c. The internal inspection test shall demonstrate that the zinc plate capacity of the cells satisfies the manufacturer specifications. 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.

4.25.18 Coupon Cell Acceptance

A coupon cell acceptance test shall demonstrate that the Ag-Zn cells that make up a flight battery were manufactured the same as the qualification battery cells. The Ag-Zn cells shall 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, and 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 Subsection 4.25.10.

e. The test cell shall undergo discharge at a moderate rate, using the manufacturer specification undergo two qualification load profiles from (2) of item g in Subsection 4.25.11 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 an Ag-Zn battery that will undergo charging during normal operations, the test cell shall undergo the requirements of item e above 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.

4.25.19 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 gas 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 gas leak rate satisfies its performance specification.

4.25.20 Electrolyte

A test of each electrolyte lot for battery activation shall demonstrate that the electrolyte satisfies the manufacturer specifications, including volume and concentration.

4.25.21 Battery Case and Mount Weld

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.

4.26 Nickel-Cadmium Batteries

The following tables describe four types of tests required for Ni-Cd batteries. Table 4-35 identifies cell LATs. Table 4-36 contains battery acceptance tests. Table 4-37 contains qualification tests. Table 4-38 lists SLE tests.

Table 4-35. Nickel-Cadmium Cell Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]
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	4.26.3	100%
Cell Screening[2,3]		
Cell Reusable Venting Devices	4.26.2.a	100%
Cell Conditioning	4.26.4	100%
Cell Characterization	4.26.5	100%
Charge Retention	4.26.6	100%
Performance At Low Temperature	4.26.7	100%
Cell leakage	4.26.19	100%
Cell Selection	4.26.20	
Final Cell Screening	4.26.20.a	100%
Final Cell Matching[4]	4.26.20.b	100%
X-ray[5]	4.11.6	Qualification cells
Non-Reusable Venting Devices[6]	4.26.2.b	Lot Sample
Post-Acceptance Storage[4]	4.26.8	100%

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 5 units and a maximum of 15 units.
[2]Unless otherwise annotated, if any cell fails any of these tests, the individual cell is disqualified for use.
[3]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, and individual cell sleeving. Screening of each lot of cells shall be completed prior to being assembled into batteries.
[4]After final cell matching, cells to be used for flight shall be assembled into batteries or stored as matched groups. Cells to be used for qualification shall be assembled into batteries using the cells that represent the widest variation in performance properties.
[5]X-ray inspection shall demonstrate tab integrity at 0° and 90° axes. These cells shall be used in the cell lot and/or battery qualification test units and shall be re-inspected by X-ray after testing.
[6]If any cell from the lot sample fails to pass these tests, the entire lot is disqualified for use.

Table 4-36. Nickel-Cadmium Battery Acceptance Test Requirements

Test[1]	Section	Quantity Tested[2]
Acceptance Tests - Cell Lot	Table 4-35	100% of Cells
Component Examination[3]	4.11	
Visual Examination[4]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[4]	4.11.5	100%

Performance Verification[3]	4.10.4	
Continuity and Isolation[4]	4.26.10	100%
Charge Retention[4]	4.26.6	100%
Monitoring Capability[4]	4.26.12	100%
Heater Circuit Verification[4]	4.26.13	100%
Non-Reusable Venting Devices (Battery Only)	4.26.2.b	Lot Sample
Environment Tests - Operating[3,5]	4.12.1	
Thermal Cycle	4.26.15	100%
Sinusoidal Vibration[6]	4.12.4	100%
Random Vibration[6]	4.12.5	100%
Acoustic Vibration[6]	4.12.6	100%
Performance Verification[7]	4.10.4	
Charge Retention	4.26.6	100%
Electrical Performance[4]	4.26.14	100%
Continuity, Isolation, and Insulation Resistance	4.26.10	100%
Component Examination[3]	4.11	
Visual Examination	4.11.2	100%
Reusable Venting Devices[7] (Battery Only)	4.26.2.a	100%
Battery Case Integrity[7]	4.26.11	100%
Post-Acceptance Storage	4.26.8	100%

[1]Each test that requires a battery to undergo a charge or discharge shall satisfy item b of Subsection 4.26.1. Unless otherwise specified, each test shall begin with the battery fully charged.

[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of three units and a maximum of nine units.

[3]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 four years from the date of cell manufacturing.
2. An SLE beyond four 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 one year after the initial service life has expired. Reacceptance testing may only be repeated two times on the same battery.
   b. All SLE testing shall be IAW Table 4-38.

[4]This test shall also be performed at the range just before installation.

[5]If any cell failure occurs during environmental acceptance testing, all cells within the battery shall be rejected. The battery case may be recycled and populated with all new cells to be used in a new acceptance test. Cells that fail prior to environmental testing may be replaced with a new cell from the same matched group.

[6]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 Subsection 4.26.14 shall be performed during the operating environment. The relevant parameters shall be sampled at a minimum rate of 10,000 samples per second and demonstrate that the voltage

does not experience any dropouts.
[7]This test is only required for a sealed battery.

Table 4-37. Nickel-Cadmium Cell Lot and Battery Qualification Test Requirements

Test[1,2]	Section	Quantity Tested	
		Cell Lot[1,3] X=3 Batteries	Battery[4] X=3 Batteries
Acceptance Tests - Cell Lot and Battery	Table 4-36	X	X
Environment Tests - Non-Operating	4.14.1		
Storage Temperature	4.14.2	X	X
Transportation Vibration	4.14.4	X	X
Transportation Shock	4.14.5	X	X
Bench Handling Shock	4.14.6	X	X
Fungus Resistance	4.14.9	1	1
Fine Sand	4.14.10	1	1
Performance Verification	4.10.4		
Charge Cycle Life and Pulse Margin	4.26.9	X	X
Environment Tests - Operating	4.15.1		
Thermal Cycle	4.26.16	X	X
Thermal Vacuum[5]	4.15.3	X	X
Humidity[6]	4.15.4	1	X
Salt Fog[7]	4.15.5	X	X
Temperature/Humidity/Altitude[8]	4.15.6	1	X
Acceleration[8,9]	4.15.7	X	X
Sinusoidal Vibration[8,9]	4.15.8	X	X
Random Vibration[8,9]	4.15.9	X	X
Acoustic Vibration[8,9]	4.15.10	X	X
Shock[9]	4.15.11	X	X
EMI/EMC	4.15.12	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	4.26.6	X	X
Operational Stand Time	4.26.17	X	X
Flight Self-Discharge	4.26.21	X	X
Battery Case Integrity[10]	4.26.11	X	X
Explosive Atmosphere	4.15.13	1	1
Internal Inspection[11]	4.26.18	1	1

[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]Each test that requires a battery to undergo a charge or discharge shall satisfy item b of Subsection 4.26.1. Unless otherwise specified, each test shall begin with the battery fully charged.
[3]Cell lot qualification testing may not be required if the parts, materials, processes, chemical sources, and manufacturing equipment for cell manufacturing are placed under configuration control. 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.
[4]Qualification testing is a one-time test as long as parts, materials, and processes are maintained on the battery.
[5]Electrical testing shall be performed IAW item e of Subsection 4.26.16.
[6]The Cycle 5 performance verification test shall be a capacity discharge test to determine charge retention IAW Subsection 4.26.4 followed by an electrical test IAW Subsection 4.26.14.
[7]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.
[8]Electrical performance testing shall be performed IAW Subsection 4.26.14.
[9]The battery shall undergo continuous monitoring of its voltage and current while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a minimum rate of 10,000 samples per second.
[10]This test is only required for a sealed battery.
[11]Cells not subject to DPA shall be X-rayed at 0° and 90° axes to verify tab and cell terminal integrity. Each cell's X-ray shall be compared with its cell lot acceptance X-ray.

Table 4-38. Nickel-Cadmium Cell Lot and Battery Service Life Extension Test Requirements

Test	Section	Quantity Tested X=1
Acceptance Tests[1,2]	Table 4-36	X
Charge Cycle Life and Pulse Margin[1]	4.26.9	X
Service Life Extension[3]		
Thermal Cycle	4.26.16	X
Sinusoidal Vibration[4,5]	4.15.8	X
Random Vibration[4,5]	4.15.9	X
Shock[4]	4.15.11	X
Continuity, Isolation, and Insulation Resistance	4.26.10	X
Electrical Performance	4.26.14	X
Charge Retention	4.26.6	X
Operational Stand Time	4.26.17	X
Flight Self-Discharge	4.26.21	X
Internal Inspection	4.26.18	X

[1]This test is not required for existing qualification test assets.
[2]Reacceptance testing is not required for SLE testing.

[3]The service life of a cell lot may be extended by re-qualifying one battery built from cell lot samples. Failure of service life testing disqualifies all of the cells from that lot.

1. Any SLE of the batteries is three years from the completion date of life extension testing.
2. Batteries used for SLE testing may be from newly assembled batteries or existing qualification test assets.

[4]The battery shall undergo continuous monitoring of its voltage and current while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a minimum rate of 10,000 samples per second.

[5]An electrical performance test shall be IAW Subsection 4.26.14.

4.26.1 General

a. Compliance. Any Ni-Cd battery shall satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all of its performance requirements when subjected to each non-operating and operating environment.

b. Charging and Discharging of Cells and Batteries. Each test required by any table of this section in which a cell or battery undergoes a charge or discharge shall include all of the following.

(1) The charge or discharge rate shall be low enough to prevent any damage to the cell or battery and allow the electrical characteristics to remain consistent. Unless otherwise specified, the cell or battery shall be charged and recharged during acceptance and qualification testing using the same procedure, equipment, and parameters as used during pre-flight. 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 V.
2. A discharge of a battery shall subject the battery to the discharge rate until the battery voltage is less than 1 V 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 cell or battery is in-family.
4. A battery shall not be discharged to the point of causing damage due to cell reversal.

(2) A charge of a cell or battery shall satisfy the manufacturer charging specifications and procedures. When a cell or battery is required to be fully charged, the battery capacity shall ensure that charging will meet the specification. A cell or battery shall not be overcharged such that it will damage any of the cells or create a hazardous condition.

1. The cell or battery shall be charged with no less than 160% of the manufacturer-specified capacity to account for energy lost during the charging process. The charge rate shall not exceed C/10 unless the range user demonstrates that the higher rate does not damage the cell or battery and results in repeatable performance.
2. To avoid creating a hydrogen gas explosion hazard:

a. the cell voltage shall not exceed 1.55 V during charging; and
b. the battery voltage shall not exceed 1.55 V times the number of cells in the battery during charging.

(3) The cell's or battery's critical electrical performance parameters shall be monitored with sufficient 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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second.
2. During vibration, voltage shall be monitored with a minimum resolution of 10 mV.

(4) The number of charge/discharge cycles shall be recorded.

4.26.2 Venting Devices

A test of a cell or battery venting device shall demonstrate that the cell or 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. 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 of its performance requirements.

NOTE	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 of its performance requirements.

The test shall demonstrate that each device sample vents within ±10% of the manufacturer-specified vent pressure.

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 and 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 one day and re-check for leaks. If leakage is indicated a second time, remove the cell from screening.
4. The electrolyte in Ni-Cd cells has a very low surface tension and easily wicks. Thus, one leaky cell can easily contaminate all cells in the 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. All Ni-Cd cells shall be stored and shipped in a partially charged state IAW manufacturer's specification.
2. If delivered cells have an OCV greater than 0.9 V, then they should be discharged at a rate that will not cause damage to the cells (usually less than C/20) to the manufacturer's specified EODV.
3. If any delivered cell has an OCV less than 0.3 V, then it should be discarded. This indicates a short circuit within the cell.

e. Determine the mass (or weight) of each cell to verify that it meets the manufacturer's specification.

The mass (weight) of each cell shall be within ±0.5% of the expected nominal.

f. Discharge the cells for storage and transportation to minimize performance degradation over time and personnel hazards due to accidental short circuit during handling.

Each cell shall be discharged to less than 1 V using a discharge rate that will not cause damage to the cell.

g. Serialize the cells 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.

4.26.4 Cell Conditioning

Conditioning shall be used to stabilize the cell chemistry 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. Newly manufactured Ni-Cd cells are not chemically stable. Electrical performance measurements of newly manufactured (fresh) cells are transient and initial results are difficult to repeat over time. Therefore, each cell shall age for no less than 11 months after the manufacturer lot date code before any testing is performed.
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. If individual cell monitoring is performed as part of pre-flight testing, concern for this requirement is mitigated by verifying that no cell has been driven into reversal.

b. Initial conditioning of Ni-Cd cells shall be performed to stabilize the chemistry of new cells and to promote repeatable electrical performance in batteries that have been in storage for an extended period of time. Any battery that has been stored for over one month after its first charge shall also undergo this conditioning.

The following 2-step charge and 2-step deep discharge procedure shall be used to provide cell initial conditioning. Note: This procedure helps to distribute the electrolyte throughout the cell and into the porous plates. Repeating the initial conditioning cycle may improve performance; however, most of the benefit is gained from the first cycle.

1. The cell shall be charged and discharged at room temperature (20°C).
2. Charging equipment used shall be voltage-limited to no greater than 1.55 V/cell. Note: A cell may not have inherent overcharge protection. If the negative electrode of a cell is overcharged, cadmium hydroxide will be converted to cadmium metal and H_2 gas. If the positive electrode is overcharged, O_2 gas will be produced. Recombination of H_2 and O_2 may result in a catastrophic explosion of the cell. The problem is aggravated at elevated temperatures. Limiting the voltage to no greater than 1.55 V/cell will prevent an overcharge.
3. The cell shall be charged at a rate no greater than C/20 for at least 2 hours. Note: When charging a new Ni-Cd cell, the surface chemistry of the fresh plates will initially provide high resistance to charging. If the initial applied current is too high, the cell will respond with a high voltage, greater than 1.55 V, due to high initial impedance. For this reason the initial charge current should be limited to C/20.
4. Cell charging shall be completed at a rate of C/20 for at least 30 hours or C/10 for at least 15 hours. Note: After the initial charge at C/20 (step c), cell chemistry is sufficiently stabilized to safely handle the higher charge rate of C/10. This decreases the time for completing this charge cycle.
5. A wait period of at least 1 hour shall be observed after charging with cell open circuit.
6. The cell shall be discharged at a rate of C/2 or slower until cell voltage reaches 1 V, after which the rate shall be C/10 or slower until cell voltage is between 0.2 V and 0.4 V.

4.26.5 Cell Characterization

Characterization testing shall further 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.

Each cell shall repeatedly undergo charge and discharge cycles until the capacities for three consecutive cycles agree within 1%. Note: In general, charge and discharge cycling must be repeated five to six times before consecutive cycles agree.

1. Cells shall be charged at a rate of C/10 for at least 15 hours.

2. Cells shall be discharged at a rate of C/2 or lower until the potential is between 0.9 V and 1 V.
3. Capacity stability may be achieved in fewer cycles if discharge is continued at a rate of C/10 down to a potential of 0.4 V after the C/2 discharge (Step 2).

NOTE	Repeatable capacity performance provides for 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 three cycles.
$C_{n\text{-}min}$ = Minimum capacity from the last three 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 ± 2°C or at manufacturer's data sheet values.

4.26.6 Charge Retention and Soft Short

The test shall demonstrate that a cell or battery consistently retains its charge within the manufacturer's specified limits and contains no high-impedance shorts. The controls and procedures, including minimum stand-time, shall allow for measurable and repeatable determination of charge retention. The cell manufacturer's data for self-discharge shall be used in developing the criteria for this test.

Charge retention testing shall be performed using the following process.

1. The test shall begin with the cell or battery fully charged.
2. Discharge the cell or battery to determine a baseline capacity.
3. Undergo complete charging and then storage at 20 ± 2°C for three days.
4. Undergo complete discharging to determine its remaining capacity.
5. Demonstrate the remaining capacity is greater than 90% of the baseline capacity determined in step b and that capacity retention is in-family.

4.26.7 Performance at Low Temperature

The test shall stress the cell's chemistry performance, overcharge protection, capacity variation over low temperatures, and pulse load repeatability when subjected to a low temperature. This also serves as a pressure integrity test of the cell.

1. The following process shall be used to validate the above requirements at 0 ± 2°C.
   a. Charge the cell at a rate of C/10 for at least 16 hours. Note: The applied charging voltage should be limited to less than 1.55 V for safety.
   b. Measure and record EOCV. If EOCV is greater than expected (typically 1.53 to 1.55 V) or out-of-family, then consider the cell for rejection.
   c. Wait at least 1 hour.
   d. Discharge the cell at a rate of C/2 until voltage is 0.9 V.
   e. Measure and record the capacity.
   f. Repeat until three consecutive cycles agree to within 1% of each other. Note: In general, charge and discharge cycling must be 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 the cell at a rate of C/10 for at least 16 hours. Note: The applied charging voltage should be limited to less than 1.55 V for safety.
   b. Measure and record EOCV. If EOCV is greater than expected (typically 1.53 V to 1.55 V) or out-of-family, then consider the cell for rejection.
   c. Wait at least 1 hour.
   d. Discharge the cell at a steady-state rate of C/2 until 50% of the manufacturer's specified capacity is removed.
   e. Without interruption (less than five seconds), apply a pulse load of 2C discharge rate for 100 ms.
   f. Measure and record voltage drop during the pulse load. Cells unable to maintain voltage consistent with a majority of cells within the lot shall be considered for rejection.
   g. Resume steady-state discharge until voltage is 0.9 V.
3. The following is summary of the major performance parameters tested in this section.
   a. Each cell shall undergo repeated charge and discharge cycles at 0 ± 2°C until all the capacities for three consecutive cycles agree to within 1% of each other.
   b. Performing charging at low temperature creates a high internal pressure to test the seals that will be checked in Paragraph 4.26.19.
   c. Charging at 0°C creates a stressing condition. By demonstrating an EOCV less than 1.55 V at 0°C and a benign cell response (i.e., it does not explode), the overcharge protection is validated.

WARNING: A defective cell may generate high pressures during this test. Precautions should be taken to protect personnel from leaking or exploding cells.

4.26.8 Post-Acceptance Storage

Post-acceptance storage of a cell or battery 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.
3. Storage of the cells shall not exceed the cell storage life specified by the cell manufacturer.

4.26.9 Charge Cycle Life and Pulse Margin

The battery shall demonstrate that it satisfies all its performance specifications for the number of pulses and operating charge and discharge cycles expected of the flight battery, including acceptance testing, pre-flight checkout, and flight plus a margin.

1. The minimum number of charge/discharge cycles shall be two times the worst-case expected number of cycles on the battery throughout its lifetime. Charge/discharge cycles performed 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 IAW Subsection 4.26.14.
   b. Capacity shall be measured.
3. Pulse testing shall be performed IAW items c and d of Subsection 4.26.14. The minimum number of high-current pulses applied during testing shall be two times the worst-case expected number of pulses. Note: Pulses performed during other tests may be credited to meet this requirement.

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 Ω 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 more when measured at a potential of 500 ± 25 Vdc.

4.26.11 Battery Case Integrity

A battery case integrity test shall demonstrate the following.

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 seal of a sealed battery satisfies all of its performance requirements.

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, pre-flight, or flight conditions, whichever is higher.
2. The pressure monitoring shall have a resolution and sample rate that allows accurate determination of the battery's gas leak rate.
3. The test shall demonstrate that the battery's gas leak rate is no greater than the equivalent

of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at SLC.

4. The battery shall undergo examination to identify any condition that indicates that it might lose structural integrity or create a hazardous condition.

4.26.12 Monitoring Capability

A monitoring capability test shall demonstrate that each device that monitors a battery's voltage, current, or temperature satisfies all of its performance requirements.

4.26.13 Heater Circuit Verification

The test must demonstrate that any battery heater, including its control circuitry, satisfies all of its performance requirements.

The battery shall be tested at a temperature that allows the heater circuit to cycle at least five times.

4.26.14 Electrical Performance

An electrical performance test of a cell or battery shall demonstrate that the item satisfies all of its performance requirements and is in-family while it is subjected to a flight electrical load profile plus a margin. The test shall verify that the cell or battery meets its performance requirements throughout the specified operational capacity.

a. The test shall measure and record a cell's or battery's no-load voltage to ensure it is within the manufacturer specification limits.

b. The test shall demonstrate that the cell or battery voltage meets the manufacturer specification limits while it 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 cell or battery supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specification.

d. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum acceptance voltage for each electronic component that it powers while it is subjected to the pulse portion of the load profile.

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 ms, whichever is higher. Note: Pulse width typically is the same between ATP and qualification test procedure (QTP), but providing a margin between ATP and QTP pulse width may be acceptable.
3. The minimum required voltage regulation is typically determined by the minimum operating voltage for a receiver or auto-destruct unit.
4. The voltage must be capable of delivering 1.5 times the all-fire current to the ordnance initiator(s) in an FTS firing circuit.
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 tested at different depths of discharge and/or worst-case capacity. This testing requires specific tailoring for each test.
8. The test shall subject the cell or battery to a final discharge that determines the remaining capacity.

4.26.15 Acceptance Thermal Cycle

An acceptance thermal cycle test shall demonstrate that a Ni-Cd 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 1.5 times the maximum number of thermal cycles that the component could experience during pre-flight processing and flight (including all flight delays and recycling) or eight thermal cycles, whichever is higher.

b. The acceptance thermal cycle high temperature shall be the higher of a 30°C workmanship screening temperature and the upper MPE temperature. The acceptance thermal cycle low temperature shall be the lower of a −24°C workmanship screening temperature and the lower MPE temperature.

If the acceptance thermal cycle temperature limits exceed the manufacturer specification, then the maximum and minimum manufacturer specification values shall be used; however, additional thermal cycles shall be added to account for thermal fatigue equivalence.

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 of its performance requirements. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least 1 sample per 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies Subsection 4.26.14 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, it may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following.

Dwell time shall be a minimum of one hour for the battery to reach temperature equilibrium.

(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.

(4) After the electrical performance test at an intermediate temperature, the thermal cycle shall transition to the workmanship temperature and dwell to achieve 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.

4.26.16 Qualification Thermal Cycle

A qualification thermal cycle test shall demonstrate that a battery satisfies all of its performance requirements when subjected to pre-flight, 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 the higher of a 40°C workmanship screening level and the upper MPE + 10°C. The qualification thermal cycle low temperature shall be the lower of a −34°C workmanship screening temperature and the lower MPE − 10°C.

If the qualification thermal cycle temperature limits exceed the manufacturer specification, then the maximum and minimum manufacturer specification values 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 of its performance requirements. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least 1 sample per 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies Subsection 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 high workmanship temperature or the low workmanship temperature, it 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 upper MPE + 10°C.

(2) The intermediate low temperature shall be no greater than the lower MPE − 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 one hour.

(4) After the 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 it is at ambient temperature before the first and after the last thermal cycles.

4.26.17 Operational Stand Time Capacity Used

An operational stand time capacity used test shall demonstrate that the battery will maintain its required capacity, including all required margins, from the final charge that it receives before flight. This test shall be used to verify C_{ST} and shall include the following.

a. The battery shall undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.

b. The battery shall undergo a charge to full capacity.

c. The battery shall be subjected to the maximum predicted pre-flight temperature for the maximum predicted operational stand time with the electrical loads (TM loads, connection loads, etc.) to which it will be exposed when installed on the vehicle prior to flight. The maximum predicted operational stand time shall account for all pre-flight processing and flight delay contingencies that could occur after the battery receives its final charge.

d. After the operational stand time has elapsed, the battery shall undergo a capacity discharge to determine if the remaining capacity will meet the flight requirement.

The following process will satisfy the general requirements for charging and discharging needed to determine the operational stand time capacity used. 1. Charge the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour. 2. Apply a single-qualification-level (amplitude and time) termination electrical load pulse. 3. Discharge the battery IAW item b of Subsection 4.26.1. 4. Determine the total capacity, C_T. 5. Charge the battery under nominal pre-flight operating conditions according to flight operations procedures. Wait one hour. 6. Expose the battery to the electrical loads to which it will be subjected when installed in the vehicle prior to flight (TM loads, connection loads, etc.). This test shall be conducted at the maximum expected temperature and for the maximum expected time allowed between final charging and flight. 7. Apply a single-qualification-level (amplitude and time) termination electrical load pulse. 8. Discharge the battery IAW item b of Subsection 4.26.1. 9. Measure and record the remaining capacity, C_R. 10. Determine operational stand time capacity used, $C_{ST} = C_T - C_R$

11. Factor C_{ST} into the battery budget.

4.26.18 Internal Inspection

An internal inspection of a battery must identify any excessive wear or damage to it, including any of its cells, after it is exposed to all the qualification test environments. The following internal inspection shall satisfy Subsection 4.11.7.

1. The battery shall undergo 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. The battery shall undergo an examination to verify the integrity of all cell and wiring interconnects.
3. The battery shall undergo 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. Each cell shall be tested for leaks.
6. One cell from each corner and one cell from the middle of the qualification battery shall undergo DPA, which 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.

4.26.19 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 Paragraph 4.26.7, the cell shall undergo a full charge (C/10 for 16 hours) and then be inspected with a chemical indicator. If the chemical indicator shows that the cell has a leak, it 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 IAW Paragraph 4.26.7 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.

4.26.20 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. The following is a graphical method for final cell matching.
   a. Plot the 0°C cell capacity versus 20°C cell capacity measurements for each cell onto one graph, where (x, y) = (0°C, 20°C).
   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), downselect the cells to be assembled in the battery by choosing those with the best load performance.
2. The qualification batteries shall be assembled with cells representing the widest variation in performance properties. This worst-case mix of cells used in the qualification batteries will define the cell matching strategy (requirement) for flight batteries made from current and future lots of cells. If cells from future lots will produce batteries that have a wider cell performance variation then the cells used during qualification, the outlying cells must be rejected during the cell selection/screening process or the new (more variable) lot of cells must be validated by a new battery qualification.
3. The rejection rate of cells and cause(s) for rejection shall be provided.

4.26.21 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} and shall include the following.

a. The battery shall undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.

b. The battery shall 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 shall undergo a capacity discharge to determine that the remaining capacity will meet the flight requirement.

The following process will satisfy the general requirements for charging and discharging needed to determine the flight self-discharge.

1. Charge the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour.
2. Discharge the battery IAW item b of Subsection 4.26.1.
3. Determine total capacity, C_T.
4. Charge the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour.
5. Expose the battery to the maximum predicted temperature allowed between launch and end of Range Safety responsibility.
6. Expose the battery to the maximum expected time allowed between launch and end of Range Safety responsibility.

7. Discharge the battery IAW item b of Subsection 4.26.1.
8. Measure and record the remaining capacity, C_{RF}.
9. Determine the amount of capacity loss due to self discharge, $C_{FS} = C_T - C_{RF}$.
10. Factor C_{FS} into the battery budget.

4.27 Lithium-Ion Batteries

The following tables contain test requirements for Li-ion batteries. Table 4-39 contains cell LATs. Table 4-40 lists battery acceptance tests. Table 4-41 shows qualification tests. Table 4-42 identifies age surveillance and SLE tests.

Table 4-39. Lithium-Ion Cell Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]
Component Examination[2]	4.11	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight	4.11.4	100%
Identification Check	4.11.5	100%
Cell Inspection and Preparation	4.27.3	100%
Cell Screening[3]		
Cell Characterization	4.27.5	100%
Charge Retention	4.27.4	100%
Performance at Low Temperature	4.27.6	100%
Cell Selection	4.27.7	
Final Cell Screening	4.27.7.a	100%
Final Cell Matching[4]	4.27.7.b	100%
X-ray5	4.11.6	Qualification cells
Non Reusable Venting Devices[6]	4.27.2	Lot Sample
Post-Acceptance Storage	4.27.8	100%
Post-Storage Cell Processing	4.27.22	100%

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 5 units and a maximum of 15 units.
[2]Unless otherwise annotated, if any cell fails any of these tests, the individual cell is disqualified for use.
[3]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, etc. Screening of each lot of cells shall be completed prior to being assembled into batteries.
[4]After final cell matching, cells to be used for flight shall be assembled into batteries or stored as matched groups. Cells to be used for qualification shall be assembled into batteries using the cells that represent the widest variation in performance properties.
[5]X-ray inspection shall demonstrate tab integrity at 0° and 90° axes. These cells shall be used in the qualification test units and shall be re-inspected after qualification testing by X-ray.
[6]If any cell from the lot sample fails to pass these tests, the entire lot is disqualified for use.

Table 4-40. Lithium-Ion Battery Acceptance Test Requirements

Test[1,2,3]	Section	Quantity Tested[4]
Acceptance Tests - Cell Lot[5]	Table 4-39	100%
Component Examination	4.11	
Visual Examination[6]	4.11.2	100%
Dimensional Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[6]	4.11.5	100%
Charge State	4.27.9	100%
Performance Verification	4.10.4	
Continuity and Isolation[6]	4.27.10	100%
Monitoring Capability[6]	4.27.12	100%
Heater Circuit Verification[6]	4.27.13	100%
Non-Reusable Venting Devices (Battery Only)	4.27.2b	Lot Sample
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.27.15	100%
Sinusoidal Vibration[7]	4.12.4	100%
Random Vibration[7]	4.12.5	100%
Acoustic Vibration[7]	4.12.6	100%
Performance Verification	4.10.4	
Charge Retention[6]	4.27.4	100%
Electrical Performance Test[6]	4.27.14	100%
Continuity, Isolation, and Insulation Resistance	4.27.10	100%
Post-Acceptance		
Visual Examination	4.11.2	100%
Reusable Venting Devices[8]	4.27.2	100%
Battery Case Integrity[8]	4.27.11	100%
Post-Acceptance Storage	4.27.8	100%

[1]Each test that requires a battery to undergo a charge or discharge shall satisfy item b of Subsection 4.27.1. Unless otherwise specified, each test shall begin with the battery fully charged.
[2]If any cell failure occurs during or after operating environment testing, the battery and all cells within it shall be rejected. The battery case may be recycled and populated with all new cells to be used in a new acceptance test. Cells that fail prior to operating environment testing may be replaced with new cells from the same matched group.
[3]The initial service life of the battery shall be established based on data that demonstrates the battery will survive the MPEs at the end of its initial service life.

The initial service life of the battery is three years from the date of cell manufacturing.

[4]A lot sample shall be 10% of the lot (rounded up) with a minimum of three units and a maximum of nine units.
[5]All cells used in each qualification or flight battery shall be from a production lot that has successfully passed the cell LATs. These tests do not need to be repeated for recertification service life testing.

[6]These tests shall also be performed at the launch site just before installation.
[7]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 Subsection 4.27.14 shall be performed during the operating environment. The relevant parameters shall be sampled at a minimum rate of 10,000 samples per second and shall demonstrate that the voltage does not experience any dropouts.
[8]This test is only required for a sealed battery.

Table 4-41. Lithium-Ion Cell Lot and Battery Qualification Test Requirements

Test[1,9,10]	Section	Cell Lot[1,2] X=3 Batteries	Battery[8] X=3 Batteries
Acceptance Tests - Cell Lot and Battery	Table 4-40	X	X
Environment Tests - Non-Operating	4.14.1		
Storage Temperature	4.14.2	X	X
Transportation Vibration	4.14.4	X	X
Transportation Shock	4.14.5	X	X
Bench Handling Shock	4.14.6	X	X
Fungus Resistance	4.14.9	1	1
Fine Sand	4.14.10	1	1
Performance Verification	4.10.4		
Heater Qualification	4.27.19	X	X
Charge Cycle Life and Pulse Margin	4.27.20	X	X
Environment Tests - Operating			
Thermal Cycle	4.27.16	X	X
Thermal Vacuum[3]	4.15.3	X	X
Humidity[5]	4.15.4	1	X
Salt Fog[11]	4.15.5	X	X
Temperature/Humidity/Altitude[6]	4.15.6	1	X
Acceleration[4]	4.15.7	X	X
Sinusoidal Vibration[4]	4.15.8	X	X
Random Vibration[4]	4.15.9	X	X
Acoustic Vibration[4]	4.15.10	X	X
Shock[4]	4.15.11	X	X
EMI/EMC	4.15.12	1	1
Performance Verification	4.10.4		
Continuity, Isolation, and Insulation Resistance	4.27.10	X	X
Electrical Performance	4.27.14	X	X
Charge Retention	4.27.4	X	X
Operational Stand Time	4.27.17	X	X
Flight Self-Discharge	4.27.18	X	X
Battery Case Integrity[7]	4.27.11	X	X

Explosive Atmosphere	4.15.13	1	1
Internal Inspection[12]	4.27.21	1	1

[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, processes, chemical sources, and manufacturing equipment for cell manufacturing are placed under configuration control. 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]Electrical testing shall be performed IAW item e of Subsection 4.27.16.
[4]The battery shall undergo continuous monitoring of its voltage and current while subjected to the expected steady-state flight load. Towards the end of testing, perform pulse testing IAW Subsection 4.27.14. Voltage and current shall be sampled at a minimum rate of 10,000 samples per second.
[5]The Cycle 5 performance verification test shall be a capacity discharge test to determine charge retention IAW Paragraph 4.27.4 followed by an electrical test IAW Subsection 4.27.14.
[6]Electrical performance testing shall be performed IAW Subsection 4.27.14.
[7]This test is only required for a sealed battery.
[8]Qualification testing is a one-time test as long as parts, materials, and processes are maintained and under configuration control for the battery design.
[9]The initial service life for batteries and cells is three years after qualification testing is complete.
[10]Each test that requires a battery to undergo a charge or discharge shall satisfy item b of Subsection 4.27.1. Unless otherwise specified, each test shall begin with the battery fully charged.
[11]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.
[12]Cells not subject to DPA shall be X-rayed at 0° and 90° axes to verify tab and cell terminal integrity. Each cell's X-ray shall be compared with its cell lot acceptance X-ray.

Table 4-42. Lithium-Ion Cell and Battery Age Surveillance and Service Life Extension Test Requirements

Test[1]	Section	Quantity X=1 Battery
Acceptance Tests - Battery[2,3]	Table 4-40	X
Charge Cycle Life and Pulse Margin[2]	4.27.20	X
Service Life Extension[4]		
Thermal Cycle	4.27.16	X
Sinusoidal Vibration[5,6]	4.15.8	X
Random Vibration[5,6]	4.15.9	X
Shock[5]	4.15.11	X
Continuity, Isolation, and Insulation Resistance	4.27.10	X
Electrical Performance	4.27.14	X

Charge Retention	4.27.4	X
Operational Stand Time	4.27.17	X
Flight Self-Discharge	4.27.18	X
Internal Inspection	4.27.21	X
Age Surveillance		
Cell Inspection and Preparation	4.27.3	4 Cells/Year
Non-Reusable Venting Devices	4.27.2b	4 Cells/Year

[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]Reacceptance testing is not required for SLE testing using this table.
[4]The 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.

An SLE can be performed using one of the following methods.

1. Acceptance testing may be re-performed to extend the service life for one year. Acceptance testing may only be re-performed two times on the same battery.
2. Any SLE testing IAW Table 4-42 will extend the service life for two years.

[5]The battery shall undergo continuous monitoring of its voltage and current while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a minimum rate of 10,000 samples per second.
[6]Towards the end of testing, perform pulse testing IAW Subsection 4.27.14.

4.27.1 General

This section applies to any battery that uses Li-ion cells and is part of an FTS.

a. Compliance. Any Li-ion battery must satisfy each test or analysis identified by any table of this section to demonstrate that the battery satisfies all of its performance requirements 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 an Li-ion cell or battery 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 cell or battery and shall provide for the cell's or battery'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 pre-launch. 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 V or the cell manufacturer's specified EODV.
2. A discharge of a battery shall subject the battery to the discharge rate until the battery voltage is less than 2.8 V per cell or the cell manufacturer's specified end-of-discharge cell 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, ensure safety, and demonstrate

that the cell or battery is in-family.

4. A charge of a cell or battery shall not cause any cell voltage to be greater than 4.4 V or the cell manufacturer's specified EOCV, whichever is less. The cell manufacturer's charging specifications (temperature and current) and procedures shall not be violated.

NOTE	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.

NOTE	The EOCV is chemistry-dependent. 4.4 V is an estimate for most $LiCoO_2$ cells. Do not exceed the 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 cell or battery shall satisfy the manufacturer charging specifications and procedures. When a cell or battery is required to be fully charged, the battery capacity shall ensure that charging will meet the specification. A cell or battery shall not be overcharged such that it will damage the cells or create a hazardous condition.

(4) During any test, the cell's or battery'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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second.
2. During vibration, voltage shall be monitored with a minimum resolution of 10 mV.

(5) The number of charge/discharge cycles shall be recorded.

4.27.2 Venting Devices

A test of a cell venting device shall demonstrate that the cell or battery will not experience within a year of launch 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 of its performance requirements.

The test shall demonstrate that each device sample vents within ±10% of the manufacturer nominal specified vent pressure.

NOTE	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 of its performance requirements.

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°C above the qualification temperature;
   c. no thermal runaway occurs.

4.27.3 Cell Inspection and Preparation

A cell removed from storage shall undergo inspection and preparation prior to undergoing any testing.

a. Record the lot date code and part number and verify cells were manufactured consecutively as part of a single lot.

For limited-productio n lot date codes, cell serial numbers shall be consecutive.

b. Demonstrate that the cell is clean and free of physical defects.

1. Inspect the cell for loose internal 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 (SOC). Record cell voltages.

NOTE	Delivery voltages are usually around 3.2 to 3.4 V. This data may be used as the baseline for supporting the charge retention test.

NOTE	For most cell designs, if delivered cells have an OCV less than 2.8 V they should be discarded. A low OCV indicates the delivered cell may not perform consistently.

d. Serialize the cells 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.

4.27.4 Charge Retention and Soft Short

The test shall demonstrate that a cell or battery consistently retains its charge within the manufacturer's specified limits and contains no high-impedance shorts. The controls and

procedures, including minimum stand-time, shall allow for measurable and repeatable determination of charge retention. The cell manufacturers' data for self-discharge shall be used in developing the criteria for this test.

1. Charge retention testing shall be performed using the following process.
   a. The test shall begin with the cell or battery fully charged.
   b. Discharge the cell or battery to determine a baseline capacity.
   c. Undergo complete charging and then storage at 20 ± 2°C for 60 days.
   d. Undergo complete discharging to determine its remaining capacity.
   e. Demonstrate the remaining capacity is greater than 90% of the baseline capacity determined in step b and that capacity retention is in-family.
2. Accelerated charge retention testing may be performed to shorten test time as follows.
   a. After cell or battery charging, the item shall stand for one week at 20 ± 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 the temperature to 20 ± 2°C for at least one hour.
   d. Measure OCV of each cell and discharge to determine the remaining capacity of each cell.
3. The test shall demonstrate the remaining capacity is greater than 95% 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.

4.27.5 Cell Characterization

Characterization testing shall verify repeatable capacity and stability of the cell's chemistry and shall determine the cell's capacity. A cell characterization shall satisfy the following.

a. Initial conditioning or charge cycling of an Li-ion cell shall follow the 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%.

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:

$$[\,3 * (C_{n\text{-}max} - C_{n\text{-}min})] / (C_n + C_{n-1} + C_{n-2})] < 0.01$$

Where:

C_n = Capacity of the last charge/discharge cycle.
C_{n-1} = Capacity of the charge/discharge cycle prior to last.
C_{n-2} = Capacity of the charge/discharge cycle 2nd from last.
$C_{n\text{-}max}$ = Maximum capacity from the last three cycles.
$C_{n\text{-}min}$ = Minimum capacity from the last three 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 ± 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

4.27.6 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.

1. Charge cells using the same procedure that will be used during pre-launch operations.
2. Discharge the cell at a steady-state rate no greater than recommended by the cell manufacturer until 50% 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 may be used to efficiently discriminate substandard cells.

3. Apply one operational pulse load for 100 ms. Measure and record the voltage during the pulse-load and post-pulse-load recovery.

NOTE	Any delay between the steady-state load and the operational pulse load shall be consistent from cell to cell testing.

4. Resume the steady-state discharge until voltage is 2.8 V or the manufacturer's specification.

4.27.7 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 used for matching shall be dependent on the cell/battery design and operational application. The priority for using charge retention, cell characterization, and cell performance tests 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 possible allowed for flight batteries. The qualification batteries shall be built with the worst-case mix of cells to validate the cell matching strategy.

4.27.8 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 six months or more.

b. Storage shall be in an open-circuit configuration.

c. The cumulative storage time shall not exceed the manufacture's recommendations. It is recommended that time at ambient temperature be logged for aging engineering data.

d. Cells and batteries shall be protected and safely stored with the appropriate SOC 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 the storage container to avoid condensation and thermal shock.

g. A maintenance plan for batteries and cells in storage shall be provided to Range Safety for approval.

4.27.9 Charge State

The battery shall be tested to demonstrate that the OCV of each cell is within specification.

4.27.10 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 Ω 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 more when measured at a potential of 500 ± 25 Vdc.

4.27.11 Battery Case Integrity

A battery case integrity test of a sealed Li-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 gas leak rate satisfies all of its performance requirements.

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, pre-flight, or flight conditions, whichever is higher.
2. The pressure monitoring shall have a resolution and sample rate that allows accurate determination of the battery's gas leak rate.
3. The test shall demonstrate that the battery's gas leak rate is no greater than the equivalent of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at SLC.
4. The battery shall undergo examination to identify any condition that indicates that the battery might lose structural integrity or create a hazardous condition.

4.27.12 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.

4.27.13 Heater Circuit Verification

The test must demonstrate that any battery heater, including its control circuitry, satisfies all of its performance requirements.

The battery shall be tested at a temperature that allows the heater circuit to cycle at least five times.

4.27.14 Electrical Performance Test

An electrical performance test of a battery must demonstrate that it satisfies all battery performance specifications and is in-family while it 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 cell or battery voltage meets the manufacturer specification limits while the item 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 cell or battery supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specification.

d. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum acceptance voltage for each electronic component that it powers while it is subjected to the pulse portion of the load profile. The test shall be conducted at its lowest operational SOC.

The test load profile shall satisfy all of the following at each required discharge level.

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 ms, whichever is higher.

NOTE	Pulse width typically is the same between ATP and QTP, but providing a margin between ATP and QTP pulse width may be acceptable.

3. The minimum required voltage regulation is typically determined by the minimum operating voltage for a receiver or auto-destruct unit.
4. The voltage must be capable of delivering 1.5 times the all-fire current to the ordnance initiator(s) in an FTS firing circuit.
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 testing shall be performed starting at a fully charged state and every 10% SOC until all of its operational capacity (C_O) has been consumed.

4.27.15 Acceptance Thermal Cycle

An acceptance thermal cycle test shall demonstrate that an Li-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 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) or eight thermal cycles, whichever is higher.

b. The acceptance thermal cycle high temperature shall be the higher of a 30°C workmanship screening temperature and the upper MPE temperature. The acceptance thermal cycle low temperature shall be the lower of a −14°C workmanship screening temperature and the lower MPE temperature.

If the acceptance thermal cycle temperature limits exceed the manufacturer specification, then the maximum and minimum manufacturer specification values shall be used; however, additional thermal cycles shall be added to account for thermal fatigue equivalence.

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 of its performance requirements. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least 1 sample per 10 seconds.

e. The battery must undergo an electrical performance test while it is at the high and low temperatures during the first and last thermal cycles. The battery shall be charged at ambient temperature as required prior to conducting each electrical performance test IAW Subsection 4.27.14. If the battery is not capable of passing the electrical performance test at either the workmanship screening high or low temperatures, it may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following.

Dwell time shall be a minimum of one hour for the battery to reach temperature equilibrium.

(1) The intermediate high temperature shall be no less than the upper MPE.

(2) The intermediate low temperature shall be no greater than the lower MPE.

(3) The dwell time at the intermediate temperatures shall be long enough for the battery to reach thermal equilibrium.

(4) After the 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 shall undergo an electrical performance test while it is at ambient temperature before the first and after the last thermal cycles.

4.27.16 Qualification Thermal Cycle

A qualification thermal cycle test shall demonstrate that a battery satisfies all of its performance requirements when subjected to pre-flight, 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 the higher of a workmanship screening level and the upper MPE + 10°C. The qualification thermal cycle low temperature shall be the lower of a workmanship screening level and the lower MPE − 10°C. The minimum and maximum workmanship test levels shall not damage the battery.

If the qualification thermal cycle temperature limits exceed the manufacturer specification, then the maximum and minimum manufacturer specification values 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 it satisfies all of its performance requirements. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least 1 sample per 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies Subsection 4.27.14 while it 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, it may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following.

Dwell time shall be a minimum of one hour for the battery to reach temperature equilibrium.

(1) The intermediate high temperature shall be no less than the upper MPE + 10°C.

(2) The intermediate low temperature shall be no greater than the lower MPE − 10°C.

(3) The dwell time at the intermediate temperatures shall be long enough for the battery to reach internal thermal equilibrium.

(4) After the 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 it is at ambient temperature before the first and after the last thermal cycles.

4.27.17 Operational Stand Time Capacity Used

An operational stand time capacity used 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 used to verify C_{ST} and shall include the following.

a. The battery shall undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.

b. The battery shall undergo a charge to full capacity.

c. The battery shall be subjected to the maximum predicted pre-flight temperature for the maximum predicted operational stand time with the electrical loads (TM loads, connection loads, etc.) that it will be exposed to when installed on the vehicle prior to flight. The maximum predicted operational stand time shall account for all pre-flight processing and flight delay contingencies that could occur after the battery receives its final charge.

d. After the operational stand time has elapsed, the battery shall undergo a capacity discharge to determine if the remaining capacity will meet the flight requirement.

The following process will satisfy the general requirements for charging and discharging needed to determine the operational stand time capacity used.

1. Charge the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour.
2. Apply a single-qualification-level (amplitude and time) termination electrical load pulse.
3. Discharge the battery IAW item b of Subsection 4.27.1.
4. Determine the total capacity, C_T.
5. Charge the battery under nominal pre-flight operating conditions according to flight operations procedures. Wait one hour.
6. Expose the battery to the electrical loads that it will be subjected to when installed in the vehicle prior to flight (TM loads, connection loads, etc.). This test shall be conducted at the maximum expected temperature and for the maximum expected time allowed between final charging and flight.
7. Apply a single-qualification-level (amplitude and time) termination electrical load pulse.
8. Discharge the battery IAW item b of Subsection 4.27.1.
9. Measure and record the remaining capacity, C_R.
10. Determine operational stand time capacity used, $C_{ST} = C_T - C_R$
11. Factor C_{ST} into the battery budget.

4.27.18 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} and 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.

4.27.19 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 pre-launch and launch operations as well as accounting for potential launch schedule holds and launch attempts.

1. The battery shall be exposed to two times 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 higher.

4.27.20 Charge Cycle Life and Pulse Margin

The battery shall demonstrate that it satisfies all its performance specifications for the number of pulses and operating charge and discharge cycles expected of the flight battery, including acceptance testing, pre-flight 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 two times the worst-case expected number of cycles on the battery throughout its lifetime. Charge/discharge cycles performed 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 IAW Subsection 4.27.14.
   b. Capacity shall be measured.
3. Pulse testing shall be performed IAW items c and d of Subsection 4.27.14. The minimum number of high-current pulses applied during testing shall be two times the worst-case expected number of pulses. Note: Pulses performed during other tests may be credited to meet this requirement.

4.27.21 Internal Inspection

An internal inspection of a battery must identify any excessive wear or damage to it, including any of its cells, after it is exposed to all the qualification test environments. The following internal inspection shall satisfy Subsection 4.11.7.

1. The battery shall undergo 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. The battery shall undergo an examination to verify the integrity of all cell and wiring interconnects.
3. The battery shall undergo 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. Each cell shall be tested for leaks.
6. One cell from each corner and one cell from the middle of the qualification battery shall undergo DPA, which must verify the integrity of: all connections between all plate tabs and cell terminals; and the integrity of each plate and separator. The 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 Post-Storage Cell Processing

Just prior to assembling stored cells into a battery, the cells shall be tested to ensure capacity and other characteristics have not changed during storage.

NOTE	Revalidation of critical cell matching parameter(s) will satisfy this requirement. All performance parameters may not be required to be re-tested.

4.28 Lead-Acid Batteries

The following tables identify tests for lead-acid batteries. Table 4-43 contains LATs. Table 4-44 lists battery acceptance tests. Table 4-45 displays qualification tests. Table 4-46 describes SLE tests.

Table 4-43. Lead-Acid Cell Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]
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	4.28.3	100%
Cell Screening[2,3]		
Initial Cell Voltage	4.28.4	100%
Cell Reusable Venting Devices	4.28.2.a	100%
Cell Characterization	4.28.5	100%
Performance At Low Temperature	4.28.6	100%
Cell leakage	4.28.8	100%
Cell Selection	4.28.9	
Final Cell Screening	4.28.9.a	100%
Final Cell Matching[4]	4.28.9.b	100%
X-ray[5]	4.11.6	Qualification cells
Non-Reusable Venting Devices - Cell[6]	4.28.2.b	Lot Sample
Post-Acceptance Storage[4]	4.28.10	100%

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 5 units and a maximum of 15 units.
[2]Unless otherwise annotated, if any cell fails any of these tests, the individual cell is disqualified for use.
[3]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, and individual cell sleeving. Screening of each lot of cells shall be completed prior to being assembled into batteries.
[4]After final cell matching, cells to be used for flight shall be assembled into batteries or stored as matched groups. Cells to be used for qualification shall be assembled into batteries using the cells that represent the widest variation in performance properties.

[5]X-ray inspection shall demonstrate tab integrity at 0° and 90° 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.
[6]If any cell from the lot sample fails to pass these tests, the entire lot is disqualified for use.

Table 4-44. Lead-Acid Battery Acceptance Test Requirements

Test[1]	Section	Quantity Tested[2]
Acceptance Tests - Cell Lot	Table 4-43	100% of Cells
Component Examination[3]	4.11	
Visual Examination[4]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Weight Measurement	4.11.4	100%
Identification Check[4]	4.11.5	100%
Performance Verification	4.10.4	
Continuity, Isolation, and Insulation Resistance[4]	4.28.11	100%
Charge Retention[4]	4.28.16	100%
Monitoring Capability[4]	4.28.12	100%
Heater Circuit Verification[4]	4.28.13	100%
Non-Reusable Venting Devices – Battery	4.28.2.b	Lot Sample
Environment Tests – Operating[3,5]	4.12.1	
Thermal Cycle	4.28.15	100%
Sinusoidal Vibration[6]	4.12.4	100%
Random Vibration[6]	4.12.5	100%
Acoustic Vibration[6]	4.12.6	100%
Performance Verification[3]	4.10.4	
Charge Retention - Battery	4.28.16	100%
Electrical Performance[4]	4.28.14	100%
Continuity, Isolation, and Insulation Resistance[4]	4.28.11	100%
Component Examination[3]	4.11	
Visual Examination	4.11.2	100%
Reusable Venting Devices – Battery	4.28.2.a	100%
Battery Case Integrity[7]	4.28.23	100%
Post-Acceptance Storage[3]	4.28.17	100%

[1]Each test that requires a battery to undergo a charge or discharge shall satisfy Subsection 4.28.3. Unless otherwise specified, each test shall begin with the battery fully charged.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of three units and a maximum of nine units.
[3]The initial service life of the battery shall be established based on data that demonstrates the battery will survive the MPEs at the end of its initial service life.

The initial service life of the battery is four years from the date of cell manufacturing.

[4]These tests shall also be performed at the launch site just before installation.
[5]If any cell failure occurs during environmental acceptance testing, all cells within the battery shall be rejected. The battery case may be recycled and populated with all new cells to be used in

a new acceptance test. Cells that fail prior to environmental testing may be replaced with a new cell from the same matched group.
[6]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 Subsection 4.28.14 shall be performed during the operating environment. The relevant parameters shall be sampled at a minimum rate of 10,000 samples per second and demonstrate that the voltage does not experience any dropouts.
[7]This test is only required for a sealed battery.

Table 4-45. Lead-Acid Cell Lot and Battery Qualification Test Requirements

Test[1,9]	Section	Quantity Tested	
		Cell Lot[1,2] X=3 Batteries	Battery[8] X=3 Batteries
Acceptance Tests - Battery	Table 4-44	X	X
Environment Tests - Non-Operating	4.14.1		
Storage Temperature	4.14.2	X	X
Transportation Vibration	4.14.4	X	X
Transportation Shock	4.14.5	X	X
Bench Handling Shock	4.14.6	X	X
Fungus Resistance	4.14.9	1	1
Fine Sand	4.14.10	1	1
Performance Verification	4.10.4		
Charge Cycle Life and Pulse Margin	4.28.18	X	X
Environment Tests - Operating	4.15.1		
Thermal Cycle	4.28.19	X	X
Thermal Vacuum[3]	4.15.3	X	X
Humidity[5]	4.15.4	1	X
Salt Fog[10]	4.15.5	X	X
Temperature/Humidity/Altitude[6]	4.15.6	1	X
Acceleration[4,6]	4.15.7	X	X
Sinusoidal Vibration[4,6]	4.15.8	X	X
Random Vibration[4,6]	4.15.9	X	X
Acoustic Vibration[4,6]	4.15.10	X	X
Shock[4]	4.15.11	X	X
EMI/EMC	4.15.12	1	1
Performance Verification	4.10.4		
Continuity, Isolation, and Insulation Resistance	4.28.11	X	X
Electrical Performance	4.28.14	X	X
Charge Retention	4.28.16	X	X
Operational Stand Time	4.28.20	X	X
Flight Self-Discharge	4.28.22	X	X
Battery Case Integrity[7]	4.25.11	X	X

Explosive Atmosphere	4.25.13	1	1
Internal Inspection[11]	4.28.21	1	1

[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, processes, chemical sources, and manufacturing equipment for cell manufacturing are placed under configuration control. 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]Electrical testing shall be performed IAW item e of Subsection 4.28.19.
[4]The battery shall undergo continuous monitoring of its voltage and current while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a minimum rate of 10,000 samples per second.
[5]The Cycle 5 performance verification test shall be a capacity discharge test to determine charge retention IAW Paragraph 4.28.16 followed by an electrical test IAW Subsection 4.28.14 at ambient temperature.
[6]Electrical performance testing shall be performed IAW Subsection 4.28.14.
[7]This test is only required for a sealed battery.
[8]Qualification testing is a one-time test as long as parts, materials, and processes are maintained on the battery.
[9]Each test that requires a battery to undergo a charge or discharge shall satisfy Subsection 4.28.3. Unless otherwise specified, each test shall begin with the battery fully charged.
[10]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.
[11]Cells not subject to DPA shall be X-rayed at 0° and 90° axes to verify tab and cell terminal integrity. Each cell's X-ray shall be compared with its cell lot acceptance X-ray.

Table 4-46. Lead-Acid Cell and Battery Service Life Extension Test Requirements

Test	Section	Quantity X=1
Acceptance Tests[1,2]	Table 4-44	X
Charge Cycle Life and Pulse Margin[1]	4.28.18	X
Service Life Extension[3]		
Thermal Cycle	4.28.19	X
Sinusoidal Vibration[4,5]	4.15.8	X
Random Vibration[4,5]	4.15.9	X
Shock[4]	4.15.11	X
Continuity, Isolation, and Insulation Resistance	4.28.11	X
Electrical Performance	4.28.14	X
Charge Retention	4.28.16	X

Operational Stand Time	4.28.20	X
Flight Self-Discharge	4.28.22	X
Internal Inspection	4.28.21	X

[1]Not required for existing qualification test assets.
[2]Reacceptance testing is not required for SLE testing.
[3]Service life of the cell lot may be extended by re-qualifying one battery built from a lot sample. Failure of service life testing disqualifies all cells from that cell lot.

1. An SLE can be performed using one of the following methods.
   a. Acceptance testing may be re-performed to extend the service life of a flight battery for one year. Acceptance testing may only be re-performed two times on the same battery.
   b. Any SLE testing IAW Table 4-46 will extend the service life for three years.
2. An SLE of the batteries is from the completion date of life extension testing.
3. Batteries used for SLE testing may be from newly assembled batteries or from existing qualification test assets. For newly assembled batteries, acceptance testing shall be performed prior to SLE testing.

[4]The battery shall undergo continuous monitoring of its voltage and current while subjected to the expected steady-state flight load. Voltage and current shall be sampled at a minimum rate of 10,000 samples per second.
[5]Towards the end of testing, perform pulse testing IAW Subsection 4.28.14.

4.28.1 General

This section applies to any battery that uses lead-acid cells and is part of an FTS.

a. Compliance. Any lead-acid battery must satisfy each test or analysis identified by any table of this section to demonstrate the battery satisfies all of its performance requirements 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 cell or battery to undergo a charge or discharge shall include all of the following.

   (1) A charge of a cell or battery 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 to the cell or battery and provide for the item'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 pre-launch. 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 cell or battery shall be no less than 105% 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 between 2.4 V and 2.5 V 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 of 2.27 V - 2.35 V per cell at 25°C or 2.28 V - 2.36 V per cell at 22°C.
   e. Float charge can be discontinued when 100% 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 over-charging.
   c. Apply CC until peak voltage (about 2.83 V per cell at 25°C) is detected. Discontinue CC charging.
4. The battery shall be discharged until the voltage reaches its manufacturer's specified EODV, which may vary by discharge rate.

(5) The cell's or battery'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 relevant parameters shall be sampled at a minimum rate of 10,000 samples per second.
2. Voltage monitoring during vibration must have a minimum resolution of 10 mV.

(6) The number of charge/discharge cycles shall be recorded.

4.28.2 Venting Devices

A test of a cell or battery venting device shall demonstrate that the cell or 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. 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 of its performance requirements.

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% 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 of its performance requirements.

1. The test shall demonstrate that each device sample vents within ±10% of the manufacturer-specified vent pressure.
2. This test is not applicable for unsealed battery cases.

4.28.3 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 the 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 4.28.8.

e. Demonstrate that the mass (weight) of each cell meets the manufacturer's specification.

The mass (weight) of each cell shall be within ±2% of the expected nominal.

4.28.4 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 IAW manufacturer's specification. This specification is normally more than 2.1 V.
2. If delivered cells have an OCV greater than 2.6 V, 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 V.
3. If any delivered cell has an OCV less than 2.08 V, then it should be discarded. This indicates a short circuit within the cell.
4. Record each cell voltage for use in the cell matching procedure. Note: The OCV upon delivery may be useful for cell matching criteria.

4.28.5 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%. The following process shall be used to validate the above requirement at ambient temperature.
   a. Charge IAW item b of Subsection 4.28.1.
   b. Monitor and record cell voltage during charge. If the end-of-charge OCV does not meet the specification or is out-of-family, then the cell should be considered for rejection.
   c. Wait one hour prior to discharge.
   d. Discharge the cell at C/5 until the EODV is reached.
   e. Measure and record the cell capacity at the end of discharge.
   f. Repeat steps a through e until three consecutive cycles agree to within 1% of each other.
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:

$$[3 * (C_{n\text{-}max} - C_{n\text{-}min})] / (C_n + C_{n-1} + C_{n-2}) < 0.01$$

Where:

C_n = Capacity of the last charge/discharge cycle.
C_{n-1} = Capacity of the charge/discharge cycle prior to last.
C_{n-2} = Capacity of the charge/discharge cycle 2nd from last.
$C_{n\text{-}max}$ = Maximum capacity from the last three cycles.
$C_{n\text{-}min}$ = Minimum capacity from the last three cycles.

b. During cell characterization, each cell must remain at a constant ambient temperature to ensure that it is not overstressed and to allow repeatable performance.

Cell characterization tests shall be performed at 20 ± 2°C or at the manufacturer's specification.

4.28.6 Performance at Low Temperature

The test shall stress the cell's chemistry performance, overcharge protection, capacity variation at 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%. The following process shall be used to validate the above requirement at 0 ± 2°C.
   a. Charge the cell IAW item b of Subsection 4.28.1.
   b. Monitor and record cell voltage during charge. If the end-of-charge OCV does not meet the specification or is out-of-family, then the cell should be considered for rejection.
   c. Thermally condition the cell at 0 ± 2°C for at least one hour prior to discharge.
   d. Discharge the cell at a rate of C/5 until the EODV is reached.
   e. Measure and record the capacity at the end of discharge.

f. Repeat steps a through e until three consecutive cycles agree to within 1% of each other. In general, charge and discharge cycling must be repeated 6 to 10 times before consecutive cycles agree.

2. Cells unable to demonstrate repeatable capacity in comparison with 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 it is not overstressed and to allow repeatable performance.

4.28.7 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 for potentially bad cells prior to being assembled into the battery.
   a. Charge the cell at a rate of C/5 at ambient temperature for at least 6.25 hours or until voltage peaks.
   b. Measure and record EOCV. If EOCV is greater than expected or out-of-family, then consider the cell for rejection.
   c. Thermally condition the cell at 0 ± 2°C for at least one hour prior to discharge.
   d. Discharge the cell at a rate of C/2 until 50% of the manufacturer's specified capacity is removed.
   e. Without interruption (less than 5 seconds), apply a pulse load of 2C discharge rate for 200 ms.
   f. Measure and record voltage drop during pulse load.
   g. Resume steady-state discharge until EODV.
2. Cells unable to maintain voltage regulation consistent with a majority of the cells in 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 it is not overstressed and to allow repeatable performance.

4.28.8 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.

4.28.9 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 used 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. This worst-case mix of cells used in the qualification batteries will define the cell-matching strategy (requirement) for flight batteries made from current and future lots of cells. If cells from future lots will produce batteries that have a wider cell performance variation than the cells used during qualification, the outlying cells must be rejected during the cell selection/screening process or the new (more variable) lot of cells must be validated by a new battery qualification.

4.28.10 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 six 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 aging engineering data.
4. Cells and batteries shall be protected and safely stored with the appropriate SOC 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 the 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.

4.28.11 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 Ω 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 more when measured at a potential of 500 ± 25 Vdc.

4.28.12 Monitoring Capability

A monitoring capability test must demonstrate that each device that monitors a battery's voltage, current, or temperature satisfies all of its performance requirements.

4.28.13 Heater Circuit Verification

The test must demonstrate that any battery heater, including its control circuitry, satisfies all of its performance requirements.

The battery shall be tested at a temperature that allows the heater circuit to cycle at least five times.

4.28.14 Electrical Performance Test

An electrical performance test of a cell or battery shall demonstrate that the item satisfies all of its performance requirements and is in-family while it is subjected to flight electrical load profile plus a margin. The test shall verify that the cell or battery meets its performance requirements throughout the specified operational capacity.

a. The test shall measure and record a cell's or battery's no-load voltage to ensure it is within the manufacturer specification limits.

b. The test shall demonstrate that the cell or battery voltage meets the manufacturer specification limits while it 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 cell or battery supplies the required current while maintaining the required voltage regulation that satisfies the manufacturer specification.

d. The test shall demonstrate that the cell or battery voltage does not fall below the voltage needed to provide the minimum acceptance voltage for each electronic component that it powers while it is subjected to the pulse portion of the load profile. The test shall be conducted at its lowest operational SOC.

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 ms, whichever is higher.

NOTE	Pulse width typically is the same between ATP and QTP, but providing a margin between ATP and QTP pulse width may be acceptable.

3. The minimum required voltage regulation is typically determined by the minimum operating voltage for a receiver or auto-destruct unit.
4. The voltage must be capable of delivering 1.5 times the all-fire current to the ordnance initiator(s) in an FTS firing circuit.
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 tested at different depths of discharge, including its lowest SOC at the end of its operational capacity.
8. The test shall subject the cell or battery to a final discharge that determines the remaining capacity.

4.28.15 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 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, or eight thermal cycles, whichever is higher

b. The acceptance thermal cycle high temperature shall be the upper MPE or a 61°C workmanship screening level, whichever is higher. The acceptance thermal cycle low temperature shall be the lower MPE or a 0°C workmanship screening level, whichever is lower.

If the acceptance thermal cycle temperature limits exceed the manufacturer specification, then the maximum and minimum manufacturer specification values shall be used; however, additional thermal cycles shall be added to account for thermal fatigue equivalence.

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 of its performance requirements. The battery shall undergo monitoring of its OCV throughout the test.

The sample rate shall be at least 1 sample per 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies Subsection 4.28.14 while it 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, it may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following.

Dwell time shall be a minimum of one hour for the battery to reach temperature equilibrium.

(1) The intermediate high temperature shall be no less than the upper MPE.

(2) The intermediate low temperature shall be no greater than the lower MPE.

(3) The dwell time at the intermediate temperature shall be long enough for the battery to reach internal thermal equilibrium.

(4) After the 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 it is at ambient temperature before the first and after the last thermal cycles.

4.28.16 Charge Retention and Soft Short

The test shall demonstrate that a cell or battery consistently retains its charge within the manufacturer's specified limits and contains no high-impedance shorts. The controls and procedures, including minimum stand-time, shall allow for measurable and repeatable determination of charge retention. The cell manufacturer's data for self-discharge shall be used in developing the criteria for this test.

Charge retention testing shall be performed using the following process. 1. The test shall begin with the cell or battery fully charged. 2. Discharge the cell or battery to determine a baseline capacity. 3. Undergo complete charging and then storage at 45 ± 2°C for seven days. 4. Undergo complete discharging to determine its remaining capacity. 5. Demonstrate the remaining capacity is greater than 90% of the baseline capacity determined in step b and that capacity retention is in-family.

4.28.17 Post-Acceptance Storage

Post-acceptance storage of a cell or battery 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 and 5°C in a humidity-controlled environment. 3. Storage of the cells shall not exceed the cell storage life specified by the cell manufacturer.

4.28.18 Charge Cycle Life and Pulse Margin

The battery shall demonstrate that it satisfies all its performance specifications for the number of pulses and operating charge and discharge cycles expected of the flight battery, including acceptance testing, pre-flight checkout, and flight plus a margin.

1. The minimum number of charge/discharge cycles shall be two times the worst-case expected number of cycles on the battery throughout its lifetime. Charge/discharge cycles performed 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 shall be tested IAW Subsection 4.28.14.
   b. Capacity shall be measured.
3. Pulse testing shall be performed IAW items c and d of Subsection 4.28.14. The minimum number of high-current pulses applied during testing shall be two times the worst-case expected number of pulses. Note: Pulses performed during other tests may be credited to meet this requirement.

4.28.19 Qualification Thermal Cycle

A qualification thermal cycle test shall demonstrate that a battery satisfies all of its performance requirements when subjected to pre-flight, 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 the upper acceptance test level + 10°C. The qualification thermal cycle low temperature shall be the lower acceptance test level − 10°C

If the qualification thermal cycle temperature limits exceed the manufacturer specification, then the maximum and minimum manufacturer specification values 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 of its performance requirements. The battery OCV shall be monitored throughout the test.

The sample rate shall be at least 1 sample per 10 seconds.

e. The battery shall undergo an electrical performance test that satisfies Subsection 4.28.14 while it 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, it may undergo the electrical performance test at an intermediate temperature during the cycle. This shall include all of the following.

Dwell time shall be a minimum of one hour for the battery to reach temperature equilibrium.

(1) The intermediate high temperature shall be no less than the upper MPE + 10°C.

(2) The intermediate low temperature shall be no greater than the lower MPE − 10°C.

(3) The dwell time at the intermediate temperature shall be long enough for the battery to reach internal thermal equilibrium.

(4) After the 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 it is at ambient temperature before the first and after the last thermal cycles.

4.28.20 Operational Stand Time Capacity Used

An operational stand time capacity used 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 used to verify C_{ST} and shall include the following.

a. The battery shall undergo a charge to full capacity and then an immediate capacity discharge to establish a baseline capacity.

b. The battery shall undergo a charge to full capacity.

c. The battery shall be subjected to the maximum predicted pre-flight temperature for the maximum predicted operational stand time with the electrical loads (TM loads, connection loads, etc.) that it will be exposed to when installed on the vehicle prior to flight. The maximum predicted operational stand time shall account for all pre-flight processing and flight delay contingencies that could occur after the battery receives its final charge.

d. After the operational stand time has elapsed, the battery shall undergo a capacity discharge to determine if the remaining capacity will meet the flight requirement.

The following process will satisfy the general requirements for charging and discharging needed to determine the operational stand time capacity used.

1. Charge the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour.
2. Apply a single-qualification-level (amplitude and time) termination electrical load pulse.
3. Discharge the battery IAW item b of Subsection 4.28.1.
4. Determine the total capacity, C_T.
5. Charge the battery under nominal pre-flight operating conditions according to flight operations procedures. Wait one hour.
6. Expose the battery to the electrical loads that it will be subjected to when installed in the vehicle prior to flight (TM loads, connection loads, etc.). This test shall be conducted at the maximum expected temperature and for the maximum expected time allowed between final charging and flight.
7. Apply a single-qualification-level (amplitude and time) termination electrical load pulse.
8. Discharge the battery IAW item b of Subsection 4.28.1.

9. Measure and record the remaining capacity, C_R.
10. Determine operational stand time capacity used, $C_{ST} = C_T - C_R$
11. Factor C_{ST} into the battery budget.

4.28.21 Internal Inspection

An internal inspection of a battery must identify any excessive wear or damage to the battery, including any of its cells, after it is exposed to all the qualification test environments. The following internal inspection shall satisfy Subsection 4.11.7.

1. The battery shall undergo 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. The battery shall undergo an examination to verify the integrity of all cell and wiring interconnects.
3. The battery shall undergo 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. Each cell shall be tested for leaks.
6. One cell from each corner and one cell from the middle of the qualification battery shall undergo DPA, which must verify the integrity of: all connections between all plate tabs and cell terminals; and the integrity of each plate and separator. The 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.

4.28.22 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} and 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 the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour.
2. Discharge the battery IAW Subsection 4.28.3.
3. Determine total capacity, C_T.
4. Charge the battery under nominal pre-launch operating conditions according to launch operations procedures. Wait one hour.
5. Expose the battery to the maximum predicted temperature allowed between launch and end of Range Safety responsibility.

6. Expose the battery to the maximum expected time allowed between launch and end of Range Safety responsibility.
7. Discharge the battery IAW Subsection 4.28.3.
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 the battery budget.

4.28.23 Battery Case Integrity

A battery case integrity test shall demonstrate the following.

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 gas leak rate satisfies all of its performance requirements.

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, pre-flight, or flight conditions, whichever is higher.
2. The pressure monitoring shall have a resolution and sample rate that allows accurate determination of the battery's gas leak rate.
3. The test shall demonstrate that the battery's gas leak rate is no greater than the equivalent of 10^{-5} W (10^{-5} Pa m^3/s, 10^{-4} atm cm^3/s) of helium at SLC.
4. The battery shall undergo examination to identify any condition that indicates that it might lose structural integrity or create a hazardous condition.

4.29 Safe-and-Arm Devices, Low-Voltage Initiators, Rotor Leads, and Booster Charges

This section contains acceptance, qualification, and SLE tests for SADs and components. Acceptance and qualification tests for SADs appear in Table 4-47and Table 4-48, respectively. Tests for LVIs appear in Table 4-49 (lot acceptance), Table 4-50 (qualification), and Table 4-51 (SLE tests). Rotor lead and booster charge tests appear in Table 4-52 (lot acceptance), Table 4-53 (qualification), and Table 4-54 (SLE tests).

Table 4-47. Safe-and-Arm Device Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
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]	4.29.2	100%
Safety Tests	4.29.5	
Manual Safing[1]	4.29.5.d	100%
Safing-Interlock Test	4.29.5.e	100%

Abbreviated Performance Verification	4.10.5	
Thermal Performance	4.29.6	100%
Dynamic Performance	4.29.7	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration	4.12.4	100%
Random Vibration	4.12.5	100%
Acoustic Vibration	4.12.6	100%
X-ray	4.11.6	100%
Leakage	4.11.8	100%
[1]These tests shall also be performed at the launch site just before installation.		

Table 4-48. Safe-and-Arm Device Qualification Test Requirements

Test	Section	Quantity Tested			
		X=SS	X=1[1]	X=6[2]	X=3[3]
Acceptance Tests	Table 4-47	-	X	X	-
Barrier Alignment	4.29.16	X	-	-	-
Safety Tests	4.29.5				
Extended Stall	4.29.5.c	-	X	-	-
Abnormal Drop	4.14.8	-	X	-	-
Containment	4.29.5.a	-	-	-	1
Barrier Functionality	4.29.5.b	-	-	-	2
Safing Verification	4.29.5.f	-	-	X	-
Performance Verification	4.10.4				
Functional Tests	4.29.2	-	-	X	-
Safety Tests	4.29.5	-	-	X	-
Manual Safing	4.29.5.d	-	-	X	-
Safing-Interlock Test	4.29.5.e	-	-	X	-
Abbreviated Performance Verification	4.10.5				
Thermal Performance	4.29.6	-	-	X	-
Dynamic Performance	4.29.7	-	-	X	-
Cycle Life	4.29.3	-	-	2	-
Environment Tests - Non-Operating	4.14.1				
Storage Temperature	4.14.2	-	-	X	-
Transportation Vibration	4.14.4	-	-	X	-
Transportation Shock	4.14.5	-	-	X	-
Bench Handling Shock	4.14.6	-	-	X	-
Fungus Resistance	4.14.9	-	-	1	-
Fine Sand	4.14.10	-	-	1	-
Handling Drop	4.14.7	-	-	X	-
Environment Tests – Operating	4.15.1				
Thermal Cycle	4.15.2	-	-	X	-

Humidity	4.15.4	-	-	X	-
Salt Fog	4.15.5	-	-	X	-
Temperature/Humidity/Altitude	4.15.6	-	-	X	-
Acceleration	4.15.7	-	-	X	-
Sinusoidal Vibration	4.15.8	-	-	X	-
Random Vibration	4.15.9	-	-	X	-
Acoustic Vibration	4.15.10	-	-	X	-
Shock	4.15.11	-	-	X	-
Explosive Atmosphere[4]	4.15.13	-	-	2	-
Stall	4.29.4	-	-	X	-
X-ray	4.11.6	-	-	X	-
Leakage	4.11.8	-	-	X	-
Internal Inspection	4.11.7	-	-	2	-
Firing Tests	4.29.11				
High Temperature	4.29.11.f	-	-	2	-
Low Temperature	4.29.11.g	-	-	2	-

[1]One SAD shall undergo the extended stall and abnormal drop tests designated with an X.
[2]The same six sample SADs shall undergo each test designated with an X. For a test designated with a quantity of less than six, each SAD tested shall be one of the original six sample components.
[3]One SAD shall undergo the containment test and two SADs shall undergo the barrier functionality test. The SAD samples used for these tests need not be flight SADs. The test samples shall duplicate all dimensions of a flight SAD, including gaps between explosive components, free-volume, and diaphragm thickness.
[4]A SAD shall be cycled from Safe/Arm and Arm/Safe five times for this test.

Table 4-49. Low-Voltage Initiator Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]
Component Examination	4.11	
Visual Examination[2]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Electrostatic Discharge	4.29.10	100%
Component Examination	4.11	
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification	4.10.4	
Insulation Resistance[2]	4.29.8	100%
Bridgewire Resistance[2]	4.29.9	100%
Tensile Load	4.14.11	Lot Sample
Environment Tests - Non-Operating and Operating[3]	4.14.1 4.15.1	
Artificial Aging[4]	4.14.3	Lot Sample
Thermal Cycle	4.15.2.e	Lot Sample
Sinusoidal Vibration	4.15.8	Lot Sample

Random Vibration	4.15.9	Lot Sample
Shock	4.15.11	Lot Sample
No-Fire Verification	4.29.17	Lot Sample
Component Examination	4.11	
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[5]	4.29.11.a	
Ambient Temperature	4.29.11.e	
All-Fire Current	4.29.11.b	1/6 Lot Sample
Operating Current	4.29.11.c	1/6 Lot Sample
High Temperature	4.29.11.f	
All-Fire Current	4.29.11.b	1/6 Lot Sample
Operating Current	4.29.11.c	1/6 Lot Sample
Low Temperature	4.29.11.g	
All-Fire Current	4.29.11.b	1/6 Lot Sample
Operating Current	4.29.11.c	1/6 Lot Sample

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 30 units.
[2]These tests shall also be performed at the launch site.
[3]For an LVI that is internal to a SAD, the test level shall be no less than the environment that the LVI experiences when installed and the SAD is subjected to its qualification environment. No monitoring is required during environmental testing.
[4]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.
[5]When the lot cannot be evenly divided, any extra samples shall be fired at low temperature at the all-fire current.

Table 4-50. Low-Voltage Initiator Qualification Test Requirements

Test	Section	Quantity Tested[1] X=				
		5	SS[2]	SS[3]	SS[4]	105
Component Examination	4.11					
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	4.29.9	X	X	X	X	X
Insulation Resistance	4.29.8	X	X	X	X	X
Electrostatic Discharge	4.29.10	X	X	X	X	X
RF Impedance	4.29.12	-	10	-	-	-
RF Sensitivity	4.29.13	-	X	-	-	-
Statistical No-Fire Level	4.29.14	-	-	X	-	-
Statistical All-Fire Level	4.29.15	-	-	-	X	-
Environment Tests – Non-Operating	4.14.1					

and Operating[5]	4.15.1					
Artificial Aging[6]	4.14.3	-	-	-	-	30
Thermal Cycle	4.15.2.e	-	-	-	-	X
Random Vibration	4.15.9	-	-	-	-	X
Shock	4.15.11	-	-	-	-	X
No-Fire Verification	4.29.17	-	-	-	-	30
Tensile Load[7]	4.14.11	-	-	-	-	30
Auto-Ignition	4.29.18	X	-	-	-	-
Component Examination	4.11					
Visual Examination	4.11.2	-	-	-	-	X
Leakage	4.11.8	-	-	-	-	X
X-ray and N-ray	4.11.6	-	-	-	-	X
Firing Tests	4.29.11.a					
Ambient Temperature	4.29.11.e					
All-Fire Current[8]	4.29.11.b	-	-	-	-	15
Operating Current[8]	4.29.11.c	-	-	-	-	15
2 x Operating Current	4.29.11.d	-	-	-	-	5
High Temperature	4.29.11.f					
All-Fire Current[8]	4.29.11.b	-	-	-	-	15
Operating Current[8]	4.29.11.c	-	-	-	-	15
2 x Operating Current	4.29.11.d	-	-	-	-	5
Low Temperature	4.29.11.g					
All-Fire Current[8]	4.29.11.b	-	-	-	-	15
Operating Current[8]	4.29.11.c	-	-	-	-	15
2 x Operating Current	4.29.11.d	-	-	-	-	5

[1]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.
[2]For the designated column, 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 LVI.
[3]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.
[4]For the designated column, the SS shall be the quantity of sample components needed to perform a statistical firing series to determine the LVI all-fire energy level.
[5]This test shall subject each LVI sample to the qualification environmental test level. For an LVI that is internal to a SAD, the test level shall be no less than the environment that the LVI experiences when installed and the SAD is subjected to its qualification environment. No monitoring is required during environmental testing.
[6]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.
[7]This test is not required if any other test verifies that each LVI has not been damaged during installation.
[8]All the LVI samples that undergo artificial aging, no-fire verification tests, or tensile load tests shall be evenly distributed between the all-fire current and operating current firing tests.

Table 4-51. Low-Voltage Initiator Service Life Extension Test Requirements

Test	Section	Quantity Tested[1]	
		1 Year X=5	3 Years 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
Performance Verification	4.10.4		
Bridgewire Resistance	4.29.9	X	X
Insulation Resistance	4.29.8	X	X
Electrostatic Discharge	4.29.10	X	X
Environment Tests – Non-Operating and Operating[2]	4.14.1 4.15.1		
Artificial Aging	4.14.3	-	X
Thermal Cycle	4.15.2.e	X	X
Sinusoidal Vibration	4.15.8	X	X
Random Vibration	4.15.9	X	X
Shock	4.15.11	X	X
Component Examination	4.11		
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	4.29.11.a		
All-Fire Current	4.29.11.b		
Ambient Temperature	4.29.11.c	1	3
High Temperature	4.29.11.d	2	3
Low Temperature	4.29.11.e	2	4

[1]To extend the service life of a component, sample components shall undergo each test required by the one-year extension column or the three-year extension column. All SLE samples shall be from the same production lot as the flight components and shall be stored with the flight component or in an environment that duplicates the storage conditions of the flight component.
[2]For an LVI that is internal to a SAD, the test levels shall be no less than the environment that the LVI experiences when installed and the SAD is subjected to its qualification environment. No monitoring is required during environmental testing.

Table 4-52. Safe-and-Arm Rotor Lead and Booster Charge Lot Acceptance Test Requirements[1]

Test	Section	Quantity Tested[2]
Component Examination	4.11	
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%
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1	
Artificial Aging[3]	4.14.3	Lot Sample
Thermal Cycle[4]	4.15.2.e	Lot Sample
Component Examination	4.11	
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests[5]	4.29.11.a	
High Temperature	4.29.11.f	1/2 Lot Sample
Low Temperature	4.29.11.g	1/2 Lot Sample

[1]This table applies to any rotor lead or booster charge that is used inside a SAD.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of nine units.
[3]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of five years. If it is not performed, the lot will have an initial service life of one year.
[4]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 SAD is subjected to its qualification environment. No monitoring is required during environmental testing.
[5]When the lot cannot be evenly divided, the extra sample shall be fired at low temperature.

Table 4-53. Safe-and-Arm Rotor Lead and Booster Charge Qualification Test Requirements[1]

Test	Section	Quantity Tested[2] X=21
Component Examination	4.11	
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
Environment Tests - Non-Operating and Operating[3]	4.14.1 4.15.1	
Artificial Aging[4]	4.14.3	10
Thermal Cycle	4.15.2.e	X
Sinusoidal Vibration	4.15.8	X
Random Vibration	4.15.9	X
Shock	4.15.11	X
Component Examination	4.11	
Leakage	4.11.8	X
X-ray and N-ray	4.11.6	X
Firing Tests	4.29.11.a	
Ambient Temperature	4.29.11.e	7
High Temperature	4.29.11.f	7

Low Temperature	4.29.11.g	7

[1]This table applies to any rotor lead or booster charge that is used inside a SAD.
[2]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.
[3]The test level shall be no less than the environment that the ordnance experiences when installed and the SAD is subjected to its qualification environment. No monitoring is required during environmental testing.
[4]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of five years. If it is not performed, the lot will have an initial service life of one year.

Table 4-54. Safe-and-Arm Rotor Lead and Booster Charge Service Life Extension Test Requirements[1]

Test	Section	Quantity Tested[2]	
		1 Year X=5	5 Years 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
Environment Tests - Non-Operating and Operating[3]	4.14.1 4.15.1		
Artificial Aging	4.14.3	-	X
Thermal Cycle	4.15.2.e	X	X
Component Examination	4.11		
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.29.11.a		
High Temperature	4.29.11.f	2	5
Low Temperature	4.29.11.g	3	5

[1]This table applies to any rotor lead or booster charge that is used by a SAD.
[2]To extend the service life of a component, sample components shall undergo each test required by the 1-year extension column or the 5-year extension column. All SLE samples shall be from the same production lot as the flight components and shall be stored with the flight component or in an environment that duplicates the storage conditions of the flight component.
[3]For ordnance that is internal to a SAD, the test level shall be no less than the actual environment that the ordnance experiences when installed and the SAD is subjected to its qualification environment.

4.29.1 General

a. This section applies to an electromechanical SAD with an internal LVI, external LVI's rotor lead, or booster charge.

b. Acceleration-armed SADs will require additional tailoring not included in the tables of this section.

c. Any SAD, 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 of its performance requirements when subjected to each non-operating and operating environment.

4.29.2 Functional Tests

A SAD 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 materials 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%.
3. The insulation resistance between all insulated parts shall be 2 MΩ or more.

b. The S&A transition time from Safe/Arm and Arm/Safe shall be tested through multiple S&A transition cycles.

c. The LVI firing circuit (i.e., bridgewire resistance) consistency shall be tested through multiple S&A transition cycles.

For electrically armed SADs, 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 SAD is in the proper configuration.

1. The presence of the arm indication shall be displayed when the SAD is armed.
2. The presence of the safe indication shall be displayed when the SAD is safed.

e. For continuity and isolation, the test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all of its performance requirements.

1. Isolation resistance shall be 2 MΩ or more.
2. The test shall measure the continuity of the internal circuits to demonstrate that the continuity resistances satisfy their performance specifications.

4.29.3 Cycle Life

This test shall demonstrate that the S&A transition, such as rotational or sliding operation, satisfies all of its performance requirements.

The test shall demonstrate the ability of a SAD to satisfy all of its performance requirements when subjected to five times the maximum predicted number of safe-to-arm and arm-to-safe cycles.

1. For SADs that are electrically armed, the unit shall be designed to withstand at least 1000 cycles of transition between safe and arm (2 transitions per cycle) without any malfunction, failure, or deterioration in performance.
2. If less than 1000 cycles are used, the range user shall provide the following.
   a. The SAD shall be qualified for a cycle life of at least two times the total expected cycles that will include acceptance, bench tests, pre-launch checkout, and launch attempts.
   b. Data sheets shall accompany each SAD 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. Any SADs that exceed 50% of the qualification number of cycles will not be allowed for flight. Any SADs that do not have an accompanying data sheet for review by Range Safety personnel will not be allowed for flight.
3. A functional test shall be performed IAW Subsection 4.29.2 at every one-third interval of cycle time.

4.29.4 Stall

A stall test shall demonstrate that a SAD satisfies all of its performance requirements after being locked in its safe position and subjected to an operating arming voltage for the maximum time that could occur inadvertently. The device must still be useable for flight or five minutes, whichever is greater, at the conclusion of the test.

4.29.5 Safety Tests

The following safety tests shall demonstrate that a SAD can be handled safely.

a. Containment. A containment test shall demonstrate that a SAD will not fragment when any internal LVI or rotor charge is initiated. A SAD 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 a SAD's internal LVI is fired, the ordnance output will not propagate to an ETS. This demonstration shall include all of the following.

   (1) With the ETS configured for flight, the test shall consist of firings at high and low temperature extremes.

   (2) The high-temperature firing shall be initiated at the upper MPE or 71°C, whichever is higher.

   (3) The low-temperature firing shall be initiated at the lower MPE or −54°C, whichever is lower.

c. Extended Stall. An extended stall test shall demonstrate that a SAD 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 higher.

d. Manual Safing. A manual safing test shall demonstrate that a SAD can be manually safed IAW 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 a SAD's safing-interlock prevents arming IAW 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 445 N (100 lbf) or a torque of 11.3 N-m (100 in-lbf) without failure.

f. Safing Verification. A safing verification test shall demonstrate that, while a SAD is in the safe position, any internal LVI will not initiate if the SAD input circuit is accidentally subjected to a firing voltage.

4.29.6 Thermal Performance

A thermal performance test shall demonstrate that a SAD satisfies all of its performance requirements 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 SAD 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 SAD to multiple Safe/Arm cycles and measure the bridgewire continuity during each cycle to demonstrate that the continuity is consistent.

For electrically armed SADs, 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 SAD Safe/Arm and Arm/Safe cycle time to demonstrate that it satisfies the manufacturer specification.

4.29.7 Dynamic Performance

A dynamic performance test shall demonstrate that a SAD satisfies all of its performance requirements when subjected to the dynamic operational environments, including random vibration, sinusoidal vibration, acoustic vibration, and shock. This demonstration shall include all of the following.

a. The SAD shall undergo the test while subjected to each required dynamic operational environment.

b. The test shall continuously monitor the SAD firing circuit (bridgewire) for continuity with the SAD in the arm position to detect variation in amplitude. Any amplitude variation constitutes a test failure.

c. The test shall continuously monitor the SAD monitor circuit for continuity. Any dropouts constitute a test failure.

d. The test shall continuously monitor the SAD to demonstrate that it remains in the fully armed position throughout all dynamic environment testing.

4.29.8 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 materials 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%.
3. The insulation resistance between all insulated parts shall be 2 MΩ or more.

4.29.9 Bridgewire Resistance

A bridgewire resistance test shall be performed to demonstrate that the LVI meets its performance requirements.

1. The measurement error shall be less than 2%.
2. Apply a maximum current of 10% of the statistical no-fire current or 10 mA, whichever is less, and measure the bridgewire resistance.

4.29.10 Electrostatic Discharge

An ESD test shall demonstrate that an LVI can withstand an ESD that it could experience from contact with personnel or conductive surfaces without firing and still satisfy all of its performance requirements. Note: Some ordnance manufacturers have argued against performing this test on all units due to the potential for causing some level of damage to the units. While the potential for damage is acknowledged, the focus of this test is on personnel safety. The fact that qualification units are able to function properly after exposure to this discharge argues that the units should be sufficiently robust to withstand this test without being damaged to the point of being inoperable.

The test shall subject the LVI to the greater of the following. Note: Pins shall be shorted for pin-to-case mode.

1. A 25-kV, 500-pF pin-to-pin discharge through a 5-kΩ resistor and a 25-kV, 500-pF pin-to-case discharge with no resistor.
2. The maximum predicted pin-to-pin and pin-to-case ESDs. See Figure 4-11 for the test setup.

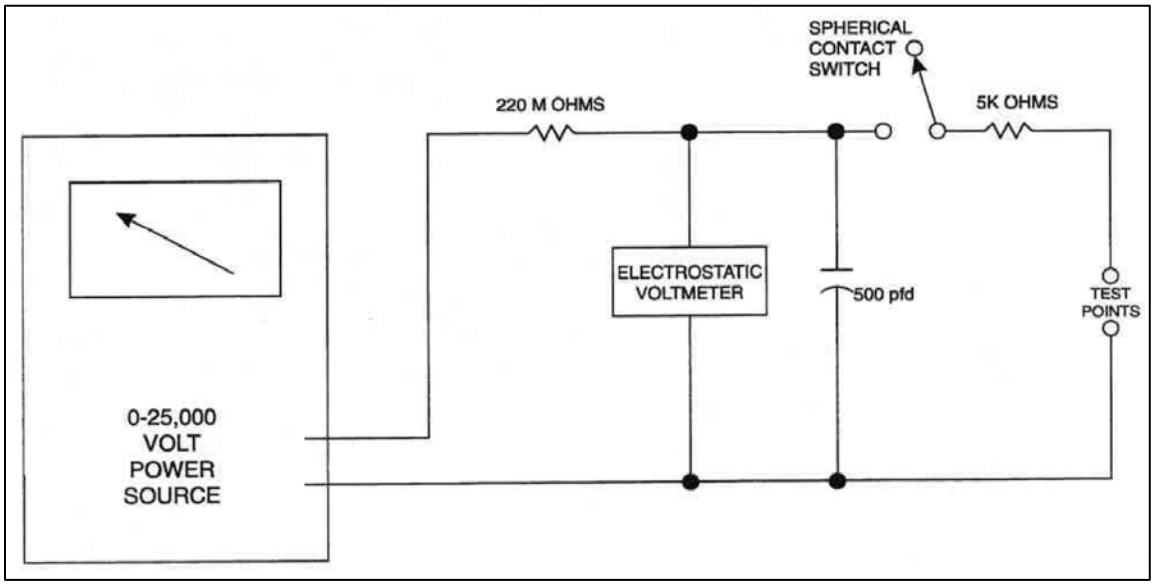

Figure 4-11. Electrostatic Discharge Test

4.29.11 Firing Tests

a. General. Each firing test of a SAD, 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 a SAD 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 an LVI not installed internally within a SAD, 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 LVI test shall measure ordnance output using a measuring device, such as a swell cap or dent block, to demonstrate that the output satisfies all of its performance requirements.

1. 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.

2. Detonating explosives shall be tested using a metal witness plate to record output through a dent depth measurement technique.

3. The device shall meet the requirements of the component qualification.

(5) The SAD shall use a flight-representative configured interface to verify the output meets its performance requirements.

The SAD shall use an ETS on the S&A output.

(6) Each test of a SAD 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-ms 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 of its performance requirements.

b. All-Fire Current. Each all-fire current test shall subject the component sample to the manufacturer-specified all-fire current value.

c. Operating Current. Each operating current test shall subject each component sample to the vehicle operating current value that shall be a minimum of 1.5 times all-fire current.

d. Double-Operating Current. Each double-operating current test shall subject each component sample to a minimum of two times the vehicle operating current value.

This test shall subject each component sample to a firing current of 22 A.

e. Ambient Temperature. Each sample shall be fired at ambient temperature.

f. High Temperature. Each sample shall be fired at the qualification high-temperature level.

g. Low Temperature. Each sample shall be fired at the qualification low-temperature level.

4.29.12 Radio Frequency 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 mW 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 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. Impedances shall be measured at 10 frequencies distributed in approximately equal logarithmic increments between 1 MHz and 1.2 GHz and shall include any frequency corresponding to a known high-power density in the LVI's operational environment.

4.29.13 Radio Frequency Sensitivity

This test shall consist of a statistical firing series of samples to determine the RF no-fire power level. The firing series shall determine the highest continuous RF power level to which the device can be subjected and not fire with a reliability of 0.999 at a 95% 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 statistical sensitivity 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 known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the required no-fire level.
5. At least 10 frequencies shall be used in the probing tests. These frequencies shall be chosen to cover the frequency range from 1 MHz to 32 GHz and shall include any frequency corresponding to a known high-power density in the LVI'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 Table 4-55 shall be used.

Table 4-55. 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
[1]CW = Continuous Wave. [2]P = Pulsed modulation with pulse width of 1 µs and pulse repetition rate of 1 kHz.	

8. Probing Test

   a. At each test frequency, test 10 LVIs for five 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 5 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 2-pin single-bridge device and 25 items for a dual-bridge device.

9. Analysis

   a. Count the number of firings at each frequency.
      (1) At any particular frequency, if two or less fire, the DC 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 Radio Frequency No-Fire Level

   a. Perform a 5-minute no-fire statistical sensitivity test at the most sensitive frequency/ modulation stimulus for each configuration. The same equipment shall be used in the probing tests.
   b. The appropriate number of test items, as determined by the test methodology, shall be used for each firing configuration of the device being tested.
   c. The 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 IAW tailored requirements using MIL-STD-1576,[30] Method 2208 as a baseline.

4.29.14 No-Fire Level

This test shall consist of a statistical firing series of samples to determine the no-fire current level. The firing series shall determine the highest current at which the device will not fire with a reliability of 0.999 at a 95% confidence level when subjected to a continuous current pulse.

[30] Department of Defense. Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems. MIL-STD-1576. 31 July 1984. May be superseded by update. Available at http://quicksearch.dla.mil/.

1. A known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the required no-fire level.
2. A firing pulse shall be a minimum of five minutes.
3. Testing shall be performed at worst-case hot temperature operational conditions.

4.29.15 All-Fire Level

This test shall consist of a statistical firing series to determine the all-fire current level. This firing series shall determine the lowest current at which the device will fire with a reliability of 0.999 at a 95% confidence level.

1. A known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the required all-fire level.
2. The firing pulse shall use a CC pulse of 30 ms.

4.29.16 Barrier Alignment

A barrier alignment test shall consist of a statistical test firing series that demonstrates that the device's safe-to-arm transition motion provides for ordnance initiation with a reliability of 0.999 at a 95% 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% confidence level. This test may employ a reusable SAD subassembly that simulates the flight configuration.

1. The number of required test units shall be determined by the susceptibility of the electro-mechanical mechanism to degradation during firing and the ability for it to be reloaded with ordnance for subsequent tests.
2. A known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the no-fire rotor angle and shall be repeated to demonstrate the all-fire rotor angle.

4.29.17 No-Fire Verification

An ordnance initiator shall demonstrate its specified no-fire current. An ordnance initiator shall not fire when exposed to continuous application of the no-fire current, with a reliability of no less than 0.999 at a 95% 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 of its performance requirements.

The test shall subject each sample LVI to the greater of:

1. the maximum predicted leakage current level and duration plus a 20-dB margin that could occur in an operating condition for five minutes; or
2. 1 A and 1 W for five minutes. If the DC sensitivity does not represent worst case (WC), then an RF-induced no-fire level shall be used for this test.

4.29.18 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 higher.
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 High-Energy Firing Units

This section applies to any firing unit and ordnance system that uses voltages higher than 500 V to directly initiate a secondary explosive. Acceptance and qualification tests for high-energy firing units appear in Table 4-56 and Table 4-57, respectively. Tests for EBWs and EFIs appear in Table 4-58 (LATs), Table 4-59 (qualification), and Table 4-60 (SLEs).

Table 4-56. High-Energy Firing Unit Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Examination[1]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check[1]	4.11.5	100%
Performance Verification[1]	4.10.4	
Continuity and Isolation	4.30.2	100%
Input Current[2]	4.30.3	100%
High-Voltage Circuitry[2]	4.30.4	100%
High-Voltage Charging Circuit[2]	4.30.5	100%
Command Processing[1]	4.30.6	100%
Output Monitoring[2]	4.30.8	100%
Abbreviated Performance Verification[3]	4.10.5	
Input Current	4.30.3	100%
Abbreviated Command Processing	4.30.7	100%
Output Monitoring	4.30.8	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration[3]	4.12.4	100%
Random Vibration[3]	4.12.5	100%
Acoustic Vibration[3]	4.12.6	100%
Leakage	4.11.8	100%

[1]This test shall also be performed as part of pre-flight testing at the launch site.
[2]This test shall be performed during the hot and cold dwells of the first and last cycles of the thermal cycle and thermal vacuum tests. A component shall undergo an input current and output monitor test during all thermal cycles and transitions.
[3]Abbreviated performance verification tests shall be performed during dynamic operating environments.

Table 4-57. High-Energy Firing Unit Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Acceptance Tests	Table 4-56	X
Performance Verification	4.10.4	
Resistance	4.30.2	X
Input Current[2]	4.30.3	X
High-Voltage Circuitry[2]	4.30.4	X
High-Voltage Charging Circuit[2]	4.30.5	X
Command Processing [2]	4.30.6	X
Output Monitoring[2]	4.30.8	X
Abbreviated Performance Verification[3]	4.10.5	X
Input Current[4]	4.30.3	X
Abbreviated Command Processing	4.30.7	X
Output Monitoring[4]	4.30.8	X
Environment Tests - Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Environment Tests - Operating	4.15.1	
Thermal Cycle	4.15.2	X
Thermal Vacuum	4.15.3	X
Humidity	4.15.4	X
Salt Fog	4.15.5	X
Temperature/Humidity/Altitude	4.15.6	X
Acceleration[3]	4.15.7	X
Sinusoidal Vibration[3]	4.15.8	X
Random Vibration[3]	4.15.9	X
Acoustic Vibration[3]	4.15.10	X
Shock[5]	4.15.11	X
EMI/EMC	4.15.12	2
Explosive Atmosphere	4.15.13	2
Repetitive Functioning	4.30.9	X

Circuit Protection	4.30.10	1
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

[1]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.
[2]This test 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.
[3]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
[4]This test shall be performed during shock testing.
[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.

Table 4-58. Exploding Bridgewire And Exploding Foil Initiator Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]
Component Examination	4.11	
Visual Examination[2]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Electrostatic Discharge	4.30.11	100%
Component Examination	4.11	
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification	4.10.4	
Bridgewire Resistance[2]	4.30.12	100%
Insulation Resistance[2]	4.30.13	100%
Tensile Load	4.14.11	Lot Sample
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1	
Artificial Aging[3]	4.14.3	Lot Sample
Thermal Cycle	4.15.2.e	Lot Sample
Sinusoidal Vibration	4.15.8	Lot Sample
Random Vibration	4.15.9	Lot Sample
Shock	4.15.11	Lot Sample
No-Fire Verification	4.30.15	Lot Sample
Component Examination	4.11	
Visual Examination	4.11.2	100%
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests	4.30.16.a	
Ambient Temperature	4.30.16.e	

All-Fire Voltage	4.30.16.b	1/6 Lot Sample
Operating Voltage	4.30.16.c	1/6 Lot Sample
High Temperature	4.30.16.f	
All-Fire Voltage	4.30.16.b	1/6 Lot Sample
Operating Voltage	4.30.16.c	1/6 Lot Sample
Low Temperature	4.30.16.g	
All-Fire Voltage	4.30.16.b	1/6 Lot Sample
Operating Voltage	4.30.16.c	1/6 Lot Sample

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 30 units.
[2]This test shall also be performed at the launch site.
[3]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.

Table 4-59. Exploding Bridgewire and Exploding Foil Initiator Qualification Test Requirements

Test	Section	Quantity Tested[1,2]						
		SS[3]	5	5	SS[4]	SS[5]	SS[6]	105
Component Examination	4.11							
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	4.30.12	X	X	X	X	X	X	X
Insulation Resistance	4.30.13	X	X	X	X	X	X	X
Electrostatic Discharge	4.30.11	X	X	X	X	X	X	X
RF Impedance	4.30.17	-	-	-	10	-	-	-
RF Sensitivity	4.30.18	-	-	-	X	-	-	-
Statistical No-Fire Energy Level	4.30.19	-	-	-	-	X	-	-
Statistical All-Fire Energy Level	4.30.20	-	-	-	-	-	X	-
Safety No-Fire Test	4.30.22	-	X	-	-	-	-	-
Bridgewire Degradation Test	4.30.14	X		-	-	-	-	-
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1							
Storage Temperature	4.14.2	-	-	-	-	-	-	X
Transportation Vibration	4.14.4	-	-	-	-	-	-	X
Transportation Shock	4.14.5	-	-	-	-	-	-	X
Bench Handling Shock	4.14.6	-	-	-	-	-	-	X
Fungus Resistance	4.14.9	-	-	-	-	-	-	X
Fine Sand	4.14.10	-	-	-	-	-	-	X
Artificial Aging[7]	4.14.3	-	-	-	-	-	-	30
Thermal Cycle	4.15.2.e	-	-	-	-	-	-	X

Humidity	4.15.4	-	-	-	-	-	-	X
Salt Fog	4.15.5	-	-	-	-	-	-	X
Acceleration	4.15.7	-	-	-	-	-	-	X
Sinusoidal Vibration	4.15.8	-	-	-	-	-	-	X
Random Vibration	4.15.9	-	-	-	-	-	-	X
Acoustic Vibration	4.15.10	-	-	-	-	-	-	X
Shock	4.15.11	-	-	-	-	-	-	X
No-Fire Verification Test	4.30.15	-	-	-	-	-	-	X
Handling Drop	4.14.7	-	-	-	-	-	-	X
Tensile Load	4.14.11	-	-		-	-	-	30
Abnormal Drop	4.14.8	-	-	X	-	-	-	-
Auto-Ignition	4.30.21	-	-	X	-	-	-	-
Component Examination	4.11							
Visual Examination	4.11.2	-	-	-	-	-	-	X
Leakage	4.11.8	-	-	-	-	-	-	X
X-ray and N-ray	4.11.6	-	-	-	-	-	-	X
Firing Tests	4.30.16.a							
Ambient Temperature	4.30.16.e							
All-Fire Voltage	4.30.16.b	-	-	-	-	-	-	15
Operating Voltage	4.30.16.c	-	-	-	-	-	-	15
High Operating Voltage	4.30.16.d	-	-	-	-	-	-	5
High Temperature	4.30.16.f							
All-Fire Voltage	4.30.16.b	-	-	-	-	-	-	15
Operating Voltage	4.30.16.c	-	-	-	-	-	-	15
High Operating Voltage	4.30.16.d	-	-	-	-	-	-	5
Low Temperature	4.30.16.g							
All-Fire Voltage	4.30.16.b	-	-	-	-	-	-	15
Operating Voltage	4.30.16.c	-	-	-	-	-	-	15
High Operating Voltage	4.30.16.d	-	-	-	-	-	-	5

[1]All initiator samples used in qualification testing shall be from a production lot that has passed the LATs required by Table 4-58.
[2]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.
[3]The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the degradation current.
[4]The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the RF sensitivity of the device. 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.
[5]The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the no-fire energy level.
[6]The SS shall be the quantity of sample components needed to perform a statistical firing series to determine the all-fire energy level.
[7]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial

service life of three years. If it is not performed, the lot will have an initial service life of one year.

Table 4-60. Exploding Bridgewire and Exploding Foil Initiator Service Life Extension Test Requirements

Test	Section	Quantity Tested[1]	
		1 Year X=5	3 Years 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
Performance Verification	4.10.4		
Bridgewire Resistance	4.30.12	X	X
Insulation Resistance	4.30.13	X	X
Electrostatic Discharge	4.30.11	X	X
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1		
Artificial Aging	4.14.3	-	X
Thermal Cycle	4.15.2.e	X	X
Sinusoidal Vibration	4.15.8	X	X
Random Vibration	4.15.9	X	X
Shock	4.15.11	X	X
No-Fire Verification	4.30.15	X	X
Component Examination	4.11		
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	4.30.16.a		
All-Fire Voltage	4.30.16.b		
Ambient Temperature	4.30.16.e	1	3
High Temperature	4.30.16.f	2	3
Low Temperature	4.30.16.g	2	4

[1]To extend the service life of a component, sample components shall undergo each test required by the 1-year extension column or the 3-year extension column. All SLE samples shall be from the same production lot as the flight components and shall be stored with the flight component or in an environment that duplicates the storage conditions of the flight component.

4.30.1 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 of its performance requirements 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 designed purely for Range Safety purposes (EAFD) or purely for tactical systems (ESAD). The requirements specified here shall apply any such device used for Range Safety purposes.

4.30.2 Continuity and Isolation

The test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all of its performance requirements.

Isolation resistance shall be 2 MΩ or more.

4.30.3 Input Current

Input current of the firing unit shall be monitored to demonstrate that it satisfies all performance requirements.

Input current to the firing unit's input power and arm power shall be monitored.

4.30.4 High-Voltage Circuitry

This test shall demonstrate that a firing unit's high-voltage circuitry satisfies all of its performance requirements 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 of its performance requirements when subjected to the worst-case high and low arm voltages that it could experience during bench testing, pre-launch 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% 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 satisfies 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% of the initiator all-fire qualification voltage level (i.e., a 50% margin on all-fire qualification voltage).

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.

4.30.5 High-Voltage Charging Circuit

The charging circuits of the firing unit shall be tested to demonstrate that it satisfies all performance requirements.

Where applicable, trigger circuit threshold, capacitor charge time, and arming time shall be tested.

4.30.6 Command Processing

A command processing test shall demonstrate that an initiator firing unit's input trigger circuit satisfies all of its performance requirements 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 vehicle.

1. The firing unit's command and firing circuits shall trigger at 75% of the amplitude and 50% 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% amplitude and 150% 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 dropout for a period of 50 ms.

d. The firing unit shall be tested to demonstrate that its response time is IAW 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 of its performance requirements 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-V signal is applied for five minutes.

4.30.7 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 of its

performance requirements. The firing unit's output circuitry shall fire into a load that simulates the flight-representative high-voltage initiator circuit.

4.30.8 Output Monitoring

An output-monitoring test shall measure all output monitors to demonstrate that they satisfy their performance requirements.

4.30.9 Repetitive Functioning

This test shall demonstrate that a firing unit satisfies all of its performance requirements 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% 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, pre-launch 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. Any EAFDs (or ESADs) that exceed 50% 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.

4.30.10 Circuit Protection

A circuit protection test shall demonstrate that any circuit protection allows a firing unit to satisfy all of its performance requirements 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 of its performance requirements 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 the OCV of the power source or 45 Vdc, whichever is higher, to the power input port for a period not less than five 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 V to the maximum specified voltage and back to 0 V 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 a firing unit shall not change state for at least 50 ms.

d. A watchdog circuit shall satisfy all of its performance requirements.

e. A test of the firing unit shall 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 shall satisfy all of its performance requirements after being subjected to any reverse-polarity voltage that could occur during launch processing.

4.30.11 Electrostatic Discharge

An ESD test shall demonstrate that an initiator can withstand an ESD that it could experience from contact with personnel or conductive surfaces without firing and still satisfy all of its performance requirements. Note: Some ordnance manufacturers have argued against performing this test on all units due to the potential for causing some level of damage to the units. While the potential for damage is acknowledged, the focus of this test is on personnel safety. The fact that qualification units are able to function properly after exposure to this discharge argues that the units should be sufficiently robust to withstand this test without being damaged to the point of being inoperable.

The test shall subject the initiator to the greater of the following. Note: Pins shall be shorted for pin-to-case mode.

1. A 25 kV, 500 pF pin-to-pin discharge through a 5-kΩ resistor and a 25-kV, 500-pF pin-to-case discharge with no resistor.
2. The maximum predicted pin-to-pin and pin-to-case ESDs. See Figure 4-11 for the test setup.

4.30.12 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% of the true value. A maximum current of 10% of the bridge degradation current or 10 mA, 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. Voltage tests for EBW gap breakdown shall verify compliance with the component specification.

4.30.13 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 materials are not damaged.

1. Insulation resistance measurements shall be taken at a minimum of 1 kVdc between the 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%.
3. The insulation resistance between all insulated parts shall be 20 MΩ or more.

4.30.14 Bridgewire Degradation Test

This test shall determine the highest DC current level that will not damage or degrade the initiator with a reliability of at least 0.999 with a 95% confidence level at the MPE temperature plus a margin. The worst-case current that a flight initiator experiences shall be a minimum of 20 dB below the bridgewire degradation current.

1. A known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the required no-fire level.
2. The initiator shall be temperature-conditioned to the qualification high temperature.
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 DC level applied across the input pins to the initiator for a minimum of five minutes.
5. The DC (at the Langlie, Bruceton, or Neyer 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.

4.30.15 No-Fire Verification

An ordnance initiator shall demonstrate its specified no-fire voltage. An ordnance initiator shall not fire when exposed to continuous application of the no-fire voltage with a reliability of no less than 0.999 at a 95% confidence level.

1. The initiator shall be capable of being exposed to the bridge degradation current for five minutes and one 45-V firing pulse without dudding or degrading.
2. If the DC sensitivity does not represent WC, then an RF-induced no-fire level shall be used for this test.

4.30.16 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 of its performance requirements 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 it 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 of its performance requirements.

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 voltage is unknown, the test shall use no less than 200% of the all-fire voltage (i.e., a 100% margin on all-fire voltage).
2. The operating voltage 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% of the operating voltage (i.e., a 50% margin on operating voltage).

e. Ambient Temperature. This test shall function each initiator sample while at ambient temperature.

f. High Temperature. Each high-temperature test shall function each initiator sample while it is subjected to the qualification high-temperature level.

g. Low Temperature. Each low-temperature test shall function each initiator sample while it is subjected to the qualification low-temperature level.

4.30.17 Radio Frequency 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 mW 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 possible.
5. Impedances shall be measured at periodic frequency intervals throughout the operational spectrum. At a minimum, 10 frequencies shall be uniformly selected from 1 MHz to 1.2 GHz. The test spectrum shall include any frequency corresponding to any known high-power density in the initiator's operational environment.
6. The individual measurement frequencies should be selected so that neighboring frequencies differ from each other by an approximately equal logarithmic increment.

4.30.18 Radio Frequency Sensitivity

This test shall consist of a statistical firing series of samples to determine the RF no-fire power level. The firing series shall determine the highest continuous RF power level to which the device can be subjected and not fire with a reliability of 0.999 at a 95% 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. Radio Frequency 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 sensitivity 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 known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the required RF no-fire level.
6. Frequencies for Probing Tests. 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.

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 Table 4-61 shall be used.

Table 4-61. 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

[1]CW = Continuous Wave
[2]P = Pulsed modulation with pulse width of 1 μs and pulse repetition rate of 1 kHz

9. Probing Test. At each test frequency, 10 initiators shall be tested for five minutes in the pin-to-pin configuration and 10 initiators in the pin-to-case configuration. Initiators that do not fire in the pin-to-pin test can be reused in the pin-to-case function.
10. Analysis
    a. Count the number of firings at each frequency.
        (1) At any particular frequency, if two or less fire, the DC 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 Radio Frequency No-Fire Level
    a. Perform a five-minute no-fire sensitivity test at the most sensitive frequency/ modulation stimulus for each configuration. The same equipment shall be used in the probing tests.
    b. The 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 IAW tailored

requirements using MIL-STD-1576, Method 2208 as a baseline.

4.30.19 No-Fire Voltage Level

A no-fire voltage test shall consist of a statistical firing series of initiator lot samples to determine the highest voltage at which the initiator will not fire with a reliability of 0.999 with a 95% confidence level when subjected to a continuous voltage. The test shall demonstrate that the no-fire voltage is no less than the no-fire voltage 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.

4.30.20 All-Fire Voltage Level

An all-fire voltage test shall consist of a statistical firing series of initiator lot samples to determine the lowest voltage at which the initiator will fire with a reliability of 0.999 with a 95% 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 voltage does not exceed the all-fire voltage used in the FTS design and analysis.

4.30.21 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 higher.
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.

4.30.22 Safety No-Fire Test

This test shall demonstrate that the initiator shall not fire when exposed to the worst-case voltage from GSE or vehicle systems plus a margin.

The initiator shall be exposed to 500 Vdc for five minutes without firing.

4.31 Laser Firing Units, Fiber-Optic Cable Energy Transfer Systems, and Laser-Initiated Detonators

This section applies to LFUs, fiber-optic cable energy transfer systems, and LIDs. Tests for LFUs are listed in Table 4-62 (acceptance) and Table 4-63 (qualification). Table 4-64, Table 4-65, and Table 4-66 identify tests for LIDs (LATs, qualification, and SLE tests, respectively). For fiber-optic cable assemblies, acceptance tests appear in Table 4-67 and qualification tests appear in Table 4-68.

Table 4-62. Laser Firing Unit Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Inspection	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification Check	4.11.5	100%
Performance Verification	4.10.4	
Resistance	4.31.8	100%
Input Current[1]	4.31.7	100%
Command Processing[1]	4.31.2	100%
Output Firing Circuit[1]	4.31.3	100%
Inhibit/Safing Circuitry[1]	4.31.4	100%
Output Monitors[1]	4.31.5	100%
Built-In Test[1]	4.31.6	100%
Abbreviated Performance Verification[1]	4.10.5	
Input Current	4.31.7	100%
Abbreviated Functional Test	4.31.9	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration[2]	4.12.4	100%
Random Vibration[2]	4.12.5	100%
Acoustic Vibration[2]	4.12.6	100%
Leakage	4.11.8	100%

[1]This test shall be performed during the hot and cold dwells of the first and last cycles of the 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 4-63. Laser Firing Unit Qualification Test Requirements

Test	Section	Quantity Tested[1] X=3
Acceptance Tests[2]	Table 4-62	X
Performance Verification	4.10.4	
Resistance	4.31.8	X
Input Current[3]	4.31.7	X
Command Processing[3]	4.31.2	X
Output Firing Circuit[3]	4.31.3	X
Inhibit/Safing Circuitry[3]	4.31.4	X
Output Monitors[3]	4.31.5	X
Built-in Test[3]	4.31.6	X
Abbreviated Performance Verification[4]	4.10.5	

Input Current	4.31.7	X
LFU Abbreviated Functional Test	4.31.9	X
Environment Tests - Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	1
Fine Sand	4.14.10	1
Environment Tests - Operating	4.15.1	
Thermal Cycle	4.15.2	X
Thermal Vacuum	4.15.3	X
Humidity	4.15.4	X
Salt Fog	4.15.5	2
Temperature/Humidity/Altitude	4.15.6	X
Acceleration[4,5]	4.15.7	X
Sinusoidal Vibration[4,5]	4.15.8	X
Random Vibration[4,5]	4.15.9	X
Acoustic Vibration[4,5]	4.15.10	X
Shock[5,6]	4.15.11	X
EMI/EMC	4.15.12	2
Explosive Atmosphere	4.15.13	2
Repetitive Functioning	4.31.11	X
Output Monitoring	4.31.5	1
BIT Verification[7]	4.31.22	X
Circuit Protection	4.31.10	2
Leakage	4.11.8	X
Internal Inspection	4.11.7	X

[1]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.
[2]Each qualification test component shall successfully complete all acceptance tests before undergoing qualification testing.
[3]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.
[4]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
[5]Optical continuity shall be monitored using a flight fiber-optical cable in a flight configuration during all operating environmental tests.
[6]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.
[7]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.

Table 4-64. Laser-Initiated Detonator Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]
Component Examination	4.11	
Visual Examination[2,3]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Electrostatic Discharge	4.31.12	100%
Component Examination	4.11	
Leakage	4.11.8	100%
X-ray and N-ray	4.11.6	100%
Performance Verification[3,4]	4.10.4	
Optical Reflectivity	4.31.13	100%
Abbreviated Performance Verification[4,5]	4.10.5	
Optical Continuity	4.31.23	Lot Sample
Tensile Load[6]	4.14.11	Lot Sample
Environment Tests - Non-Operating and Operating[7]	4.14.1 4.15.1	
Artificial Aging[8]	4.14.3	Lot Sample
Thermal Cycle[4]	4.15.2.e	Lot Sample
Sinusoidal Vibration[5]	4.15.8	Lot Sample
Random Vibration[5]	4.15.9	Lot Sample
Shock[5]	4.15.11	Lot Sample
Safety No-Fire Test	4.31.24	Lot Sample
Optical Reflectivity	4.31.13	Lot Sample
Component Examination	4.11	
Visual Examination[2]	4.11.2	Lot Sample
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests	4.31.14	
Ambient Temperature	4.31.14.e	
All-Fire Power/Energy	4.31.14.b	1/6 Lot Sample
Operating Power/Energy	4.31.14.c	1/6 Lot Sample
High Temperature	4.31.14.f	
All-Fire Power/Energy	4.31.14.b	1/6 Lot Sample
Operating Power/Energy	4.31.14.c	1/6 Lot Sample
Low Temperature	4.31.14.g	
All-Fire Power/Energy	4.31.14.b	1/6 Lot Sample
Operating Power/Energy	4.31.14.c	1/6 Lot Sample

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of 30 units.
[2]Visual inspection shall include magnified inspection of the LID optical window for cracks, de-laminations, or misalignment.
[3]This test shall also be performed at the launch site.

[4]The optical reflectivity test shall be performed during the hot and cold dwells of the first, middle, and last thermal cycles. Optical continuity shall be continuously monitored during all other thermal cycles.
[5]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
[6]Any LIDs using fiber-optic pigtails shall be pull-tested to specification value and function within their performance requirements.
[7]Optical continuity shall be monitored using a flight-like fiber-optic cable during all operating environmental tests.
[8]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.

Table 4-65. Laser-Initiated Detonator Qualification Test Requirements

Test	Section	Quantity Tested[1]					
		SS[2]	5	5	SS[3]	SS[4]	105
Component Examination	4.11						
Visual Examination[5]	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[6]	4.10.4						
Optical Reflectivity	4.31.13	X	X	X	X	X	X
Electrostatic Discharge	4.31.12	X	X	X	X	X	X
Abbreviated Performance Verification[6,7]	4.10.5						
Optical Continuity	4.31.23	-	-	-	-	-	X
Statistical No-Fire Level	4.31.17	-	-	-	X	-	-
Statistical All-Fire Level	4.31.18	-	-	-	-	X	-
RF sensitivity[6]	4.31.25	-	-	-	-	-	X
Safety No-Fire Test	4.31.24	-	X	-	-	-	-
Optical Degradation Test	4.31.26	X	-	-	-	-	-
Environment Tests - Non-Operating and Operating[8]	4.14.1 4.15.1						
Storage Temperature	4.14.2	-	-	-	-	-	X
Transportation Vibration	4.14.4	-	-	-	-	-	X
Transportation Shock	4.14.5	-	-	-	-	-	X
Bench Handling Shock	4.14.6	-	-	-	-	-	X
Fungus Resistance	4.14.9	-	-	-	-	-	X
Fine Sand	4.14.10	-	-	-	-		X
Artificial Aging[9]	4.14.3	-	-	-	-	-	30
Thermal Cycle[6]	4.15.2.e	-	-	-	-	-	X
Humidity[6]	4.15.4	-	-	-	-	-	X
Salt Fog	4.15.5	-	-	-	-	-	X

Acceleration[7]	4.15.7	-	-	-	-	-	X
Sinusoidal Vibration[7]	4.15.8	-	-	-	-	-	X
Random Vibration[7]	4.15.9	-	-	-	-	-	X
Acoustic Vibration[7]	4.15.10	-	-	-	-	-	X
Shock[7]	4.15.11	-	-	-	-	-	X
Handling Drop	4.14.7	-	-	-	-	-	X
Tensile Load[10]	4.14.11	-	-	-	-	-	30
Abnormal Drop	4.14.8	-	-	X	-	-	-
Auto-Ignition	4.31.20	-	-	X	-	-	-
Component Examination	4.11						
Visual Examination[5]	4.11.2	-	X	-	-	-	X
Leakage	4.11.8	-	X	-	-	-	X
X-Ray and N-Ray	4.11.6	-	X	-	-	-	X
Firing Tests	4.31.14						
Ambient Temperature	4.31.14.e						
All-Fire Energy	4.31.14.b	-	1	-	-	-	15
Operating Energy	4.31.14.c	-	-	-	-	-	15
High-Operating Energy	4.31.14.d	-	-	-	-	-	5
High Temperature	4.31.14.f						
All-Fire Energy	4.31.14.b	-	2	-	-	-	15
Operating Energy	4.31.14.c	-	-	-	-	-	15
High-Operating Energy	4.31.14.d	-	-	-	-	-	5
Low Temperature	4.31.14.g						
All-Fire Energy	4.31.14.b	-	2	-	-	-	15
Operating Energy	4.31.14.c	-	-	-	-	-	15
High-Operating Energy	4.31.14.d	-	-	-	-	-	5

[1]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 the column.
[2]The SS quantity needed to perform a statistical firing series to determine the LID no-degradation energy for a given range of light frequencies shall be subjected to each test designated with an X.
[3]The SS quantity needed to perform a statistical firing series to determine the LID no-fire energy shall be subjected to each test designated with an X.
[4]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.
[5]Visual inspection shall include magnified inspection of the LID's optical window for cracks, delaminations, scratches, cleanliness, and misalignment.
[6]The optical reflectivity test shall be performed during the hot and cold dwells of the first, middle, and last thermal cycles. Optical continuity shall be continuously monitored during all other thermal cycles.
[7]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
[8]Optical continuity shall be monitored using a flight fiber-optic cable in a flight configuration during all operating environmental tests.

[9]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.
[10]Any LIDs using fiber-optic pigtails shall be pull-tested to specification value and function within their performance requirements.

Table 4-66. Laser-Initiated Detonator Service Life Extension Test Requirements

Test	Section	Quantity Tested[1]	
		1 Year X=5	3 Years X=10
Component Examination	4.11		
Visual Inspection[2]	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[3]	4.10.4		
Optical Reflectivity	4.31.13	X	X
Electrostatic Discharge	4.31.12	X	X
Abbreviated Performance Verification[3,4]	4.10.5		
Optical Continuity	4.31.23	X	X
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1		
Artificial Aging	4.14.3	-	X
Thermal Cycle[3]	4.15.2.e	X	X
Random Vibration[4]	4.15.9	X	X
Shock[4]	4.15.11	X	X
No-Fire Verification	4.31.24	X	X
Component Examination	4.11		
Visual Inspection[2]	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.31.14		
All-Fire Energy	4.31.14.b		
Ambient Temperature	4.31.14.e	1	3
High Temperature	4.31.14.f	2	3
Low Temperature	4.31.14.g	2	4

[1]To extend the service life of a component, sample components shall undergo each test required by the 1-year extension column or the 3-year extension column. All SLE samples shall be from the same production lot as the flight components and shall be stored with the flight component or in an environment that duplicates the storage conditions of the flight component.
[2]Visual inspection shall include magnified inspection of the LID optical window for cracks, delaminations, scratches, cleanliness, and misalignment.
[3]Performance verification tests shall be performed during the hot and cold dwells of the first,

middle, and last thermal cycles. Optical continuity shall be continuously monitored during all other thermal cycles.
[4]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests. Optical continuity shall be monitored using a flight-like fiber-optic cable during all operating environmental tests.

Table 4-67. Fiber-Optic Cable Assembly Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Inspection[1]	4.11.2	100%
Dimension Measurement	4.11.3	100%
Identification	4.11.5	100%
X-ray/N-ray[2]	4.11.6	100%
Performance Verification[3]	4.10.4	
Optical Transmission	4.31.16	100%
Tensile Load	4.12.7	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%

[1]Visual inspection shall include magnified inspection for cracks, delaminations, scratches, cleanliness, and misalignment.
[2]X-ray and/or N-ray are only required where applicable to adequately screen fiber-optic cable and connectors.
[3]This test shall be performed during the hot and cold dwells of the first and last thermal cycles using the main laser and BIT frequencies and power levels.

Table 4-68. Fiber-Optic Cable Assembly Qualification Test Requirements

Test	Section	Quantity Tested[1] (X=3)
Acceptance Tests	Table 4-67	X
Performance Verification[2]	4.10.4	
Optical Transmission[3]	4.31.16	X
Tensile Load[4]	4.14.11	X
Repetitive Function	4.30.19	X
Connector Mate/Demate	4.31.21	X
Abbreviated Performance Verification[5]	4.10.5	
Continuity	4.31.15	X
Environment Tests - Non-Operating	4.14.1	
Storage Temperature	4.14.2	X
Transportation Vibration	4.14.4	X
Transportation Shock	4.14.5	X
Bench Handling Shock	4.14.6	X
Fungus Resistance	4.14.9	X
Environment Tests - Operating	4.15.1	
Thermal Cycle[3]	4.15.2	X

Thermal Vacuum[3]	4.15.3	X
Humidity[3]	4.15.4	X
Salt Fog	4.15.5	X
Temperature/Humidity/Altitude[3]	4.15.6	X
Acceleration[5]	4.15.7	X
Sinusoidal Vibration[5]	4.15.8	X
Random Vibration[5]	4.15.9	X
Acoustic Vibration[5]	4.15.10	X
Shock[5]	4.15.11	X
Component Examination	4.11	
Visual Inspection	4.11.2	X
X-ray/N-ray[6]	4.11.6	X

[1]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.
[2]These tests shall be performed before the first and after the last non-operating environment test and before the first and after the last operating environment test.
[3]An optical transmission test shall be performed for these tests.
[4]Fiber-optic cables and connectors shall be pull-tested to specification value and function within their performance requirements.
[5]Abbreviated performance verification tests shall be performed during all dynamic operating environmental tests.
[6]X-ray and/or N-ray are only required where applicable to adequately screen fiber-optic cable and connectors.

4.31.1 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 IAW the acceptance, qualification, and age surveillance test matrices and accompanying requirements of this section.

4.31.2 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-V signal is applied for five 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 vehicle.

1. The firing unit's command and firing circuits shall trigger at 75% of the amplitude and 50% 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% amplitude and 150% 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 dropout for a period of 50 ms.

d. An LFU shall be tested to demonstrate that its response time is IAW 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.

4.31.3 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.

4.31.4 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 three seconds, and then powered up again. The unit shall power up in a safe state.

d. Manual safing plugs integral to the firing unit must be tested to ensure that they interrupt the 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.

4.31.5 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:

1. the status of all inhibits;
2. continuous spurious energy monitor and/or detection circuit on the input firing line capable of indicating at least one-tenth of the minimum input firing voltage;
3. indication of termination firing output;
4. the status of the Master Arm/Safe circuit;
5. the status or result of a BIT.

4.31.6 Built-in Test

A BIT using a low-power laser to verify the continuity of the 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. The 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 their performance specifications. Measurements shall be taken to ensure there is no spurious energy at the main laser firing frequency.

c. The BIT testing shall be performed with flight fiber-optic cable assemblies and a flight-like LID simulator.

4.31.7 Input Current

Input current of the firing unit shall be monitored to demonstrate that it satisfies all its performance requirements.

Input current to the firing unit's input power and arm power shall be sampled at a minimum rate of 1000 samples per second.

4.31.8 Resistance

Pin-to-pin and pin-to-case resistances of the firing unit shall be measured to demonstrate that it satisfies all performance requirements.

4.31.9 Laser Firing Unit Abbreviated Functional Test

An abbreviated functional test shall exercise an LFU's flight-critical functions while it is subjected to each required operating environment. This shall include subjecting the LFU to the fire command during each environment while monitoring function time and the optical output waveform to demonstrate that each satisfies all of its performance requirements. The LFU's output shall demonstrate that the power, frequency, and pulse duration meet its performance requirements.

4.31.10 Circuit Protection

A circuit protection test shall demonstrate that any circuit protection allows a firing unit to satisfy all of its performance requirements 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 of its performance requirements when subjected to the maximum input voltage of the unit's ground or airborne power source.

The firing unit shall not be damaged when it is subjected to the application of up to the OCV of the FTS power source or 45 Vdc, whichever is higher, to the power input port for a period of not less than five 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 V to the maximum specified voltage and back to 0 V 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 ms.

d. Any watchdog circuit satisfies all of its performance requirements.

e. A test of the firing unit shall 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 of its performance requirements when subjected to any reverse-polarity voltage that could occur during launch processing.

4.31.11 Laser Firing Unit Repetitive Function

This test shall demonstrate that an LFU satisfies all of its performance requirements 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 LFU

shall also function within its performance specification without degradation for 50% 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, pre-launch 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. Any LFUs that exceed 50% 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.

4.31.12 Electrostatic Discharge

A LID shall be tested to verify that it can withstand, without firing or degradation in performance, an ESD that it could experience from personnel or conductive surfaces.

This test shall subject the LID to a 25-kV, 500-pF discharge to any non-continuous conductive surface.

4.31.13 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.

4.31.14 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 of its performance requirements 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 it 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 of its performance requirements.

b. All-Fire Power. Each all-fire power test shall subject each initiator sample to the specified all-fire power for frequency, power, and pulse duration.

c. Operating Power. Each operating power test shall subject each initiator sample to the firing unit's manufacturer-specified operating intensity, frequency, and pulse duration.

1. If the operating power is unknown, the test shall use no less than 200% of the all-fire power.
2. The operating power 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 Power. This test shall subject each initiator to the firing unit's manufacturer-specified operating power and pulse duration plus a margin.

Initiators shall be tested to 150% of the operating power (i.e., a 50% margin on operating power).

e. Ambient Temperature. This test shall function each initiator sample while at ambient temperature.

f. High Temperature. Each high-temperature test shall function each initiator sample while it is subjected to the qualification high-temperature level.

g. Low Temperature. Each low-temperature test shall function each initiator sample while it is subjected to the qualification low temperature.

4.31.15 Continuity

The fiber-optic cable assembly attenuation loss shall be tested to ensure there are no optical fluctuations or dropouts.

4.31.16 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.

4.31.17 No-Fire Level

A no-fire power level test shall consist of a statistical firing series of initiator lot samples to determine the highest optical power level at which the initiator will not fire with a reliability of 0.999 with a 95% confidence level when subjected to a continuous optical energy. The test shall demonstrate that the no-fire power level is no less than the no-fire power level used in the FTS design and analysis. The worst-case power that a flight initiator experiences shall be a minimum of 20 dB below the no-fire test level.

4.31.18 All-Fire Level

An all-fire power level test shall consist of a statistical firing series of initiator lot samples to determine the lowest optical power level at which the initiator will fire with a reliability of 0.999 with a 95% confidence level when subjected to optical power simulating the firing unit output waveform characteristics. Each initiator sample shall be in its flight

configuration. The test shall demonstrate that the all-fire power level does not exceed the all-fire power level used in the FTS design and analysis.

4.31.19 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, pre-flight 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 2 times the maximum firing optical power for no less than 10 times the duration of the maximum firing pulse.

4.31.20 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 higher.
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.

4.31.21 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.

All connectors shall be mated and demated for at least five times the maximum expected number of cycles required for acceptance tests, pre-flight tests, and flight operations, including potential retests due to schedule delays, or 100 cycles, whichever is higher.

4.31.22 Built-In Test 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.

4.31.23 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.

4.31.24 Safety No-Fire Test

This test shall demonstrate that the initiator shall not fire or degrade when exposed to the worst-case optical power from a ground processing environment or vehicle systems plus a margin.

The initiator shall be exposed to the following for five minutes.

1. Focused sunlight.
2. A BIT laser energy 20 dB higher than maximum expected BIT power.
3. 20 dB higher than the maximum expected stray energy source.
4. The guaranteed no-fire level at the main firing and BIT frequencies.

4.31.25 Radio Frequency Sensitivity

The test shall subject samples of initiators to the maximum expected RF level plus a margin. The 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 Table 4-69 shall be used.

Table 4-69. 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

[1]CW = Continuous Wave.
[2]P = Pulsed modulation with pulse width of 1 µs and pulse repetition rate of 1 kHz.

8. The LIDs exposed to testing shall not fire and shall satisfy all performance specifications.

4.31.26 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% 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. A known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the required no-degradation.
2. The initiator shall be temperature-conditioned to the qualification high temperature.
3. The initiator shall be subjected to the test environment for a minimum of five 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.
5. 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.

4.32 Ordnance Interrupters

This section applies to any ordnance interrupter, including any rotor lead or booster charge that is used by the interrupter. Ordnance interrupter acceptance tests are listed in Table 4-70 and qualification tests are listed in Table 4-71. Rotor lead and booster charge tests appear in Table 4-72 (LATs), Table 4-73 (qualification), and Table 4-74 (SLE tests).

Table 4-70. Ordnance Interrupter Acceptance Test Requirements

Test	Section	Quantity Tested
Component Examination	4.11	
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	4.32.2	100%
Safety Tests	4.32.5	
Manual Safing	4.32.5.d	100%
Safing-Interlock Test	4.32.5.e	100%
Abbreviated Performance Verification	4.10.5	

Dynamic Performance	4.32.7	100%
Thermal Performance	4.32.6	100%
Environment Tests - Operating	4.12.1	
Thermal Cycle	4.12.2	100%
Thermal Vacuum	4.12.3	100%
Sinusoidal Vibration	4.12.4	100%
Random Vibration	4.12.5	100%
Acoustic Vibration	4.12.6	100%
X-ray	4.11.6	100%
Leakage	4.11.8	100%

Table 4-71. Ordnance Interrupter Qualification Test Requirements

Test	Section	Quantity Tested			
		X=SS	X=1[1]	X=6[2]	X=3[3]
Acceptance Tests	Table 4-70	-	X	X	-
Barrier Alignment	4.32.8	X	-	-	-
Safety Tests	4.32.5				
Extended Stall	4.32.5.c	-	X	-	-
Abnormal Drop	4.14.8	-	X	-	-
Containment	4.32.5.a	-	-	-	1
Barrier Functionality	4.32.5.b	-	-	-	2
Safing Verification	4.32.5.f	-	-	X	-
Performance Verification	4.10.4				
Functional Tests[5]	4.32.2	-	-	X	-
Safety Tests	4.32.5	-	-	X	-
Manual Safing	4.32.5.d	-	-	X	-
Safing-Interlock Test	4.32.5.e	-	-	X	-
Abbreviated Performance Verification	4.10.5				
Dynamic Performance	4.32.7	-	-	X	-
Thermal Performance	4.32.6	-	-	X	-
Cycle Life	4.32.3	-	-	2	-
Environment Tests – Non-Operating	4.14.1				
Storage Temperature	4.14.2	-	-	X	-
Transportation Vibration	4.14.4	-	-	X	-
Transportation Shock	4.14.5	-	-	X	-
Bench Handling Shock	4.14.6	-	-	X	-
Fungus Resistance	4.14.9	-	-	1	-
Fine Sand	4.14.10	-	-	1	-
Handling Drop	4.14.7	-	-	X	-
Environment Tests – Operating	4.15.1				
Thermal Cycle	4.15.2	-	-	X	-
Humidity	4.15.4	-	-	X	-
Salt Fog	4.15.5	-	-	X	-

Temperature/Humidity/Altitude	4.15.6			X	
Acceleration	4.15.7	-	-	X	-
Sinusoidal Vibration	4.15.8	-	-	X	-
Random Vibration	4.15.9	-	-	X	-
Acoustic Vibration	4.15.10	-	-	X	-
Shock	4.15.11	-	-	X	-
Explosive Atmosphere[4]	4.15.13	-	-	2	-
Stall	4.32.4	-	-	X	-
X-ray	4.11.6	-	-	X	-
Leakage	4.11.8	-	-	X	-
Internal Inspection	4.11.7	-	-	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 five times for this test.
[5]All ordnance transfer gaps within the ordnance interrupter shall meet Section 4.34 for ordnance interfaces.

Table 4-72. Ordnance Interrupter Rotor Lead and Booster Charge Lot Acceptance Test Requirements[1]

Test	Section	Quantity Tested[2]
Component Examination	4.11	
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%
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1	
Artificial Aging[3]	4.14.3	Lot Sample
Thermal Cycle[4]	4.15.2.e	Lot Sample
Component Examination	4.15.11	
Leakage	4.11.8	Lot Sample
X-ray and N-ray	4.11.6	Lot Sample
Firing Tests[5]	4.32.9	
High Temperature	4.32.9.c	1/2 Lot Sample
Low Temperature	4.32.9.d	1/2 Lot Sample

[1]This table applies to any rotor lead or booster charge that is used inside an ordnance interrupter device.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of nine units.
[3]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of five years. If it is not performed, the lot will have an initial service life of one year.
[4]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.
[5]When the lot cannot be evenly divided, the extra sample shall be fired at low temperature.

Table 4-73. Ordnance Interrupter Rotor Lead and Booster Charge Qualification Test Requirements[1]

Test	Section	Quantity Tested[2] X=21
Component Examination	4.11	
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
Environment Tests - Non-Operating and Operating[3]	4.14.1 4.15.1	
Artificial Aging[4]	4.14.3	10
Thermal Cycle	4.15.2.e	X
Sinusoidal Vibration	4.15.8	X
Random Vibration	4.15.9	X
Shock	4.15.11	X
Component Examination	4.11	
X-ray and N-ray	4.11.6	X
Leakage	4.11.8	X
Firing Tests	4.32.9	
Ambient Temperature	4.32.9.b	7
High Temperature[5]	4.32.9.c	7
Low Temperature[5]	4.32.9.d	7

[1]This table applies to any rotor lead or booster charge that is used inside an ordnance interrupter device.
[2]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.
[3]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.
[4]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of five years. If it is not performed, the lot will have an initial service life of one year.
[5]If artificial aging is performed, half of the units that have undergone artificial aging shall be

fired at high temperature and half at low temperature.

Table 4-74. Ordnance Interrupter Rotor Lead and Booster Charge Service Life Extension Test Requirements[1]

Test	Section	Quantity Tested[2]	
		1 Year X=5	5 Years 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
Environment Tests - Non-Operating and Operating[3]	4.14.1 4.15.1		
Artificial Aging	4.14.3	-	X
Thermal Cycle	4.15.2.e	X	X
Component Examination	4.11	-	-
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Firing Tests	4.32.9		
High Temperature	4.32.9.c	2	5
Low Temperature	4.32.9.d	3	5

[1]This table applies to any rotor lead or booster charge that is used by an ordnance interrupter device.
[2]To extend the service life of a rotor lead or booster charge, sample components shall undergo each test required by the 1-year extension column or the 5-year extension column. All SLE samples shall be from the same production lot as the flight components and shall be stored with the flight component or in an environment that duplicates the storage conditions of the flight component.
[3]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.

4.32.1 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 of its performance requirements when subjected to each non-operating and operating environment.

4.32.2 Functional Tests

An ordnance interrupter 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 materials 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%.
3. The insulation resistance between all insulated parts shall be 2 MΩ or more.

b. The ordnance interrupter transition time shall be tested 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 shall be displayed when the ordnance interrupter is armed.
2. The presence of the safe indication shall be displayed when the ordnance interrupter is safed.

d. The continuity and isolation test shall measure all pin-to-pin and pin-to-case resistances and demonstrate that each satisfies all of its performance requirements.

1. Isolation resistance shall be 2 MΩ or more.
2. The test shall measure the continuity of the internal circuits to demonstrate that the continuity resistances satisfy their performance specifications.

4.32.3 Cycle Life

This test shall demonstrate that the S&A transition, such as rotational or sliding operation, satisfies all of its performance requirements. The test shall demonstrate the ability of an ordnance interrupter device to satisfy all of its performance requirements when subjected to five times the maximum predicted number of safe/arm cycles.

4.32.4 Stall

A stall test shall demonstrate that an ordnance interrupter device satisfies all of its performance requirements after being locked in its safe position and subjected to an operating arming voltage for the maximum time that could occur inadvertently. The device must still be useable for flight or five minutes, whichever is greater.

4.32.5 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 LVI is fired, the ordnance output will not propagate to an ETS. This demonstration shall include all of the following.

(1) With the ETS configured for flight, the test shall consist of firings at high and low temperature extremes.

(2) The high-temperature firing shall be initiated at the qualification high temperature.

(3) The low-temperature firing shall be initiated at the qualification low temperature.

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 higher.

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 IAW 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 IAW 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 445 N (100 lbf) tension or a torque of 11.3 N-m (100 in-lb.) 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.

4.32.6 Thermal Performance

A thermal performance test shall demonstrate that an ordnance interrupter device satisfies all of its performance requirements 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.

4.32.7 Dynamic Performance

A dynamic performance test shall demonstrate that an ordnance interrupter device satisfies all of its performance requirements when subjected to the dynamic operational environments, including random vibration, sinusoidal vibration, acoustic vibration, 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 environment test.

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.

4.32.8 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% 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% confidence level. This test may employ a reusable ordnance interrupter subassembly that simulates the flight configuration.

1. The number of required test units shall be determined by the susceptibility of the electro-mechanical mechanism to degradation during firing and the ability for it to be reloaded with ordnance for subsequent tests.
2. A known statistical sensitivity test, such as Bruceton, Langlie, or Neyer, shall be used to demonstrate the no-fire rotor angle and shall be repeated to demonstrate the all-fire rotor angle.

4.32.9 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 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 of its performance requirements.

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 of its performance requirements.

b. Ambient Temperature. Each sample shall be fired at ambient temperature.

c. High Temperature. Each sample shall be fired at the qualification high temperature.

d. Low Temperature. Each sample shall be fired at the qualification low temperature.

4.33 Percussion-Initiated Device

This section applies to any PID that is part of an FTS, including any primer charge it uses. Table 4-75 identifies LATs. Table 4-76 contains qualification tests. Table 4-77 contains acceptance tests for PID primer charges. Table 4-78 lists qualification tests for PID primer charges. Table 4-79 describes SLE tests.

Table 4-75. Percussion-Initiated Device Lot Acceptance Test Requirements[1]

Test	Section	Quantity Tested[2]
Component Examination	4.11	
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%
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1	
Artificial Aging[3]	4.14.3	Lot Sample
Thermal Cycle	4.15.2.e	Lot Sample
Sinusoidal Vibration[4]	4.15.8	Lot Sample
Random Vibration[4]	4.15.9	Lot Sample
Shock[4]	4.15.11	Lot Sample
Safety Tests	4.32.2	Lot Sample
Component Examination	4.11	
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	4.33.3.a	
Ambient Temperature	4.33.3.b	1/3 Lot Sample

High Temperature	4.33.3.c	1/3 Lot Sample
Low Temperature	4.33.3.d	1/3 Lot Sample

[1]The tests required by this table apply to a fully assembled PID, including all internal ordnance.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of nine units.
[3]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.
[4]These tests shall be performed without the safing interlock installed.

Table 4-76. Percussion-Initiated Device Lot Qualification Test Requirements

Test	Section	Quantity Tested[1]	
		X=5	X=21
Component Examination	4.11		
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		
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1		
Storage Temperature	4.14.2	-	X
Transportation Vibration	4.14.4	-	X
Transportation Shock	4.14.5	-	X
Bench Handling Shock	4.14.6	-	X
Fungus Resistance	4.14.9	-	X
Fine Sand	4.14.10	-	X
Handling Drop	4.14.7	-	X
Artificial Aging[2]	4.14.3	-	X
Thermal Cycle	4.15.2.e	-	X
Humidity	4.15.4	-	X
Salt Fog	4.15.5	-	X
Temperature/Humidity/Altitude	4.15.6	-	X
Acceleration[3]	4.15.7	-	X
Sinusoidal Vibration[3]	4.15.8	-	X
Random Vibration[3]	4.15.9	-	X
Acoustic Vibration[3]	4.15.10	-	X
Shock[3]	4.15.11	-	X
Safety Tests	4.32.2	X	X
Abnormal Drop	4.14.8	1	-
Auto-Ignition[4]	4.32.6	X	-
Component Examination	4.11		
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[5]
Firing Tests	4.33.3.a		
Ambient Temperature	4.33.3.b	-	6
High Temperature	4.33.3.c	-	6
Low Temperature	4.33.3.d	-	6

[1]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.
[2]This step is optional. If artificial aging is performed prior to testing, the lot will have an initial service life of three years. If it is not performed, the lot will have an initial service life of one year.
[3]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.
[4]An auto-ignition test applies to any ordnance internal to a PID. The ordnance may undergo the test in a subassembly.
[5]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.

Table 4-77. Percussion-Initiated Detonator Primer Charge Lot Acceptance Test Requirements[1]

Test	Section	Quantity Tested[2]	
Component Examination	4.11		
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%	
Environment Tests - Operating	4.15.1		
Thermal Cycle	4.15.2.e	Lot Sample	-
Component Examination	4.11		
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	4.33.5		
All-Fire Impact[3]			
Ambient Temperature	4.33.5.b	1/3 Lot Sample	-
High Temperature	4.33.5.c	1/3 Lot Sample	-
Low Temperature	4.33.5.d	1/3 Lot Sample	-
All-Fire Energy Level[4]	4.33.4	-	SS[5]

[1]Each test required by this table applies to a primer charge before its installation in a PID.
[2]A lot sample shall be 10% of the lot (rounded up) with a minimum of 30 units.
[3]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.
[4]This test shall demonstrate that the production lot all-fire level is in-family with the

qualification baseline.
[5]The SS size shall be determined by the all-fire energy sensitivity test methodology used.
Note: The SS is NOT the same as the lot sample.

Table 4-78. Percussion-Initiated Detonator Primer Charge Qualification Test Requirements

Test	Section	Quantity Tested	
		X=SS[1]	X=105
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
Statistical All-Fire Energy Level[2]	4.32.4	X	-
Environment Tests – Operating	4.15.1		
Thermal Cycle	4.15.2.e	-	X
Component Examination	4.11		
Visual Examination	4.11.2	-	X
Leakage	4.11.8	-	X
X-ray and N-ray	4.11.6	-	X
Primer Charge Firing Tests	4.33.5		
Ambient Temperature	4.33.5.b		
All-Fire Impact[3]	4.33.5.a	-	15
Operational Impact[4]	4.33.5.a	-	15
2 x Operational Impact	4.33.5.a	-	5
High Temperature	4.33.5.c		
All-Fire Impact[3]	4.33.5.a	-	15
Operational Impact[4]	4.33.5.a	-	15
2 x Operational Impact	4.33.5.a	-	5
Low Temperature	4.33.5.d		
All-Fire Impact[3]	4.33.5.a	-	15
Operational Impact[4]	4.33.5.a	-	15
2 x Operational Impact	4.33.5.a	-	5

[1]The SS size shall be determined by the all-fire energy sensitivity test methodology used.
[2]This test shall demonstrate that the production lot is a representative sample of the all-fire baseline established during qualification testing.
[3]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.
[4]This test shall subject each sample primer charge to no less than the operational impact that it would receive from the PID assembly according to the device's performance specifications.

Table 4-79. Percussion-Initiated Detonator Service Life Extension Test Requirements

Test	Section	Quantity Tested[1]	
		1 Year X=5	3 Years X=10
Component Examination	4.11		
Visual Examination	4.11.2	X	X
Leakage	4.11.8	X	X
X-ray and N-ray	4.11.6	X	X
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1		
Artificial Aging	4.14.3	-	X
Thermal Cycle	4.15.2.e	X	X
Random Vibration[2]	4.15.8	X	X
Shock[2]	4.15.11	X	X
Component Examination	4.11		
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	4.33.3.a		
High Temperature	4.33.3.c	2	5
Low Temperature	4.33.3.d	3	5

[1]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. Each test required by this table applies to a fully assembled PID, including all internal ordnance.
[2]These tests shall be performed with the firing pin removed.

4.33.1 General

Any PID or primer charge shall satisfy each test or analysis identified by any table of this section to demonstrate that it satisfies all of its performance requirements when subjected to each non-operating and operating environment.

NOTE	These devices are also known as lanyard pull initiators and separation plane initiators.

4.33.2 Safety Tests

a. General. Each safety test shall demonstrate that a PID is safe to handle and use on the vehicle.

b. No-Fire Pull Test. A no-fire pull test shall demonstrate that when a PID is pulled with the guaranteed no-fire pull force:

(1) the device will not fire;

(2) the device's primer initiation assembly will not disengage;

(3) the device will continue to satisfy all of its performance requirements including pull force versus distance.

c. Safing-Interlock Locking. A safing-interlock test shall demonstrate that a PID, with its safing-interlock in place, will continue to satisfy all of its performance requirements 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) 2 times the worst-case pull force that the device can experience after it is installed on the vehicle.

1. The safing interlock shall remain engaged when subjected to a minimum 890 N (200 lbf) pull force.
2. The device's firing assembly movement shall be less than one half the no-fire pull distance.

d. Safing-Interlock Retention Test. A safing-interlock retention test shall demonstrate that a PID's safing-interlock cannot be removed when a no-fire pull or greater force is applied to the PID 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 445 N (100 lbf) when the lanyard is pulled with the no-fire pull force or greater.

4.33.3 Percussion-Initiated Device Firing Tests

a. General. Each firing test of a PID shall satisfy all of the following.

(1) The test shall demonstrate that the device satisfies all of its performance requirements 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 of its performance requirements.

(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.

d. Low Temperature. A low-temperature test shall initiate each ordnance sample while it is subjected to no higher than the qualification low temperature.

4.33.4 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% confidence level. The test shall use a firing pin and configuration that is representative of the flight configuration.

4.33.5 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 of its performance requirements when subjected to all qualification stress conditions.

All PIDs 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 of its 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.

d. Low Temperature. A low-temperature test shall initiate each ordnance sample while it is subjected to no higher than the qualification low temperature

4.33.6 Auto-Ignition

This test shall demonstrate that any ordnance internal to a PID 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 longer.

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.

4.34 Explosive Transfer System, Ordnance Manifolds, and Destruct Charges

This section applies to any ETS, ordnance manifold, or destruct charge. Table 4-80 contains LATs for all three components. Table 4-81 contains qualification tests for destruct charges. Table 4-82 contains ETS and ordnance manifold qualification tests. Table 4-83 contains SLE tests for all three components.

Table 4-80. Explosive Transfer System, Ordnance Manifold, and Destruct Charge Lot Acceptance Test Requirements

Test	Section	Quantity Tested[1]		
		Ordnance Manifolds[2,3]	ETS[4]	Destruct Charges
Component Examination	4.11			
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%
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1			
Artificial Aging[5]	4.14.3	Lot Sample	Lot Sample	Lot Sample
Thermal Cycle	4.15.2.e	Lot Sample	Lot Sample	Lot Sample
Sinusoidal Vibration	4.15.8	Lot Sample	Lot Sample	Lot Sample
Random Vibration	4.15.9	Lot Sample	Lot Sample	Lot Sample
Shock	4.15.11	Lot Sample	Lot Sample	Lot Sample
Tensile Load	4.14.11	-	Lot Sample	Lot Sample
Component Examination	4.11			
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	4.34.2			
Ambient Temperature	4.34.2.b	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample
High Temperature	4.34.2.c	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample
Low Temperature	4.34.2.d	1/3 Lot Sample	1/3 Lot Sample	1/3 Lot Sample

[1]A lot sample shall be 10% of the lot (rounded up) with a minimum of nine units.
[2]Any inert manifold need only undergo visual examination and dimension measurement.
[3]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.
[4]The required quantity applies to each configuration of ETL end-tip.
[5]This step is optional. If artificial aging is performed, the lot will have an initial service life of 3, 5, or 10 years as indicated in Subsection 4.14.3. If it is not performed, the lot will have an initial service life of 1 year.

Table 4-81. Destruct Charge Qualification Test Requirements

Test	Section	Quantity Tested			
		X=6	X=2	X=1	X=21
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
Environment Tests - Non-Operating and Operating	4.14.1 4.15.1				
Storage Temperature	4.14.2	-	-	-	X
Transportation Vibration	4.14.4	-	-	-	X
Transportation Shock	4.14.5	-	-	-	X
Bench Handling Shock	4.14.6	-	-	-	X
Fungus Resistance	4.14.9	-	-	-	X
Fine Sand	4.14.10	-	-	-	X
Artificial Aging[1]	4.14.3	-	-	-	10
Thermal Cycle	4.15.2.e	-	-	-	X
Humidity	4.15.4	-	-	-	X
Salt Fog	4.15.5	-	-	-	X
Acceleration	4.15.7	-	-	-	X
Sinusoidal Vibration	4.15.8	-	-	-	X
Random Vibration	4.15.9	-	-	-	X
Shock	4.15.11	-	-	-	X
Handling Drop	4.14.7	-	-	-	X
Abnormal Drop	4.14.8	-	-	X	-
Tensile Load	4.14.11	-	-	-	X
Component Examination	4.11				
Visual Examination	4.11.2	-	-	-	X
Leakage	4.11.8	-	-	-	X
X-ray and N-ray	4.11.6	-	-	-	X
Penetration Margin Test[2]	4.34.3				
High Temperature	4.34.2.c	3	-	-	-
Low Temperature	4.34.2.d	3	-	-	-
Propellant Detonation	4.34.4	-	X	-	-

Firing Tests	4.34.2				
Ambient Temperature	4.34.2.b	-	-	-	7
High Temperature[3]	4.34.2.c	-	-	-	7
Low Temperature[3]	4.34.2.d	-	-	-	7

[1]This step is optional. If artificial aging is performed, the lot will have an initial service life of 3, 5, or 10 years as indicated in Subsection 4.14.3. If it is not performed, the lot will have an initial service life of 1 year.
[2]One third of the sample shall be functioned at minimum standoff and two thirds of the sample at maximum standoff.
[3]If artificial aging is performed, half of the units that have undergone artificial aging shall be fired at high temperature and half at low temperature.

Table 4-82. Explosive Transfer System and Ordnance Manifold Qualification Test Requirements

Test	Section	Quantity Tested[1,2]	
		X=1	X=21
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
Environment Test - Non-Operating and Operating	4.14.1 4.15.1		
Storage Temperature	4.14.2	-	X
Transportation Vibration	4.14.4	-	X
Transportation Shock	4.14.5	-	X
Bench Handling Shock	4.14.6	-	X
Fungus Resistance	4.14.9	-	X
Fine Sand	4.14.10	-	X
Artificial Aging[3]	4.14.3	-	10
Thermal Cycle	4.15.2.e	-	X
Humidity	4.15.4	-	X
Salt Fog	4.15.5	-	X
Acceleration[5]	4.15.7	-	X
Sinusoidal Vibration[4,5]	4.15.8	-	X
Random Vibration[4,5]	4.15.9	-	X
Shock[4,5]	4.15.11	-	X
Handling Drop	4.14.7	-	X
Abnormal Drop	4.14.8	X	-
Tensile Load	4.14.11	-	X
Component Examination	4.11		
Visual Examination	4.11.2	-	X
Leakage	4.11.8	-	X

X-ray and N-ray	4.11.6	-	X
Firing Tests	4.34.2		
Ambient Temperature	4.34.2.b	-	7
High Temperature	4.34.2.c	-	7
Low Temperature	4.34.2.d	-	7

[1]The quantity of test samples required by the column applies to ETLs and explosive manifolds with internal ordnance.
[2]The required quantity applies for each configuration of ETL end-tip.
[3]This step is optional. If artificial aging is performed, a lot will have an initial service life of 3, 5, or 10 years as indicated in Subsection 4.14.3. If it is not performed, the lot will have an initial service life of 1 year.
[4]Any ETS shall undergo this test attached to a dynamically equivalent test fixture that simulates each flight-configured interface.
[5]Any ETS manifold and destruct charge shall undergo this test with its ETS assembly attached.

Table 4-83. Explosive Transfer System, Explosive Manifold, and Destruct Charge Service Life Extension Test Requirements

Test	Section	Quantity Tested[1]		
		1 Year[2] X=5	3 Years[3] X=10	5 Years[4] 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
Environment Test - Non-Operating and Operating[5]	4.14.1 4.15.1			
Artificial Aging	4.14.3	-	X	X
Thermal Cycle	4.15.2.e	X	X	X
Random Vibration	4.15.9	X	X	X
Shock	4.15.11	X	X	X
Tensile Load	4.14.11	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	4.34.2			
High Temperature	4.34.2.c	2	5	5
Low Temperature	4.34.2.d	3	5	5

[1]The quantity required by each column applies for each configuration of ETL 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.

[2]5 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.
[3]Devices that use deflagration to detonation interfaces or that use a small ordnance load, such as in a shock tube, may only be extended three years.
[4]10 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.
[5]For any explosive manifold with internal ordnance, the ordnance may undergo each test installed in the manifold or separately.

4.34.1 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 of its performance requirements when subjected to each non-operating and operating environment.

4.34.2 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 of its performance requirements 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 of its performance requirements 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 of its performance requirements.

   (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.

d. Low Temperature. A low-temperature test shall initiate each ordnance sample while it is subjected to no higher than the qualification low temperature.

4.34.3 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 severing or penetrating no less than 150% of the thickness of the target material.

1. Choose the destruct/terminate charge margin option below.

- Option 1, Severance Margin. Take a single-target plate with a thickness that is no less than 150% of the flight material to be cut and verify that firing of the destruct charge severs the target plate.
- Option 2, Penetration Margin. Take one or more target plates with a combined (stacked) thickness that is 150% or greater of the flight material to be cut and verify that firing of the destruct charge achieves 150% penetration into the target plate(s) (stack). Severance of the entire stack is not required so long as the depth of penetration is 150% of the flight material thickness.

2. Both options require a witness plate and a target plate(s). Witness plates shall be thick enough to measure the depth of the cut without cutting all the way through the plate.

   a. Witness plates provide a measure of process control throughout the production life of the destruct charge, ensuring each lot is in-family. Target plates provide a well-defined pass-fail demonstration of destruct ordnance performance. Witness plate penetration data will be evaluated to determine the pass-fail criteria for subsequent LATs and SLE tests.
   b. Witness plate material shall be consistent throughout qualification and subsequent LAT and SLE. Witness plate material (as well as target plate material) shall be approved by Range Safety. Witness plate material must have adequate properties to assess performance.
   c. Temperature extremes for the margin test shall match the temperature extremes required by LAT/SLE for the ordnance, target, and witness plates. Use of actual MPE temperatures rather than default temperatures may be acceptable for supplemental margin tests, where LAT/SLE comparisons are not required by Range Safety.
   d. Witness plates and targets may be combined into a single test set-up by placing the target material under half of the charge and a witness plate under the other half of the charge. Test set-up, including charge set-up, shall be approved by Range Safety. Test set-ups for various testing should be consistent so as to allow for in-family comparison.

4.34.4 Propellant Detonation

A propellant detonation test or analysis shall demonstrate that a destruct charge will not detonate the propellant of its intended target.

4.35 Ordnance Interfaces and Manifold Qualification

4.35.1 General

This section applies to any ordnance interface or manifold. Each ordnance interface or manifold shall undergo a qualification test that demonstrates that the item satisfies its performance specifications with a reliability of 0.999 at a 95% confidence level.

This requirement includes any internal gaps in an ordnance component.

4.35.2 Interfaces

A qualification test of an ordnance interface shall demonstrate its 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 7.6 mm (0.30 inches) shall not be used.

c. The test shall account for performance variability due to qualification temperature extremes.

4.35.3 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 PIDs.
2. The 0.999 at 95% requirement shall be verified using one of the following methods.
   a. A known statistical sensitivity test 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% confidence level. Any statistical sensitivity method acceptable to safety may be used (e.g., Bruceton, Langlie, Neyer, etc.).
   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% of the combined minimum system gap
3. Testing shall be performed at qualification low temperature.

4.35.4 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 PIDs, PIs, ordnance delays, and shock tubes.
2. The 0.999 at 95% reliability 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% 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% confidence level.

c. Firing all of the following units to demonstrate a sufficient gap margin:

(1) 5 units using 80% of a nominal donor charge load across the maximum gap at qualification cold temperature;

(2) 5 units using 120% 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.

4.36 Shock and Vibration Isolators

Table 4-84 contains acceptance tests for shock and vibration isolators. Table 4-85 contains qualification tests.

Table 4-84. Shock And Vibration Isolator Acceptance Test Requirements1

Test	Section	Quantity Tested
Component Examination	4.11	
Visual Examination	4.11.2	100%
Dimension Measurement	4.11.3	100%
Performance Verification Tests	4.10.4	
Load Deflection	4.36.2	100%
Dynamic Response	4.36.3	100%

[1]Each isolator shall undergo the tests required by this table in a configuration that demonstrates that the isolator satisfies all of its performance requirements. The test configuration need not be the flight configuration.

Table 4-85. Shock and Vibration Isolator Qualification Test Requirements

Test	Section	Quantity Tested[1]
Component Examination	4.11	
Visual Examination	4.11.2	3
Dimension Measurement	4.11.3	3
Performance Verification Tests	4.10.4	
Load Deflection[2]	4.36.2	3
Dynamic Response[2]	4.36.3	3
Characterization Tests[3]	4.36.4	
Thermal Performance	4.36.4.a	3
Compression	4.36.4.b	3

[1]The 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.
[2]The test configuration need not be the flight configuration and only requires testing in one

vibration axis.
[3]The test configuration must be in a flight-like configuration. Characterization tests shall be performed in three perpendicular axes.

4.36.1 General

Any isolator shall satisfy each test or analysis identified by Table 4-84 to demonstrate that it has repeatable performance and is free of any workmanship defects.

4.36.2 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.

4.36.3 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. The pass/fail criteria of isolators' natural frequency shall be ±10% of the natural frequency used for qualification testing.

4.36.4 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 in to the qualification test margin will become the tolerance used for the 100% screen test in Subsection 4.36.3. The following tests shall be performed.

a. Thermal Response. Isolators shall be subjected to the dynamic response tests of Subsection 4.36.3 at ambient and qualification temperature extremes.

b. Acceleration Response. Isolators shall be subjected to the dynamic response tests of Subsection 4.36.3 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 in to hardmount qualification.

CHAPTER 5

Flight Termination System Component, Subsystem, and System Pre-launch Test and Launch Requirements

5.1 General

An FTS, its subsystems, and components shall undergo the pre-flight tests required in this chapter to demonstrate that the system satisfies all of its performance requirements during pre-launch, countdown, and vehicle flight. If the integrity of the system, subsystem, or component is compromised after successful completion of any pre-flight test 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 pre-flight 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. 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 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.

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, 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 one day. Data shall be provided in a timely manner that allows Range Safety sufficient time to review documentation that supports program schedule.

A detailed description with any supporting data shall be provided in writing within two weeks 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 in a timely manner that allows sufficient time to review documentation that 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., TM) 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. Pre-flight component test equipment tolerances, instrumentation/sensor error, and calibration error shall be quantified and factored in to pass/fail criteria.

5.1.7 Flight Termination System 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 pre-launch tests, launch, or whenever the FTS is powered up.

1. Any 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 TM measurements.

d. The range user shall provide synthesized FTS parameter channel identification/ calibration TM playback data that is compatible with range instrumentation. The range user shall contact each affected range for specific requirements for media and format.

1. The TM playback is used to facilitate the setup of real-time recorders, certify de-commutation capability, and verify displays.
2. All FTS measurements shall be varied during playback to reflect expected pre-launch 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 Pre-flight Component Tests

5.2.1 Pre-flight Testing

A component shall undergo one or more pre-flight 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 Pre-flight Test Scope

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.

1. Component certification tests are conducted on FTS components to certify them for flight before installation in a higher assembly or vehicle.
2. Tests are usually performed in a laboratory-type environment and include electrical and functional tests.
3. These tests may be required to be conducted at ambient and workmanship high and low temperatures.
4. Certification tests are designed to detect changes in performance since the manufacturer acceptance test or the last range certification test was carried out.
5. 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.
6. 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. Manually Activated Silver-Zinc Batteries. A battery shall undergo pre-flight processing and testing that satisfies all of the following.

(1) Batteries shall be conditioned and processed to ensure they meet critical performance parameters. Pre-flight 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) Coupon cells associated with the flight batteries shall be tested IAW the capacity verification test in Table 4-32.

1. Coupon cell testing shall be completed prior to the start of flight battery processing/testing. 2. For secondary (rechargeable) batteries, coupon cell testing shall validate every charge 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 4-32 (note 3).

(4) The test results from the coupon and battery tests of item (2) and item (3) above 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 OCV 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 OCV 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 4-28 (note 6) for remotely activated Ag-Zn batteries and Table 4-30 (note 7) for thermal batteries.

c. Nickel-Cadmium Batteries. A battery shall undergo pre-flight processing and testing that satisfies all of the following.

(1) Batteries shall be conditioned and processed to ensure they satisfy all performance parameters. Pre-flight 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 4-36 (note 4).

1. Testing shall be performed within four weeks prior to launch. 2. Testing shall be performed at the launch site.

(3) The test results from the battery acceptance tests of Table 4-36 shall be compared to data from the pre-flight tests. The flight battery test data shall be evaluated to identify any out-of-family performance.

d. Lithium-Ion Batteries. A battery shall undergo pre-flight processing and testing that satisfies all of the following.

(1) Batteries shall be conditioned and processed to ensure they satisfy all performance parameters. Pre-flight 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 4-40 (note 6).

1. Testing shall be performed within four weeks prior to launch. 2. Testing shall be performed at the launch site.

(3) The test results from the battery acceptance tests of Table 4-40 shall be compared to data from the pre-flight 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 OCV are only due to a self discharge.

e. Lead-Acid Batteries. A battery shall undergo pre-flight processing and testing that satisfies all of the following.

(1) Batteries shall be conditioned and processed to ensure they satisfy all performance parameters. Pre-flight 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 4-44 (note 4).

1. Testing shall be performed within four weeks prior to launch.
2. Testing shall be performed at the launch site.

(3) The test results from the battery acceptance tests of Table 4-44 shall be compared to data from the pre-flight tests. The flight battery test data shall be evaluated to identify any out-of-family performance.

5.2.4 Pre-flight Testing of a Safe-and-Arm Device With an Internal Low-Voltage Initiator

An internal LVI in a SAD shall undergo a pre-flight test that satisfies all of the following.

a. The SAD 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.

NOTE	Most LVIs in SADs incorporate EEDs.

b. Each SAD shall undergo the required tests at ambient temperature IAW Table 4-47 (note 1).

5.2.5 Acceleration-Armed Safe-and-Arm Devices

a. Certification testing shall be conducted on all acceleration-armed SADs before installation on the 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 Pre-flight Testing of an External Low-Voltage Initiator

An external LVI that is part of a SAD shall undergo a pre-flight 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.

NOTE	Most LVIs in SADs incorporate 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 4-49 (note 2).

5.2.7 Pre-flight Testing of an Exploding Bridgewire/Exploding Foil Initiator

An EBW/EFI shall undergo a pre-flight 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 4-58 (note 2).

5.2.8 Pre-flight Testing of a Laser-Initiated Detonator

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 4-64 (note 3).

5.2.9 Pre-flight Testing for Flight Termination Receivers and Other Electronic Components

This section includes any component that contains piece-part circuitry (such as a command receiver decoder, 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 vehicle.
3. Alternate procedures for testing the component on the vehicle may be performed.
4. An acceptance test may be substituted for the pre-flight test if it 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 Pre-flight 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 vehicle.
3. Alternate procedures for testing the component on the vehicle may be performed.
4. An acceptance test may be substituted for the pre-flight test if it is performed no earlier than 180 calendar days before flight.

b. Each component shall undergo the required tests at ambient temperature IAW Table 4-62 (note 1).

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 Pre-flight Testing for Flight Termination System 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 vehicle.

4. Alternate procedures for testing the component on the vehicle may be performed.
5. An acceptance test may be substituted for the pre-flight test if it is performed within the required timelines.

b. Each component shall undergo the required tests at ambient temperature IAW Table 4-19 (note 2), Table 4-22 (note 2), or Table 4-23 (note 2), as applicable.

c. Pressurized lines that control FTS valves shall not leak when proof-tested in their final flight configuration at the MEOP 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 Pre-launch Subsystem and System-Level Tests

It is important to note that an FTS shall undergo pre-flight subsystem and system-level testing after the components are installed on a vehicle.

5.3.1 Test Data

Data obtained from this test shall be compared to data from the pre-flight 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-level tests are the final checkouts of an FTS.
2. Subsystem tests may be performed during or after system assembly.
3. Monitoring may be accomplished either through TM or a hard line to the GSE.

5.3.3 Radio Frequency System Pre-flight Test

All RF systems shall undergo a pre-flight 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. The 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. Calibrated antenna terminations (covers) and couplers (hats) shall be provided for all FTS antennas.
2. Covers and hats are mandatory for all in-vehicle closed-loop testing required in this chapter.
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 flight.

5.3.4 Standard Flight Termination Receiver 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 flight as possible and after all vehicle processing has occurred in the FTS component locations.

1. The test shall take place within three days before flight. Earlier testing may be granted by Range Safety on a case-by-case basis.
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, mating/demating of any connector or wiring harness, lightning strikes, or other event;
   b. the flight is delayed.
3. If the flight is delayed and the FTS configuration is not broken or modified, the requirement to re-perform the end-to-end 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 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 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 satisfies all performance requirements.

b. A standard 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 one hour 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) The 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 High-Alphabet Command Terminate System

a. Initial Open-Loop Test of a High-Alphabet Command Terminate System. Any FTS that uses a 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 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 onto 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 onto the command control transmitting system and the FTRs.

(3) Each command receiver decoder shall be powered by either the ground or 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 High-Alphabet Command Terminate System. Any FTS that uses a 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 (ISDSs). The test shall satisfy all of the following.

(1) The system shall undergo the test no earlier than 3 days 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 3 days 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 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 systems and ISDSs deliver the energy required to initiate the FTS ordnance.

(5) The FTS shall undergo the test while powered by the batteries that the 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 vehicle RF receiving system.

(7) The test shall demonstrate that all primary and redundant vehicle FTS components and circuits are operational.

(8) The test shall exercise the triggering mechanism of all electrically initiated ISDSs to demonstrate that they are operational.

c. Abbreviated Closed-Loop Test of a High-Alphabet Command Terminate System. Any FTS that uses a high-alphabet command receiver decoder shall undergo an abbreviated closed-loop test if, due to a launch scrub or delay, more than three days pass since the end-to-end test of item b above. 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 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 vehicle RF receiving system.

(5) The test shall demonstrate that the vehicle command terminate system, including each command receiver decoder and all batteries, is functioning properly.

d. Final Open-Loop Test of a High-Alphabet Command Terminate System. Any FTS that uses a high-alphabet command receiver decoder shall undergo a final open-loop RF test no earlier than one hour before flight to validate the entire RF command terminate link from the command control transmitting system to 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 Flight Termination System 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 three days before flight. Earlier testing may be granted by Range Safety on a case-by-case basis.
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, mating/demating of any connector or wiring harness, lightning

strikes, or other event affecting the integrity of the system;

b. the flight is delayed.

3. If the flight is delayed and the FTS configuration is not broken or modified, the requirement to re-perform the end-to-end 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 satisfies 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 Subsection 4.19.2 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 GSE 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. Flight Termination System Software Verification

(1) The AFTS shall output all software and firmware contents in memory to GSE 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 satisfy 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 TM, transponder, and payload;

c. all support equipment transmitter sources such as repeaters, support aircraft, support ships, and communications;

d. any unintentional radiating sources produced by electronic components that are not intended to be transmitters.

The compatibility test may be broken up into pre-launch 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 Post-Flight Telemetry Validation

The range user shall review all in-flight TM 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 In-Flight Failures and Anomalies

Any in-flight failure/anomaly occurring in an FTS or any identical component shall be reported immediately to Range Safety. All 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 RSO. 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 pre-launch 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 shall constitute a failure if it 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 Mission Failure Necessitating Flight Termination System Action

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 failure analysis shall identify the cause and mechanism of the failure, 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.

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CHAPTER 6

Flight Termination System Ground Support and Monitoring Equipment Design Requirements

6.1 General

This section references GSE that 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 pre-launch 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, Occupational Safety and Health Administration, National Fire Protection Association, and other applicable standards.

6.1.2 Ground Support Equipment Maintenance

a. All GSE used for checkout and monitoring of the FTS shall be verified on a periodic basis.

b. The pass/fail criteria and frequency of verification shall be documented in a formal procedure.

6.1.3 Test Equipment Calibration

a. All instruments used for testing and monitoring the FTS shall be calibrated prior to use by a calibration laboratory conforming to ISO/IEC 17025:2005[31] using calibration standards 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

a. An ordnance initiator simulator shall be provided for all command, fail-safe, and ADS tests, dress rehearsals, countdown demonstration tests, or similar tests (such as range pre-launch tests). The ordnance initiator simulator shall:

(1) have electrical and/or optical operational characteristics matching those of the actual ordnance initiator;

[31] International Electrotechnical Commission and International Organization for Standardization. *General Requirements for the Competence of Testing and Calibration Laboratories*. ISO/IEC 17025-2005. Geneva: International Organization of Standardization, 2005.

(2) 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.

(3) have the ability to remain connected throughout ground processing until the electrical connection of the actual initiators is accomplished;

(4) 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;

(5) for any LVI, 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 detecting as low as 10% of the no-fire current.

This stray current monitoring device shall be installed in the firing line.

b. An analysis shall be provided to demonstrate compliance.

6.3 Laser Test Equipment

a. All laser test equipment that has the capability to fire the LID directly or indirectly shall be assessed and approved by Range Safety.

b. Laser test equipment shall be designed to meet the following criteria.

(1) 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.

(2) The energy level shall be 10 dB below the no-fire level of the LID for a dual piece-part failure.

(3) The test source shall emit a different wavelength than the firing unit laser.

6.4 Range Safety Console

Key points regarding the range safety console (RSC) are as follows.

- The RSC is located in the launch control center (blockhouse).
- The RSC displays the status of the FTS and vehicle-peculiar functions critical to flight safety during pre-launch and up to liftoff.
- The RSC provides control capability to operate the FTS.
- Combining multiple measurements into a single measurement requires specific Range Safety approval.

a. The RSC design shall be developed and submitted to Range Safety for review and approval.

b. 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.

c. The RSC design shall take human factors engineering into consideration.

The RSC shall comply with the requirements in MIL-STD-1472[32] or equivalent.

d. When applicable, the following vehicle FTS status shall be provided continuously to the RSC during pre-launch and up to liftoff.

NOTE	Range Safety may require FTS status during flight.

(1) The SSTO voltage for each FTR.

(2) Monitors for all command outputs for each electronic component.

All FTR tones and commands shall be monitored.

(3) Status of all arming devices and all inhibits.

- Optical interrupter devices. Barrier position (safe/arm), barrier locked/ unlocked, and electrical power status of the main laser.
- Ordnance interrupter devices. Safe and Arm.
- Electromechanical SADs. Safe and Arm.
- High-energy firing unit. Trigger capacitor voltage, high-voltage capacitor voltage, arm and fire input, inhibit input, and power.
- Any LFUs.

The exact circuits to be monitored shall be determined by Range Safety.

- Other electronic arming devices or inhibits.

The exact circuits to be monitored shall be determined by Range Safety.

(4) Battery status.

- Voltages of each FTS airborne battery and ground power supplies.
- Temperature of each FTS airborne battery.
- Current of each FTS airborne battery and ground power supplies.
- Provisions for monitoring battery life, operating time, or other means of monitoring energy remaining for flight.

[32] Department of Defense. Human Engineering. MIL-STD-1472G. 11 January 2012. May be superseded by update. Available at http://quicksearch.dla.mil/.

(5) Proper functioning of ordnance initiator simulators.

(6) Status of the FTS power source (on/off and airborne/ground).

(7) Monitors for vehicle-peculiar functions critical to flight safety and other vehicle-peculiar functions critical to FTS as identified by Range Safety.

(8) Status of the range command transmitter carrier (On/Off).

e. 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.

1. Power source selection
2. Safing and arming the FTS
3. Squib-activated battery activation
4. Battery charging
5. BIT testing

f. Electronic displays shall provide an indicator that the screen is receiving new data updates and has not locked up.

g. 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 Provided by the Range User

6.5.1 Flight Termination Receivers

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 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).

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% confidence level.

1. The mission time used in the reliability predictions includes a minimum of 150% of the predicted flight time verified by analysis IAW the parts stress analysis of MIL-HDBK-217[33] using the applicable environmental factor.
2. A reliability analysis shall be performed IAW the requirements in ANSI/GEIA-STD-0009-2008[34] 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 (FMECA);

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.

[33] Department of Defense. Reliability Prediction of Electronic Equipment. MIL-HDBK-217F. 2 December 1991. May be superseded by update. Available at http://quicksearch.dla.mil.
[34] TechAmerica. *Reliability Program Standards for System Designs, Development, and Manufacturing*. ANSI/GEIA-STD-0009-2008. Arlington: TechAmerica, 2008.

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 Link

a. The RF link analyses shall be performed to demonstrate:

   (1) A 12-dB margin over 95% of the antenna radiation pattern using a nominal trajectory;

   (2) A 12-dB margin using actual antenna patterns for a nominal trajectory.

b. When demonstrating the 12-dB margin, each link analysis shall account for the following nominal system performance and attenuation factors:

   (1) path losses due to plume or flame attenuation;

Plume attenuation for solid-rocket motors shall be a maximum of 20 dB within a 20° aspect angle when referenced from the back of the vehicle

   (2) free space loss throughout the vehicle trajectory;

   (3) ground system and airborne system RF characteristics;

   (4) 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 IAW the requirement in Appendix A 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.

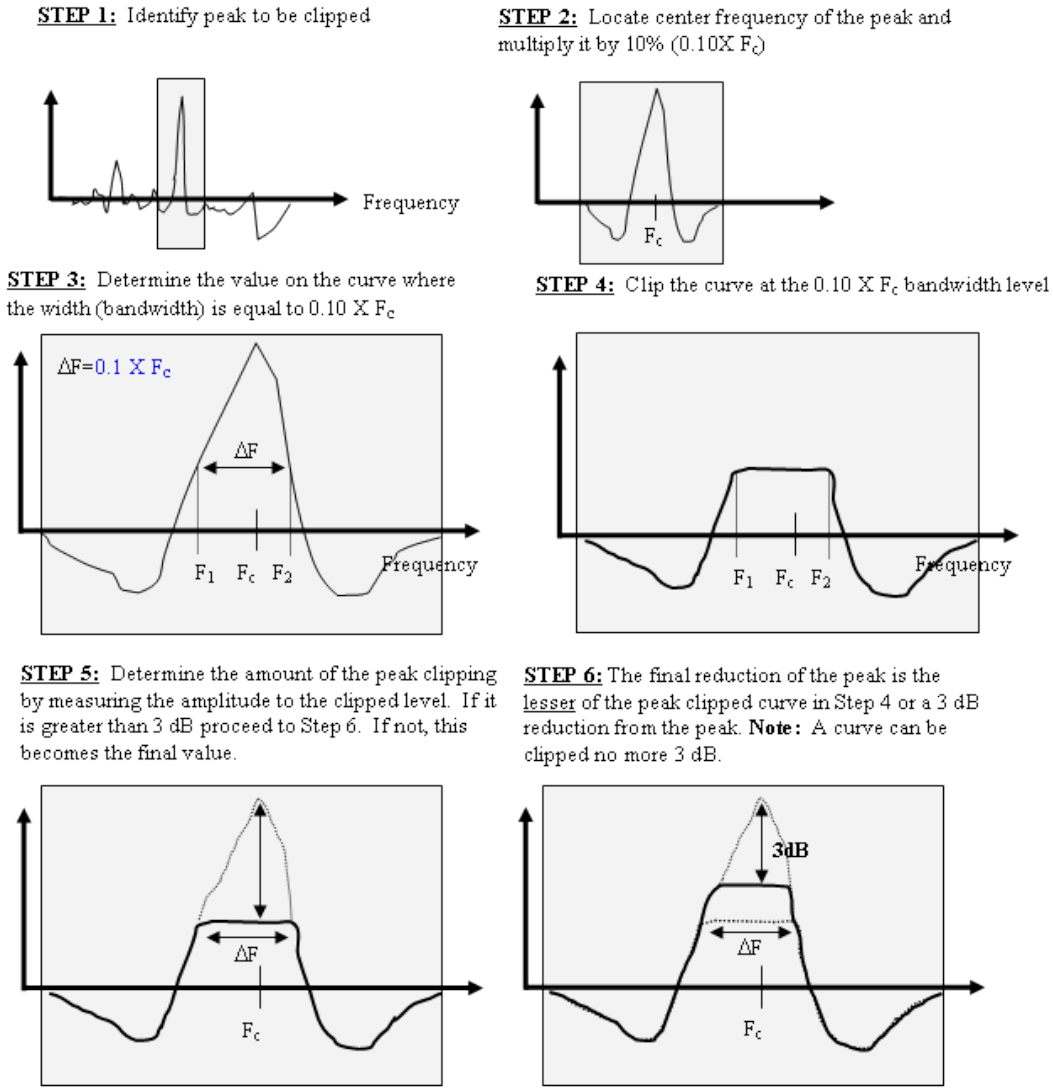
7.10 Component Maximum Predicted Environment

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 and similar vehicles, as well as 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



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 Radio Frequency Radiation Analysis

An RF radiation analysis shall demonstrate that the system and components satisfy 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 components were tested to correct levels.
2. Emitting sources include radiated emissions from FTS and other vehicle components.

7.15 Flight Termination System 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 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 time steps no more than five seconds apart.
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

A tip-off analysis of standoff autodestruct systems crossing staging or breakup interfaces 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 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 Flight Termination System Analysis

A post-flight 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 Flight Termination System Laser-Initiated Detonator 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 Flight Termination System 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 LAT

(4) Date of modification with brief description of the modification

(5) Reuse or captive-carry time log

(6) Bench test or other pre-launch 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

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 IAW the required timelines. A summary of qualification test failures shall be included in the FTSR.

8.2 Flight Termination System Report

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 TM data.

8.3 Flight Termination System Report Submittal Process

One hard copy and an electronic copy of the FTSR shall be submitted to each applicable RSO.

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.

The initial and updates of 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. 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. The design, drawings, and documentation as delivered shall be reviewed. 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 flight schedule.

The final FTSR shall be submitted to the ranges for review and approval no later than four months before the first scheduled flight.

8.4 Final Approval

Formal acceptance of the FTS by the RSO shall be transmitted by letter after approval of the final FTSR and appendixes. 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 RSO.

8.5 Flight Termination System Report Format

Any report format provided by the range user 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-TM 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. Flight Termination System General System Description. The general system description section shall present a brief description of the vehicle and the FTS. The following items shall be included in this section.

   (1) Vehicle Description. A brief and general description of the vehicle.

   (2) Flight Termination System 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) Flight Termination System Cable Diagram. A cable diagram of the FTS from the antennas to the termination device.

   (4) Overall Flight Termination System Schematic. A complete line schematic of the entire FTS from antenna to the termination device, including TM pick-off points and ground (umbilical) interfaces.

Schematics shall be legible and use font size of at least 8 point.

8.5.1 Flight Termination System 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 a 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 the following.

   (1) The complete FTS, showing: component values such as resistance, capacitance, and wattage; tolerance, shields, grounds, connectors, and pin numbers; and TM 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_SPC terminology and symbols.

(2) All vehicle components and elements that interface with or share common use with the FTS.

(3) An accounting of all pin assignments.

d. Drawings showing the location of all FTS system and subsystem components on the vehicle that include the following descriptions.

(1) Component locations, mounting (attach points), orientation, and cable routing.

(2) Electrical connectors, connections, and the electrical isolation of the FTS.

(3) An illustrated parts breakdown of all mechanically operated FTS components.

8.5.2 Flight Termination System 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 Flight Termination System Ordnance Classification

The classifications for each ordnance device shall be IAW the DOT, DoD, or UN regulations. Supporting documentation shall be included in this section.

8.5.4 Flight Termination System 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 IV&V shall be included.

8.5.6 Flight Termination System 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 Flight Termination System Ground Support and Monitoring Equipment

The ground support and monitoring equipment section shall include a complete description of the ground test equipment used to check out 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. the RF ground support system;

c. the 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 Flight Termination System 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 Flight Termination System Report

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 TM measurements. This section includes the following minimum information for each measurement:

a. description of each parameter;

b. a TM measurement identifier;

c. sample rate;

d. minimum and full-scale level;

e. resolution;

f. engineering units and scaling factors;

g. analog or digital.

8.7 Flight Termination System Report Appendixes

All FTS development, qualification, and age surveillance test reports shall be included as stand-alone appendixes.

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Appendix A

Software/Firmware Independent Verification and Validation

A.1 Independent Verification and Validation Analysis Support

The 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.

A.1.1 Requirements

The IV&V process starts during the definition phase by using an independent group to verify requirements and evaluate specifications for completeness, accuracy, traceability, and testability.

A.1.2 Design and Development

The IV&V personnel support design and development activities once the requirements have been defined to ensure the system satisfies all performance requirements.

A.1.3 Operational Evaluation and Test

The IV&V personnel review program testing for completeness after the system development is complete. They also 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.

A.2 Requirements

a. During the definition phase, an independent group shall verify requirements and evaluate specifications for completeness, accuracy, traceability, and testability.

b. Systems include all software, firmware, and hardware interfaces necessary to ensure public and property safety during operational missions.

c. The IV&V process ensures that compliance to requirements can be validated through test and evaluation.

d. The process may also include special studies or analyses of operational launch anomalies or failures attributed to operational and range systems.

A.3 Design and Development

The following are the processes the IV&V personnel perform in supporting the design and development activities.

a. 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.

b. 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.

c. Analyze the detailed design specified in the system design documents for correlation to the software and hardware requirements of the system requirements documents.

d. 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.

e. Validate that 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.

f. Monitor the detailed hardware/software development to determine if it meets system performance requirements, including reliability, single-fault tolerance, timing, and sizing.

g. Monitor the detailed development for correlation to the software and hardware requirements of the system requirements documents.

A.4 Operational Evaluation and Test

The following are the processes the IV&V personnel perform in supporting the operational evaluation and test.

a. 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.

b. 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.

c. Evaluate the accuracy of the algorithms using independently coded versions when numerical accuracy or rate of convergence is in question.

d. 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.

e. Model and simulate selected hardware, software, firmware, and interfaces to demonstrate compliance to system requirements.

f. 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.

g. 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.

h. Witness testing and identify any deviation from the test procedure documents.

A.5 Reporting Anomalies

The IV&V personnel report all anomalies throughout the development and operational implementation process as follows.

a. Report hardware/software single points of failures that inhibit the system from functioning 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, closed, 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. Categorize anomalies by severity and probability classifications. Table A-1 and Table A-2 shall be used when categorizing new and reevaluating anomalies.

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 or processing or display errors to Range Safety and launch software from TM, metrics, command and 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 times 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.

h. Report all anomalies found during IV&V-supported design and evaluation activities. Report on the status of anomalies pending resolution. 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. Archive and maintain all generated anomaly reports in a configuration-controlled database.

i. 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. Documentation of unverifiable failures shall include any analysis done, special testing performed, configuration of the system at the time of the failure, or any other applicable information for the future.

A.6 Reviews

The IV&V personnel shall conduct design and test readiness reviews for IV&V processes, criteria, and tools and shall participate in TIMS and program management meetings as required with the development contractor/organizations. This shall include, but not be limited to, the weekly design reviews, TIMs, and test readiness reviews. The contractor shall provide briefings and written reports as required to support the certification process.

A.7 Configuration Audit

During configuration audit, the IV&V personnel shall:

a. assess control of test and evaluation items to ensure test articles are representative of the final delivered configuration;

b. participate in the evaluation of engineering change proposals for the change control board; and

c. conduct and/or participate in functional and physical configuration audits.

A.8 Reliability Analysis

During reliability analysis, the IV&V personnel shall:

a. 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;

b. analyze the reliability assessments and predictions of the developer for accuracy and completeness;

c. evaluate FMECA and single-point-of-failures analyses for the resulting impact on mission success, performance, staff safety, and maintainability.

A.9 Human Factors Analysis

During human factors analysis, the IV&V personnel shall:

a. analyze the 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;

b. identify and report design human factor deficiencies and recommended improvements.

Appendix B

Electronic Piece-Part Procurement Requirements

B.1 Piece-Part Program Plan

A range user shall describe compliance for each applicable FTS piece-parts program plan. All electronic piece-parts used in an FTS shall successfully undergo lot qualification testing, LATs, and lot DPA IAW 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. The GIDEP alert information is available at the GIDEP Internet web page.[35]

B.2 US Military-Quality Piece-parts

a. All US military quality piece-parts used in an FTS shall meet the performance, quality, and reliability levels required by the DoD product qualification program as they apply to the following parts and classifications.

   (1) Joint Army Navy Technical Exchange, Joint Army Navy Technical Exchange with Visual inspection requirements, or Joint Army Navy Space classes for diodes and transistors

   (2) Class B (Military) or Class S (Space) for microcircuits per MIL-M-38510J[36] (Inactive)

   (3) Class H (Military) or Class K (Space) for hybrids per MIL-PRF-38534H[37]

   (4) Established reliability level R or S for passive parts

   (5) Established reliability level R for relays

   (6) Class B for crystal oscillators or filters

   (7) Electronic and RF cables to MIL-C Standard

b. All internal cavity piece-parts shall undergo particle impact noise detection (PIND) testing.

c. The Defense Supply Center, Columbus Sourcing and Qualification Unit (DSCC-VQ) maintains lists of suppliers of US military-quality parts with the classifications required by item a above. When using US military-quality parts, a range user shall select parts

[35] Government Industry Data Exchange Program Internet web page. http://www.gidep.org/.
[36] Department of Defense. Microcircuits, General Specification for. MIL-M-38510J. 15 November 1991. Inactive. May be superseded by update. Available at http://quicksearch.dla.mil/.
[37] Department of Defense. Hybrid Microcircuits, General Specifications for. MIL-PRF-38534H. 13 September 2010. May be superseded by update. Available at http://quicksearch.dla.mil/.

from a qualified manufacturers list (QML) or qualified product list (QPL), available at the DSCC-VQ web page.[38]

B.3 Custom or Non-Military Piece-parts

B.3.1 Military-Equivalent Parts

All custom or non-military parts used in an FTS shall be subjected to screening tests, LATs, qualification testing, and DPA to demonstrate equivalence to the military-quality parts. Each piece-part shall successfully undergo testing IAW the following.

a. All parts 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 LATs of production lot samples to confirm that the manufacturing process produces parts consistent with the qualified design of the part. For qualification and LATs, 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 1000-hour life test meets these requirements.

c. As part of the LATs, lot samples of each piece-part shall undergo a DPA after those samples have been subjected to the environmental stress tests. The DPA 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 DPA 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.

B.3.2 Particle Impact Noise Detection Testing

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. The PIND testing shall ensure 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% 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% 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.

[38] Defense Supply Center, Columbus Sourcing and Qualification Unit web page. http://www.dscc.dla.mil/offices/sourcing%5Fand%5Fqualification/.

B.3.3 Derating Criteria

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 electronic parts shall be performed IAW Appendix C or other standard approved by Range Safety.

B.3.4 Up-rating Criteria

Up-rating of electronic parts is strongly discouraged. Extensive studies indicate that the cost of up-rating a part significantly exceeds the cost of obtaining a part that meets the specified requirements. In addition, most manufacturers will not guarantee the operation of up-rated parts.

B.3.5 Piece-Parts

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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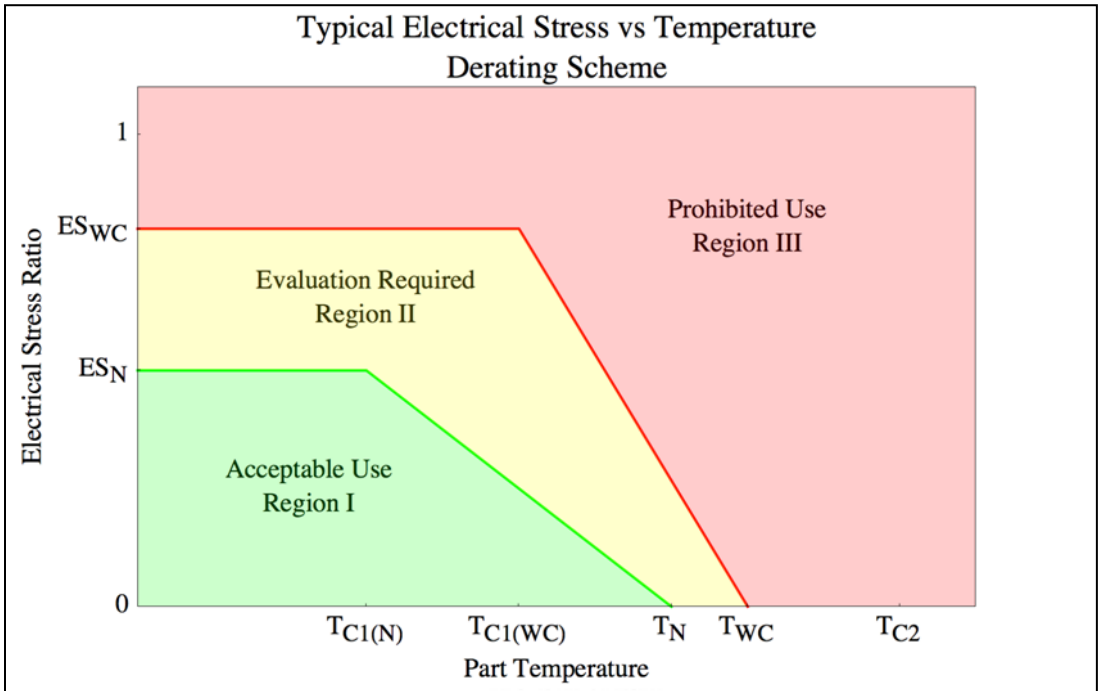
Appendix C

Electronic Piece-Part Derating Requirements

C.1 General

This appendix provides a common set of recommended electronic piece-part derating limits and procedures derived from multiple government and industry sources. Derating is the process of reducing the electrical stress level on a part below its rated value in order to increase its reliability and/or lifetime. One of the most significant factors in electrical stress is the temperature of the part. For this reason most, if not all, derating curves are generated as a plot of electrical stress ratio (voltage, current, power, etc.) versus temperature. Figure C-1 displays a graph of a typical derating scheme.



$T_{C1(N)}$ = Case temperature above which electrical stress should be reduced (Nominal)
$T_{C1(WC)}$ = Case temperature above which electrical stress should be reduced (Worst Case)
T_N = Boundary temperature (Nominal). Typically equals (T_{WC} – 10 ºC).
T_{WC} = Boundary temperature (Worst Case). Typically equals (T_{C2} – 30 ºC).
T_{C2} = Maximum allowable case temperature per the detailed specification
ES_N = Maximum steady state / average operating electrical stress (Nominal)
ES_{WC} = Maximum transient electrical stress (Worst Case).
An electrical stress ratio of 1 is equivalent to the maximum rated stress per the detailed specification.

Figure C-1. Example of a Derating Curve Plot

C.2 Capacitors

C.2.1 Military Specification Capacitor Types

Table C-1 lists reference materials for capacitors based on the different types and styles of dielectric material. All of the military specifications listed (including updated and superseded

specifications) are available from the ASSIST website,[39] the official source for specifications and standards used by the DoD.

Table C-1. Capacitors, Mil-Spec Listing (For Reference)

Dielectric Material	Mil-Spec	Style
Ceramic	MIL-PRF-39014	CKR
Ceramic	MIL-PRF-20	CCR
Ceramic	MIL-PRF-123	CKS
Ceramic, High Voltage	MIL-PRF-20	---
Ceramic Chip	MIL-PRF-55681	CDR
Mica	MIL-PRF-87164	CMS
Glass, Porcelain	MIL-PRF-23269	CYR
Supermetallized Film	MIL-PRF-83421	CRH
Supermetallized Film (Low Energy Application)	MIL-PRF-87217	CHS
Plastic Film; Metallized and Nonmetallized	MIL-PRF-19978	CQR
Tantalum Foil	MIL-PRF-39006	CLR
Solid Tantalum	MIL-PRF-39003	CSR
Solid Tantalum, Low Impedance Applications	MIL-PRF-39003/10	CSS
Solid Tantalum Chip	MIL-PRF-55365	CWR
Variable, Air, Piston, Type	MIL-PRF-14409[1]	P
Variable, Glass or Ceramic	MIL-PRF-14409[1]	---
Wet Tantalum-Tantalum	MIL-PRF-39006/22[2]	CLR 79

[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 CLR 79), manufactured by a QPL/QML source, with a double seal is approved for wet tantalum construction in expendable launch vehicle applications.

C.2.2 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.

C.2.3 Capacitor Reliability Application Derating Guidelines

Table C-2 provides derating guidelines for several types of capacitors.

Table C-2. Capacitor Derating

Type	Parameter	Maximum Stress Ratio	Comments
Ceramic	Voltage	Figure C-2	
Ceramic Chip	Voltage	Figure C-2	
Feed-Through Capacitor	See EMI Filters		

[39] Official Department of Defense ASSIST Document Repository. http://quicksearch.dla.mil/.

Glass	Voltage	Figure C-3	
Supermetallized Film (CRH)	Voltage	0.5 at 85°C max.	0.65 WC at 85°C max.
Supermetallized Film and Nonmetallized Film (CHS, CQR)	Voltage	0.5 at 85°C max.	0.65 WC at 85°C max.[1]
Mica	Voltage	Figure C-4	
Porcelain	Voltage	Figure C-3	
Tantalum Foil	Voltage	Figure C-5	[2]
Tantalum Solid	Voltage	Figure C-6	[3,4]
Solid Tantalum Chip	Voltage	Figure C-6[5]	[3]
Wet Tantalum-Tantalum	Voltage	Figure C-7	[2]
Variable	Voltage	0.5	0.7 WC[6]

[1]0.65 at 85°C, decreasing to 0 at 100°C.
[2]Temperature rise due to ripple current shall not result in an operating temperature exceeding 85°C.
[3]At least 0.1 Ω/V series resistance or equivalent current limit of 10 A shall be provided for solid tantalum and tantalum chip capacitors. Parallel tantalum capacitors do not require separate series resistors for each capacitor.
[4]Special assembly and test procedures are required to ensure that tantalum capacitors are installed with the correct polarity.
[5]The maximum surge voltage shall not exceed the steady-state rated voltage.
[6]Use only after Parts, Materials, and Process Control Board (PMPCB) review and approval.

C.2.4 Use of Derating Curves

The following steps determine the maximum permitted operating voltage. Table C-3 identifies the appropriate figure depending on capacitor material.

Table C-3. Derating Curve Figures by Capacitor Type

Capacitor Type	Applicable Figure
Ceramic or Ceramic Chip	Figure C-2
Glass or Porcelain	Figure C-3
Mica	Figure C-4
Tantalum Foil	Figure C-5
Solid Tantalum	Figure C-6
Wet Tantalum-Tantalum	Figure C-7

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 ensure that the part application meets mission requirements, and presented to the PMPCB for approval. Combinations falling 20% 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% above the Region I curve shall require acquisition activity approval.

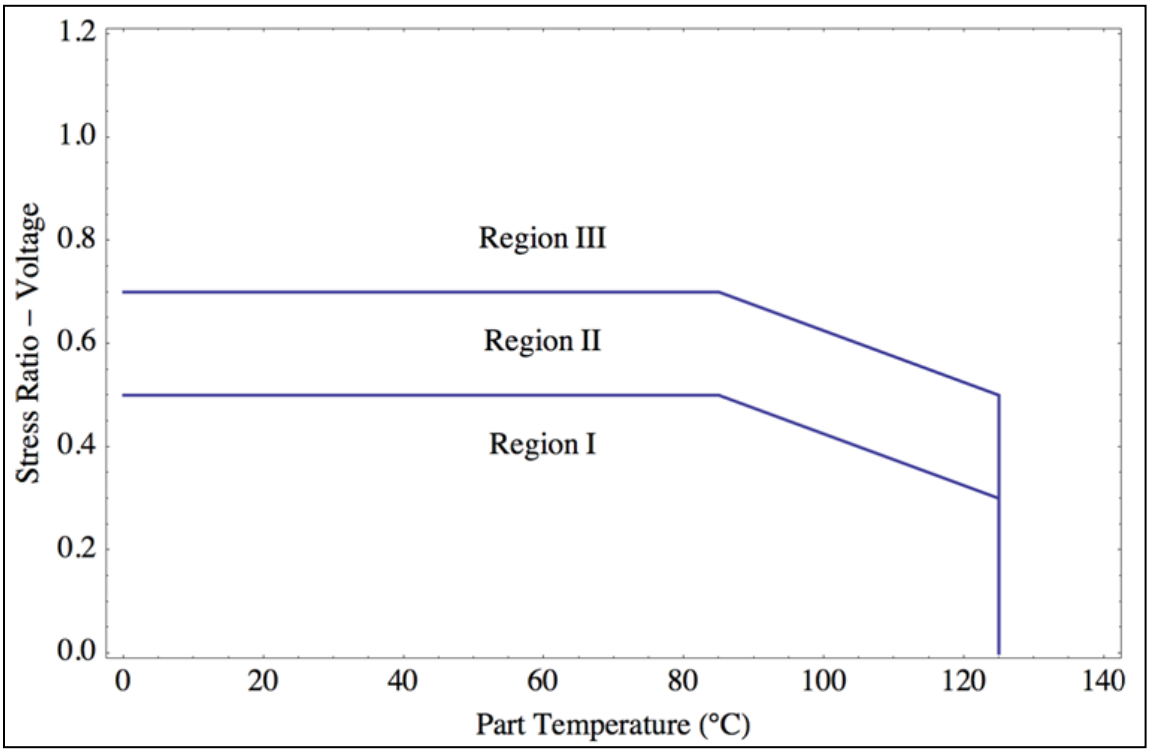


Figure C-2. Ceramic or Ceramic Chip (CKR, CCR, CKS, CDR)

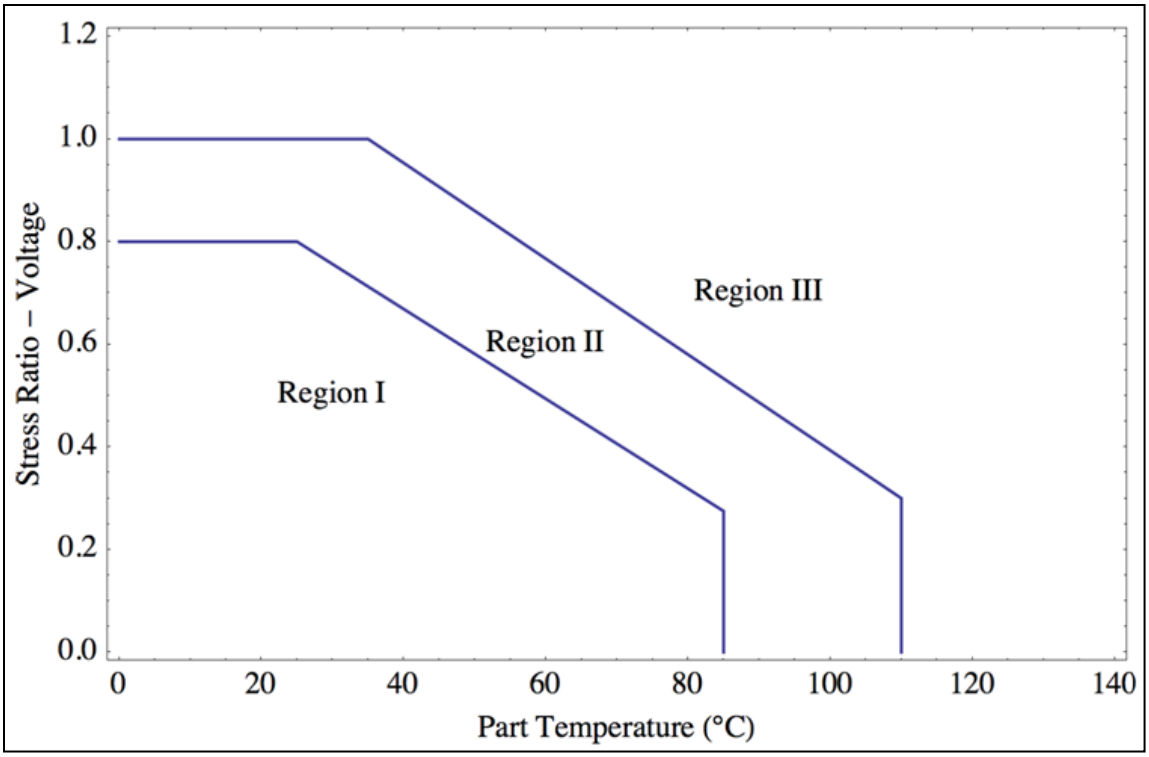


Figure C-3. Glass, Porcelain (CYR)

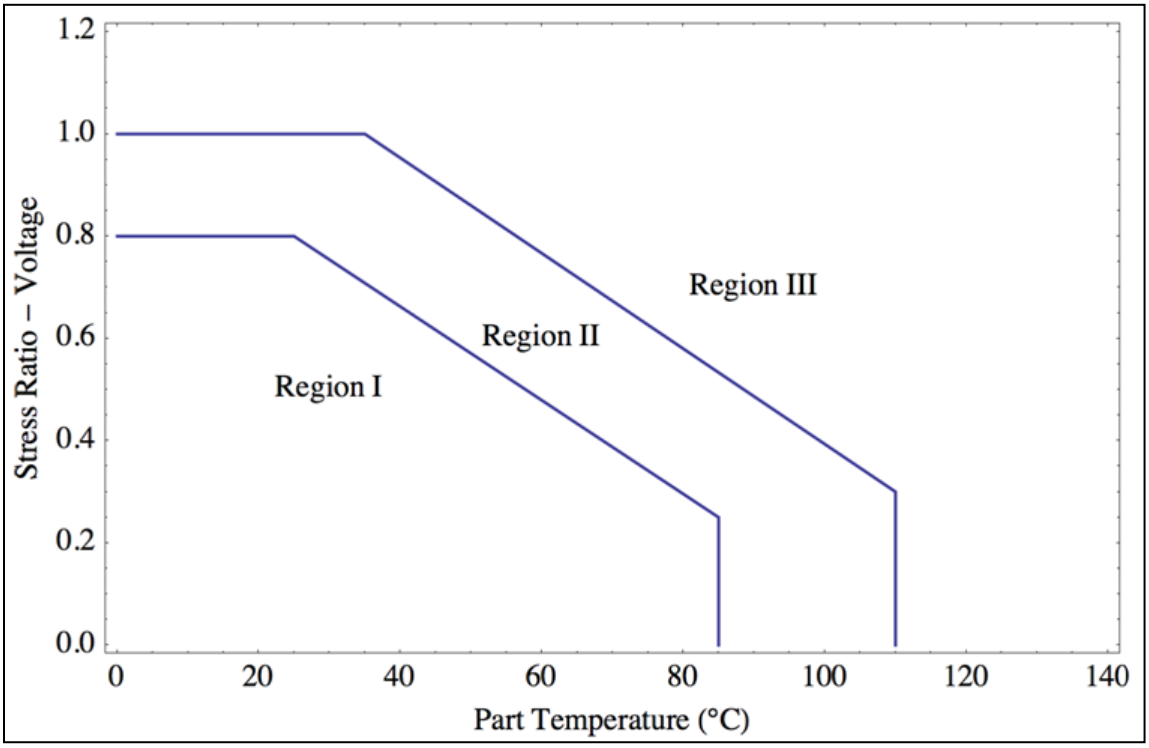


Figure C-4. Mica (CMS)

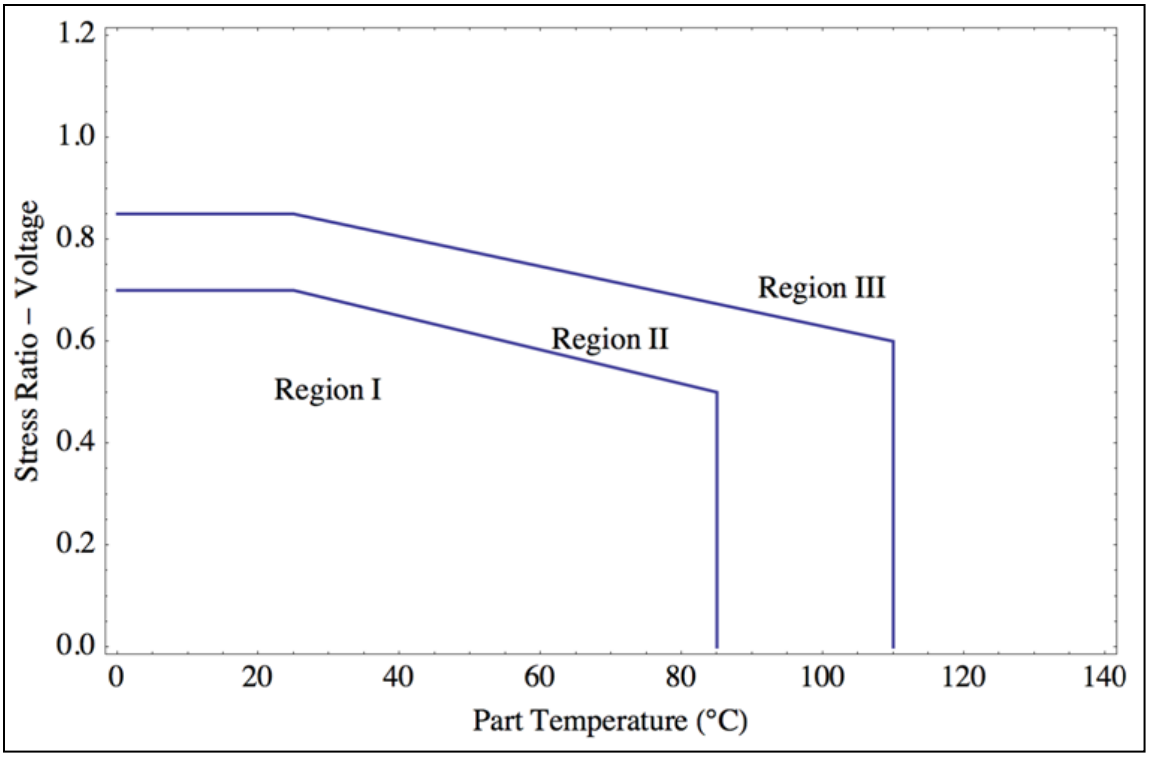


Figure C-5. Tantalum Foil (CLR 25, 27, 35, 37)

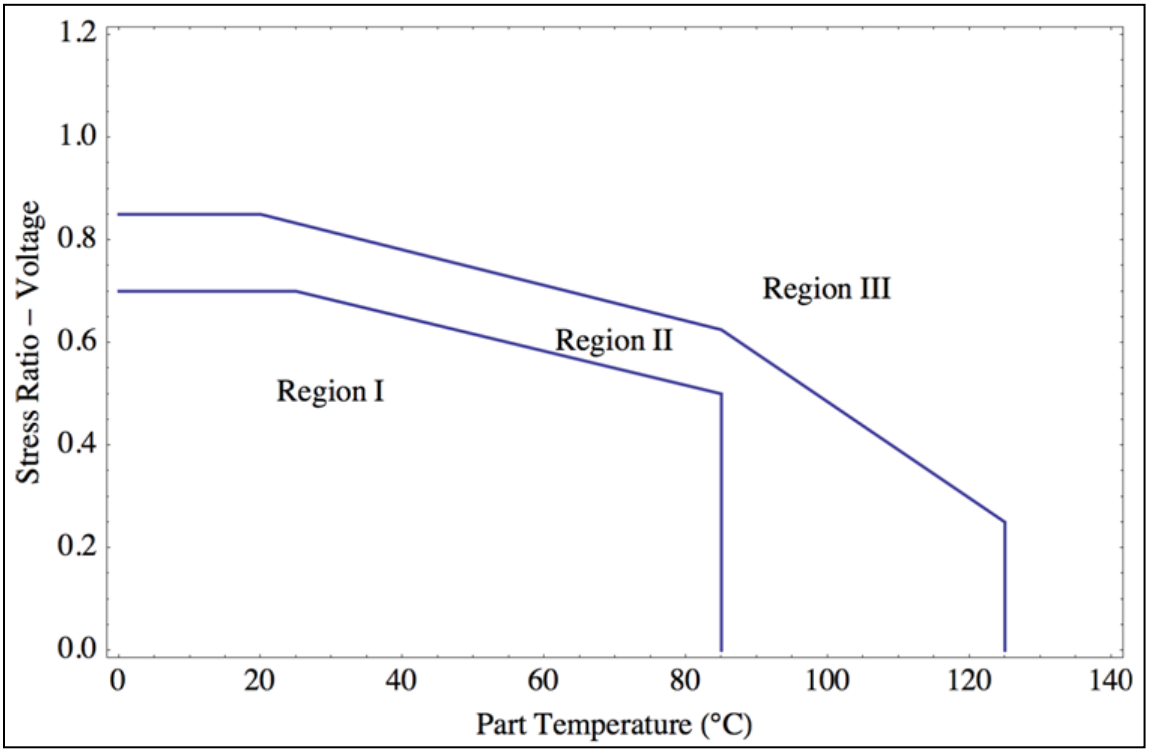


Figure C-6. Solid Tantalum (CSR, CSS)

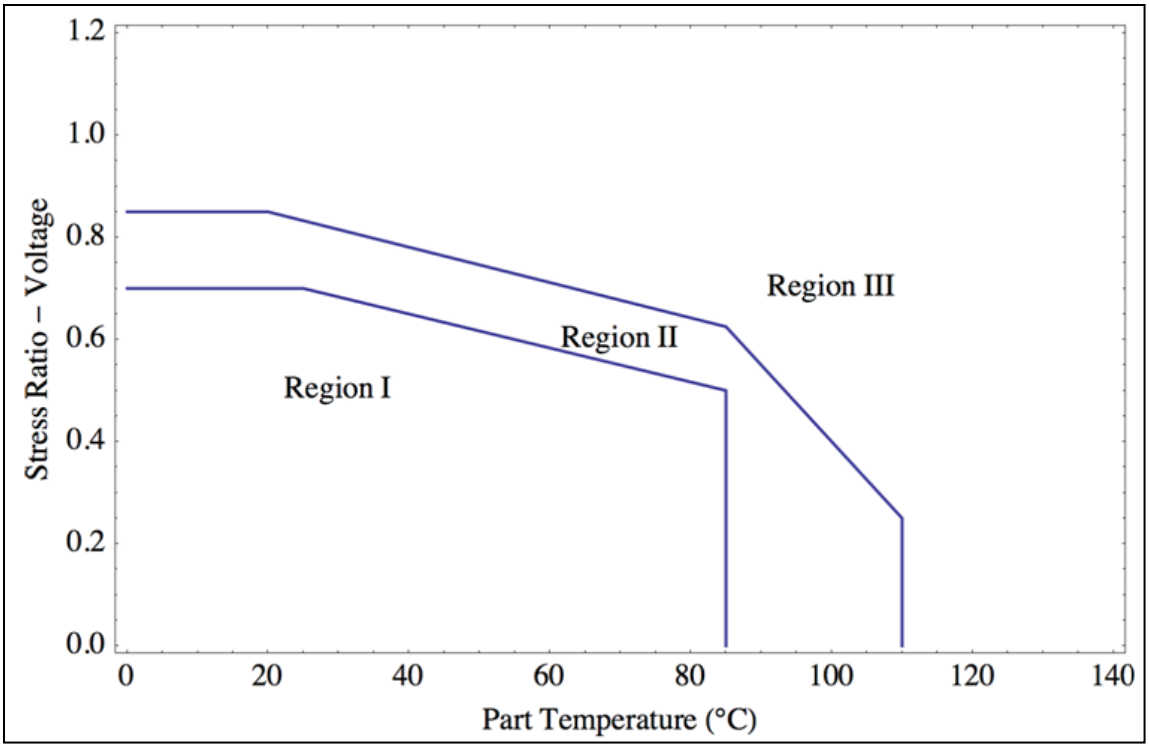


Figure C-7. Wet Tantalum-Tantalum (CLR 79)

C.3 Connectors Reliability Application Derating Guidelines

Table C-4 describes the maximum stress ratio for connectors depending on parameter. Table C-5 provides the maximum derated current depending on the number of contacts in the connector and the American Wire Gauge (AWG) thickness.

Table C-4. Connectors

Type	Parameter	Maximum Stress Ratio	Comments[1,2,3]
All	Current	0.5	When pins are connected in parallel to increase current capacity, each pin shall have the capability of conducting (within the derating criteria) 25% more current than the calculated equally divided current to compensate for current hogging.
	Voltage	0.5	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.

[1]Within the constraints of this table, use Table C-5 as a guide for contact and wire sizes.

[2]For block connectors and crimp connections, the current derating is the same as Table C-25 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 C-5. Connector Derating

Number of Contacts Used in the Connector	Contact Size	Maximum Derated Current (Amps) 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% of the rated sea level 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	

[1]Connector derating must also comply with the per-pin derating of Table C-4.

C.4 Crystal Reliability Application Derating Guidelines

Table C-6 indicates the maximum stress ratio for derating crystals.

Table C-6. Crystals

Parameter	Maximum Stress Ratio	Comments
Current (Drive Level)	0.5	50% drive current equals 25% drive power.

C.5 Diode Reliability Application Derating Guidelines

Derating information for diodes of several types are shown in the following tables.

- Table C-7: Switching, Small-Signal, Rectifier, and Transient Suppressors
- Table C-8: Step Recovery, Varactor, and Varicap
- Table C-9: Zener Diode
- Table C-10: Shottky Barrier
- Table C-11: Tunnel and Germanium
- Table C-12: Photo and Light-Emitting Diode

Table C-7. Diode (Switching, Small-Signal, Rectifier, and Transient Suppressors)

Parameter	Maximum Stress Ratio		
	Switching, Small Signal	Rectifier	Transient Suppressor
Power	0.5 (0.7 WC)	0.65 (0.7 WC)	0.75
Voltage: DC or Repetitive Pulse	0.75	0.75	----
Voltage Transients[1]	0.85	0.85	0.75
Forward Current	0.5	0.75 (0.85 WC)	
Surge Current	0.5	0.75 (0.85 WC)[2]	
Junction Temperature	125°C, or maximum rating − 20°C[3]	125°C, or maximum rating − 20°C[3]	125°C, or maximum rating − 20°C[3]

[1]Worst-case turn-on or repetitive transient.
[2]Of surge rating.
[3]Whichever is lower.

Table C-8. Diode (Step Recovery, Varactor, and Varicap)

Parameter	Maximum Stress Ratio
Power	0.5 (0.7 WC)
Voltage, DC or Repetitive pulse	0.75
Voltage Transients[1]	0.8
Forward Current	0.75
Junction Temperature	125°C, or maximum rating − 20°C[2]

[1]Worst-case turn-on or repetitive transient.
[2]Whichever is lower.

Table C-9. Zener Diode (Reference and Regulator)

Parameter		Maximum Stress Ratio
Reference Zener		
	Power	0.5 (0.85 WC)
	Junction Temperature	125°C, or maximum rating − 20°C[1,2,3]
Regulator Zener		
	Power	0.5 (0.75 WC)[1]
	Junction Temperature	125°C, or maximum rating − 20°C[1,3]

[1]Whichever is lower.
[2]Note: Temperature-compensated reference diodes must be operated at the manufacturer's specified current to optimize temperature compensation.
[3]The Zener current shall be limited to no more than IZ = IZ nominal + 0.05 (IZ maximum - IZ nominal) but do not derate to the point where the device is operating at the knee.

Table C-10. Diode, Shottky Barrier	
Parameter	**Maximum Stress Ratio**
Power	0.75 (0.85 WC)
Voltage: DC or Repetitive Pulse	0.75
Voltage Transients[1]	0.8
Junction Temperature	125°C, or maximum rating − 20°C[2]
[1]Worst-case turn-on or repetitive transient. [2]Whichever is lower.	

Table C-11. Diode (Tunnel, Germanium)[1]	
Parameter	**Maximum Stress Ratio**
Power	0.5 (0.7 WC)
Voltage: DC or Repetitive Pulse	0.7
Voltage Transients	0.8
Junction Temperature	125°C, or maximum rating − 20°C[2]
[1]Germanium diodes are not recommended for new or modified designs. [2]Whichever is lower.	

Table C-12. Diode (Photo, Light-Emitting Diode)	
Parameter	**Maximum Stress Ratio**
Current	0.5 (0.7 WC)
Junction Temperature	125°C, or maximum rating − 20°C[1]
[1]Whichever is lower.	

C.6 Electromagnetic Interference Filters - Reliability Application Derating Guidelines

Table C-13 lists the maximum stress ratio for derating electromagnetic filters.

Table C-13. Electromagnetic Filters	
Parameter	**Maximum Stress Ratio**
Voltage	0.5 of rating
Current	0.75 of rating
Temperature	Case 85°C maximum

C.7 Fuses - Reliability Application Derating Guidelines

Table C-14 provides data for fuse derating. Figure C-8 charts the maximum stress ratio of solid-body fuses.

Table C-14. Fuse Derating		
Type	**Maximum Stress Ratio**	**Comments[1,2]**
Solid Body[1]	Figure C-8	

Glass Fuses[2]		Manufacturer's current ratings are temperature-dependent.
1/8 A[3]	0.25	
1/4 A[3]	0.3	Derating factors are based on data from fuses mounted on PCBs and conformally coated. The derating criteria accounts for a possible loss of pressure that would lower the blow current rating. The criteria also accounts for a decrease in current capacity with time.
3/8 A[3]	0.35	
1/2 A[3]	0.4	
1 A	0.45	
2 A or greater	0.5	
Fusible resistors	Reliability engineering analysis desired	The allowable stress ratio must be decreased by an additional 0.005/°C above 25°C. In the event a non-standard fuse size is required, use the next-highest-rated fuse size.

[1]The parameter for each fuse type is of a current (Ampere) sensitivity characteristic.
[2]Glass fuses are derated for reliability and to allow for air loss in vacuum.
[3]Shall not be used on new or modified designs without PMPCB approval.

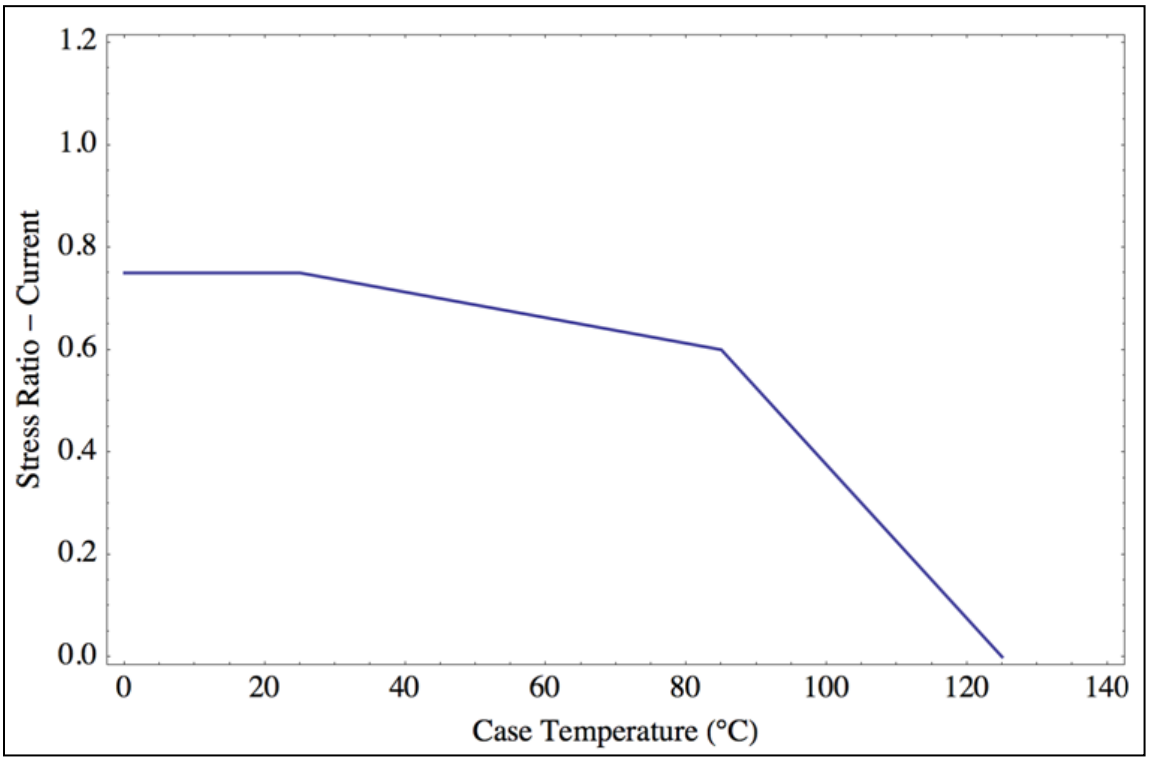


Figure C-8. Solid-Body Fuses

C.8 Inductor and Transformer Reliability Application Derating Guidelines

Table C-15 lists reference materials for inductors and transformers based on the different parameter and maximum stress ratio of the components. As with the references in Table C-1, the specifications listed are available from the ASSIST website.

Table C-15. Inductors and Transformers

Parameter	Maximum Stress Ratio	Comments (For Reference)[1,2,3]
Current	0.5	[2]
Voltage	0.5	Inductors: As established per MIL-PRF-39010 or MIL-PRF-21038 (as applicable) for DWV, induced voltage, and corona voltage. Transformers: As established per MIL-PRF-27 or MIL-PRF-21038 for DWV, induced voltage, and corona voltage.
Temperature (Inductors)	[1,4]	Classes per MIL-PRF-39010[3]
Temperature (Transformers)	[1,5]	Classes per MIL-PRF-27 or MIL-PRF-21038 as appropriate[3]

[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 C-28).
[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 the ambient temperature plus a temperature rise of +10°C (allowance for hot spot). Compute the 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.

[5]Maximum operating temperature equals the ambient temperature plus a temperature rise of +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.

*If we assume that the resistance vs. temperature relationship is linear, the model predicts that there is a temperature at which the resistance will fall to zero. This temperature is different for every conductor material. For copper wire the temperature is 38.65 K (−234.5°C).
**For accurate results, this measurement must be made in a vacuum to simulate actual operating conditions.

C.9 Integrated Circuits

C.9.1 Derating Criteria for Digital Integrated Circuits

Table C-16 provides derating information for complementary metal oxide semiconductor and transistor-transistor logic integrated circuits.

Table C-16. Complementary Metal Oxide Semiconductor and Transistor-Transistor Logic Integrating Circuits

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 0.8 (0.9 WC) of maximum rating, whichever is higher.	Not applicable to single fanout devices.
Current, Load	0.8 (0.9 WC)[2]	Not applicable to single fanout devices.
Propagation delay	1.1	Worst-case only
Power	0.8 (0.9 WC)	
Junction or Hot-Spot Temperature	125°C or maximum rating − 20°C	Whichever is lower

[1]For parts that are designed to accept an input voltage that is greater than the IC supply voltage, the maximum stress shall be 0.9 of the part manufacturer's specified rating.
[2]The derating for all outputs of digital devices must be calculated for both high and low output states.

C.9.2 Derating Criteria for Linear, Op Amp, Comparator Devices

Table C-17 describes derating for integrated circuit, linear, operational amplifier, and comparator devices.

Table C-17. Integrated Circuit, Linear, Operational Amplifier, Comparator[1]

Parameter	Maximum Stress Ratio	Comments
Power	0.75 (0.85 WC)	
Voltage, Input	0.7 (0.8 WC)	[2]
Operating Frequency (Applications)	0.75 (0.85 WC)	
Transients	Transient peaks shall not exceed the absolute maximum value	
Gain (Applications)	0.75 (0.85 WC)	

Voltage, Supply	0.9	Not to exceed the manufacturer's recommended operating voltage in WC.
Current, Output	0.75 (0.85 WC)	Of rated value, or 0.75 of the current limited value.
Junction or Hot-Spot Temperature	125°C, or maximum rating − 20°C	Whichever is lower.
[1]In general, the 10% 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.		

C.9.3 Derating Criteria for Linear Voltage Regulator Integrated Circuits

Table C-18 provides derating information for linear voltage regulator integrated circuits.

Table C-18. Integrated Circuit, Linear Voltage Regulator

Parameter	Maximum Stress Ratio	Comments
Power	0.8 (0.85 WC)	The controlling factor for voltage regulators is the input-output voltage differential, which shall be limited to 0.8 of the max. rated (V_{in}-V_{out}).
Voltage, Input	0.8 (0.85 WC)	
Current, Input	0.8 (0.9 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 maximum rating − 20°C	Whichever is lower.

C.9.4 Hybrid Chips and Wire

a. Derating Criteria for Hybrid Chips 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 0.5 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 in Table C-19.

Table C-19. 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

C.9.5 Derating Criteria (Integrated Circuits, Other)

Linear and/or digital criteria from the appropriate derating tables shall apply for large-scale integrated circuits, microcircuit chips for hybrids, and integrated circuit part types not specifically addressed in the preceding material. 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.

C.10 Motors - Derating Criteria

Table C-20 provides derating criteria for motors.

Table C-20. 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-PRF-15305.[40] 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: 0.75 of 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 C-28).
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 0.25 or less of their predicted capability under the application conditions.

C.11 Printed Wiring Boards and Printed Circuit Boards

C.11.1 Derating Criteria

The minimum conductor width for both single- and multi-layer copper foil printed wiring boards (PWBs) and PCBs is a function of the required circuit current.

Two sets of plots are provided. The top plot in each set shows the current-carrying capability of the etched foil versus the cross-sectional area required for a maximum 10°C rise in the trace. This rise ensures minimal component heating. The bottom plot in each set shows the copper trace width versus the cross-sectional area for four thicknesses of foil. The curves provided appear in full (Figure C-9) and expanded (Figure C-10) scales to improve accuracy.

[40] Department of Defense. Coils, Electrical, Fixed and Variable, Radio Frequency General Specifications for. MIL-PRF-15305E. 6 May 2013. May be superseded by update. Available at http://quicksearch.dla.mil/.

The full scale covers the current range up to 7 A and a trace cross section up to 700 square mils. The expanded scale covers the current range up to 1.8 A and a trace cross section up to 100 square mils.

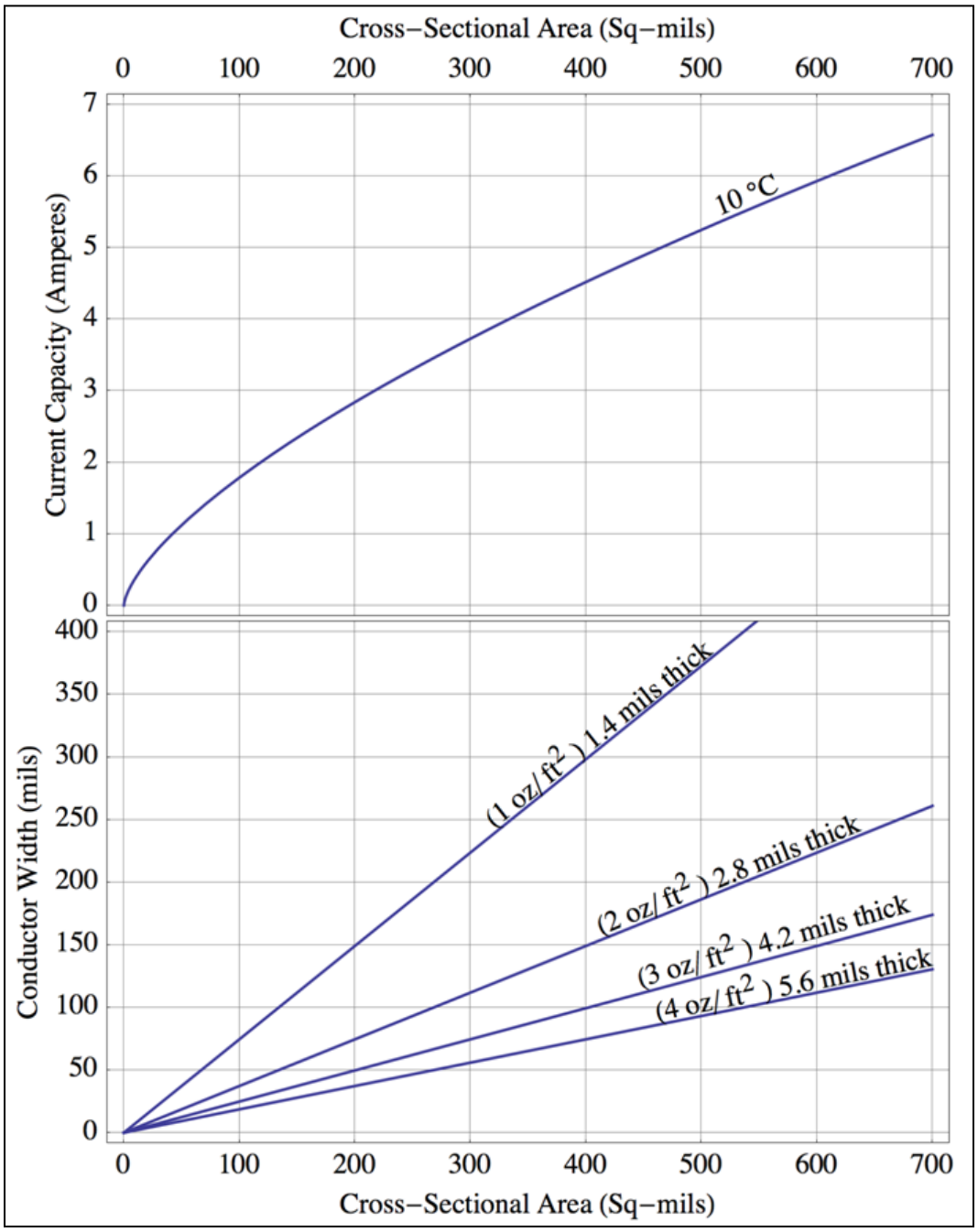


Figure C-9. Printed Circuit Board Derating Curves - Full Scale

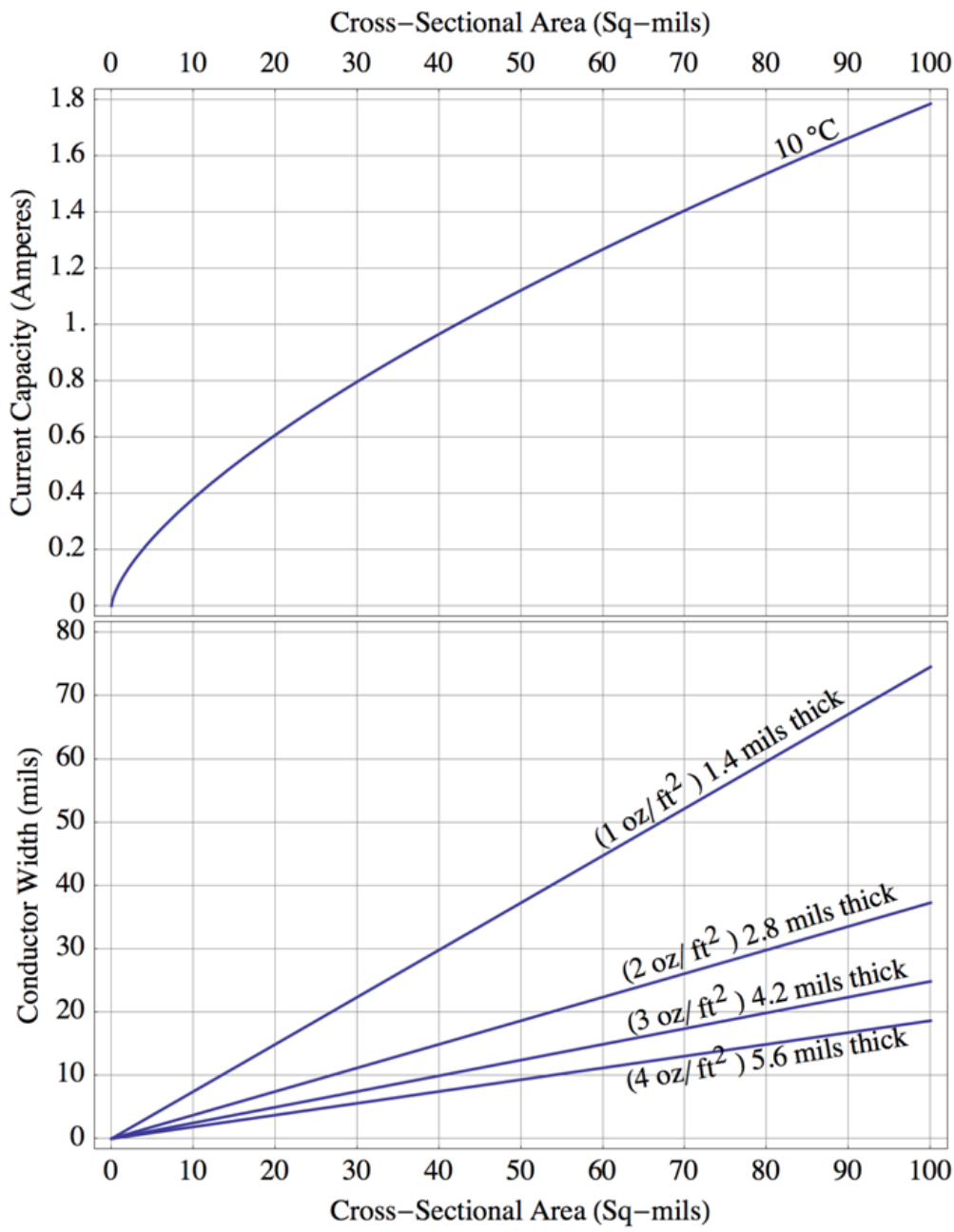


Figure C-10. Printed Circuit Board Derating Curves - Expanded Scale

C.11.2 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.

C.11.3 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 IPC-2221A,[41] Type 3, multilayer PWBs with inside traces and IPC-2152,[42] but also apply to all PWBs used in space-launched applications.

d. The curves include an industry-standard 10% 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.

C.12 Relays Derating Criteria

Table C-21 lists criteria for relay derating.

Table C-21. Relay Derating

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	0.5 of inductive load rating, or 0.4 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 0.2 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	0.1 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 ensure 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
[1]The maximum number of operations shall be limited to 0.5 of rated life when the relay is used			

[41] IPC. Generic Standard on Printed Board Design. IPC-2221A. May 2003. Available at http://www.ipc.org/toc/ipc-2221a.pdf.

[42] IPC. Standard for Determining Current-Carrying Capacity in Printed Board Design. IPC-2152. 24 September 2009. Available for purchase from http://www.ipc.org/html/ipc-store.htm.

with resistive loads, and 0.25 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 suppression circuits minimize degradation to contact life that can occur because of longer dropout 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 0.75 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 that will be expected. If the resistor-inductor circuit time constant ($\tau = L/R$) is greater than 0.1 ms, the relay contact load shall be considered to be inductive. In these cases, the contacts shall be derated using the inductive derating values rather than the resistive derating values.
[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 this table, 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 0.9 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. This table defines the limits that will ensure proper relay operation. The minimum actuation voltage supplied to the relay coil should never be less than 1.1 times the smallest voltage that will operate the relay at its maximum rated temperature. The voltage supplied to the coil should never be greater than 0.9 of the specified maximum voltage rating for the coil over the specified temperature range.

C.13 Resistors

Table C-22 lists reference materials for resistors based on the different type and style of resistor component. As with the references in Table C-1, the references listed here are available on the ASSIST website.

Table C-22. Mil-Spec Listing (For Reference)

Resistor Type	Mil-Spec	Style
Fixed, Carbon (Insulated) Composition	MIL-R-39008	RCR
Fixed Film (Insulated)	MIL-PRF-39017	RLR
Fixed Film Resistor Chips	MIL-PRF-55342	RM

Fixed Film	MIL-PRF-55182	RNC
Fixed Film, Precision	MIL-PRF-55182	RNR[1]
Fixed Film, High Voltage	MIL-PRF-55182	
Fixed, Wire-Wound (Accurate)	MIL-PRF-39005	RBR
Fixed, Wire-Wound (PWR Type)	MIL-PRF-39007	RWR
Fixed, Wire-Wound Power Type Chassis Mounted	MIL-PRF-39009	RER
Pill Resistor (Stripline)	MIL-R-10509	
Resistance Network	MIL-PRF-83401	RZ
Thermistor	MIL-PRF-23648	RTH
Variable, Nonwire-Wound (Adjustment Type)[2]	MIL-PRF-39035	RJR
Variable, Nonwire-Wound (Lead Screw Actuated)[2]	MIL-PRF-39015	RTR

[1]For solder-only applications, not for welding.
[2]Not recommended for space usage.

C.13.1 Derating Criteria

Table C-23 lists the maximum stress ratio for derating resistors.

Table C-23. Resistor Derating

Type[1]	Maximum Stress Ratio[2]
Carbon Composition	Figure C-11[3]
Metal Film RLR RNC	 Figure C-12[3] Figure C-13[3]
Film, Chip - RMO	0.5 (0.75 WC)[4,5]
Film Resistance Network	0.5 (0.75 WC)[4,5]
Wire-Wound Accurate - RBR	Figure C-14[3,6,7]
Wire-Wound Power - RWR	Figure C-15[3,8]
Wire-Wound Power - RER Chassis-Mounted	Figure C-15[3,8]
Deposited (thick film as part of a hybrid substrate)	0.5[9]
Inconel® Foil Heaters or Deposited Heaters on Kapton®	0.5[10]
Thermistors Positive Temperature Compensating	0.5
Thermistors Negative Temperature Compensating	0.5[11]
Microwave Loads, Isolators, Circulators (Pill Resistors)	0.5[12]

[1]The parameter for each Resistor type is of a power (Watts) characteristic.
[2]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.
[3]For discrete resistors, the voltage shall not exceed 0.5 of the rated voltage. Where a specific voltage rating has not been stated, the nominal rated voltage shall be determined from Ohm's Law ($E = \sqrt{PxR}$). When the voltage is applied in short pulses so that the average power of the resistor is less than 0.5 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 E^2/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.

[4]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 0.5 at 70°C to 0 at 125°C.
[5]Under relatively low humidity conditions film chip resistors, particularly those of smaller base size with high-sheet-resistance films, are subject to ESD, sudden shifts in resistance, and the temperature coefficient of resistance. Precautions against ESD are necessary in packaging and handling.
[6]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.
[7]The RBR resistors are designed as precision resistors. They are physically larger than RWR resistors for the same power rating that enables them to be used at higher power stress ratios than RWR resistors while maintaining their accuracy.
[8]For chassis-mounted applications, the resistor body temperature (hot spot) shall not exceed 140°C.
[9]Dimensions of deposited resistors are determined by the required resistance value and the resistivity of the ink used. The power rating for DuPont Birox® 1400 series inks is 155 kW/m^2 (100 W/in^2). The total power dissipated on a substrate, however, shall not exceed 6.2 kW/m^2 (4 W/in^2) and the voltage shall not exceed 59 kV/m (1.5 kV/in) of length. Consult the appropriate specification for other inks.
[10]The 0.5 derating applies only if low thermal resistance exists between the heater and the heat sink. 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.
[11]Current-limiting resistors or other methods shall be used to prevent thermal runaway. Above 25°C, linearly reduce the power derating factor from 0.5 at 25°C to 0 at 125°C (or the appropriate zero-power temperature for the thermistor used.)
[12]This is 0.5 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 the load that will still permit the circuit to function.

C.13.2 Use of Derating Curves

Use the following to determine the maximum permitted operating power. Table C-24 identifies the appropriate figure based on resistor type.

Table C-24. Derating Curve Figures by Resistor Type	
Resistor Type	**Figure**
Carbon Composition	Figure C-11
Metal Film (RLR)	Figure C-12
Metal Film (RNC, RNR)	Figure C-13
Wire-Wound Accurate Resistor	Figure C-14
Wire-Wound Power Resistor	Figure C-15

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 ensure that the part application meets mission requirements, and presented to the PMPCB for approval. Combinations falling 20% 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% above the Region I curve shall require acquisition activity approval.

d. Use of the plot in Figure C-14 requires extra information. Per MIL-STD-1547B,[43] Section 1160, voltage is limited to 0.8 of listed values for maximum voltage in MIL-HDBK-199B,[44] Table A-II for Specification MIL-PRF-39005.[45] Resistors with an initial resistance variability of 0.1% and below will include an additional power derating of 0.4. Resistors with an initial resistance variability of 1% shall include an additional power derating of 0.8. The percentages on the graph indicate the allowed increase in end-of-life resistance variability over the initial variability.

[43] Department of Defense. Electronic Parts, Materials, and Processes for Space and Launch Vehicles. MIL-STD-1547B. May be superseded by update. Available at http://quicksearch.dla.mil/.
[44] Department of Defense. Resistors, Selection and Use of. MIL-HDBK-199C. 14 August 2013. May be superseded by update. Available at http://quicksearch.dla.mil/.
[45] Department of Defense. Resistors, Fixed, Wirewound (Accurate), Nonestablished Reliability, Established Reliability General Specification for. MIL-PRF-39005G. 27 September 2013. May be superseded by update. Available at http://quicksearch.dla.mil/.

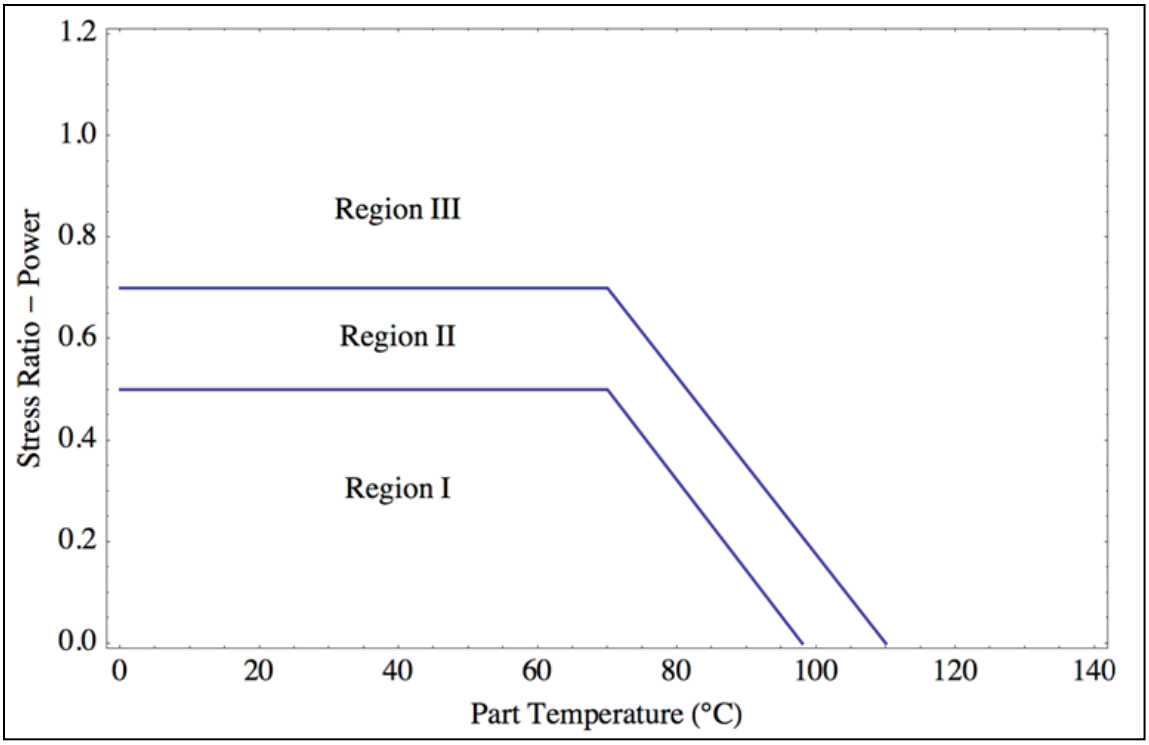


Figure C-11. Carbon Composition Resistor (RCR)

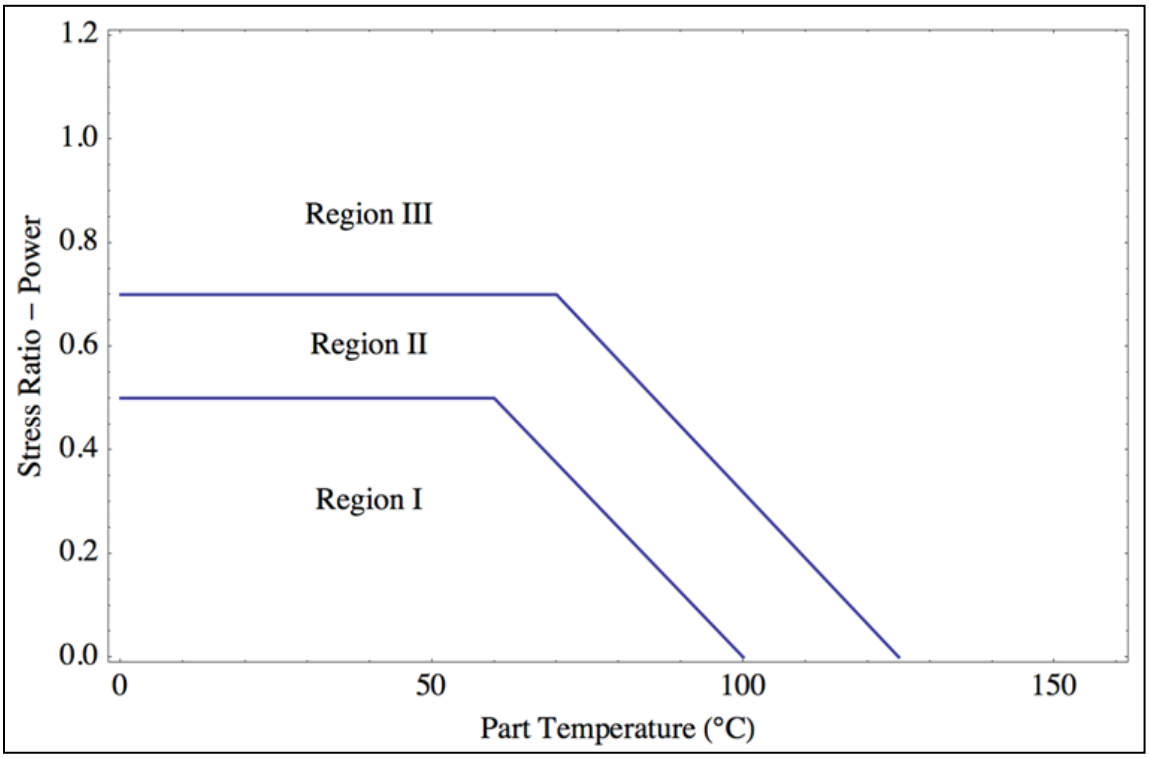


Figure C-12. Metal Film Resistor (RLR)

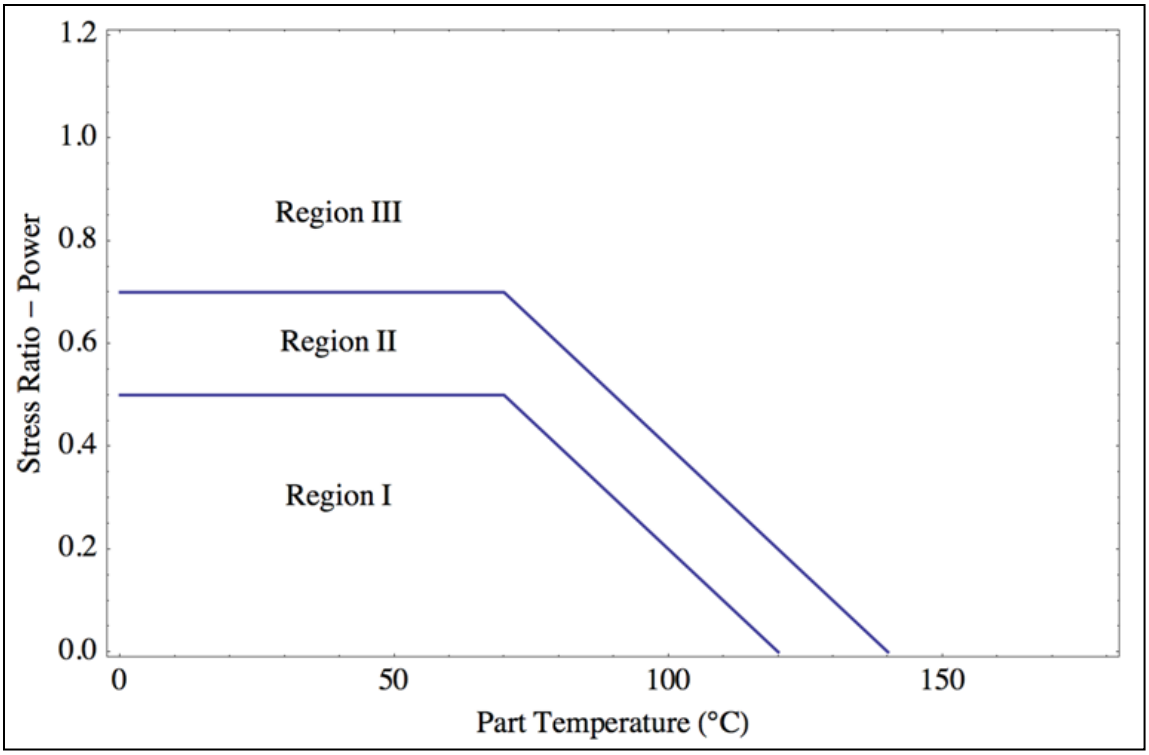


Figure C-13. Metal Film Resistor (RNC, RNR)

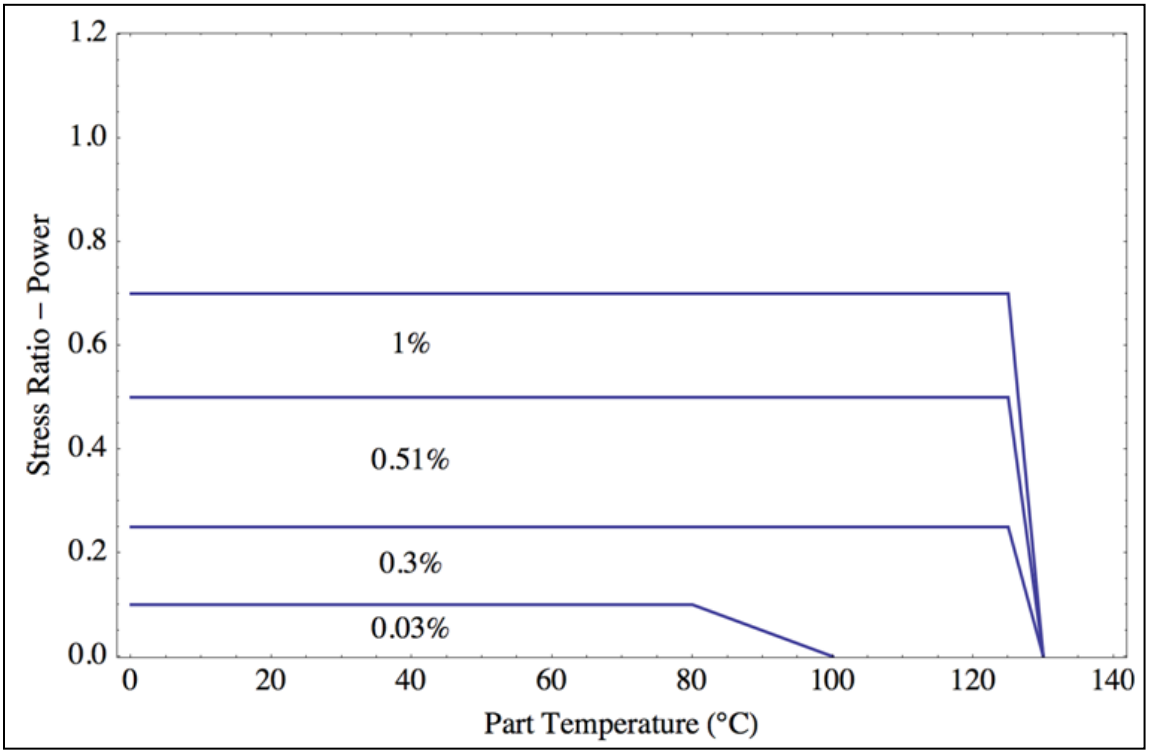


Figure C-14. Wire-Wound Accurate Resistor (RBR)

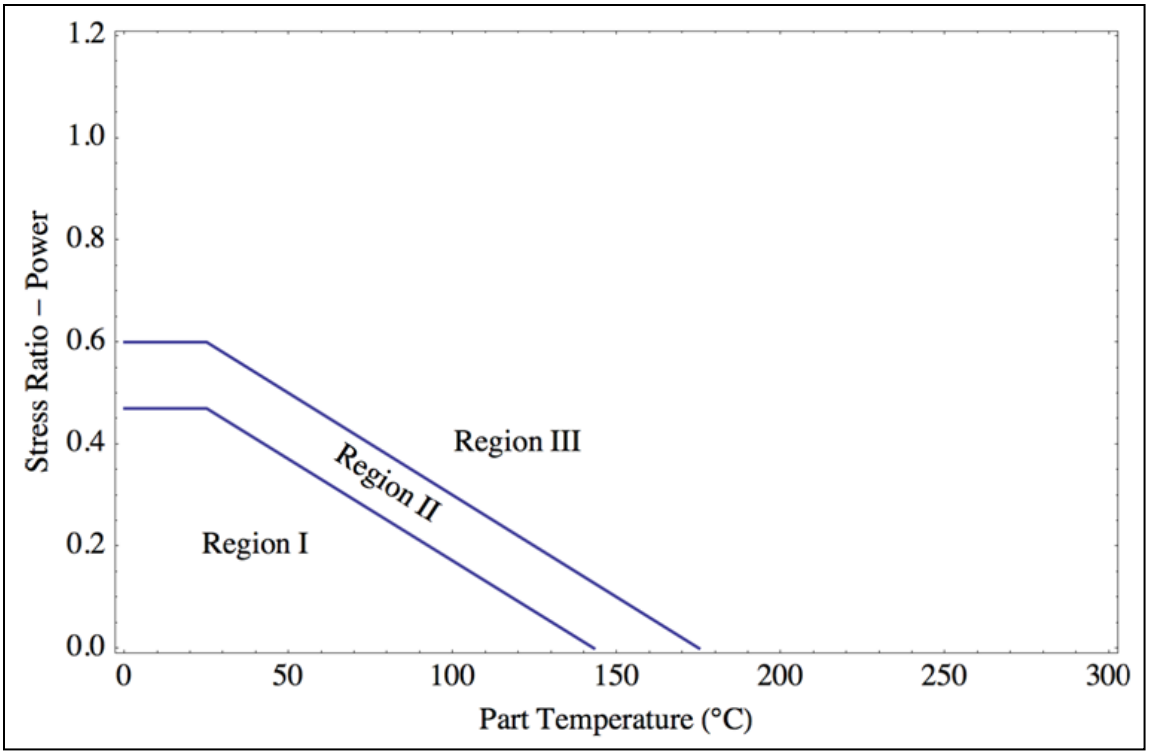


Figure C-15. Wire-Wound Power Resistor (RWR, RER)

C.14 Slip Rings - Derating Criteria

The maximum current in the slip ring shall not exceed 0.5 of the designed current-carrying capability of the slip ring. In addition, slip rings shall be designed so that when 0.5 of the rated current is being carried, the temperature of the slip rings shall not exceed 50°C above ambient.

C.15 Substrates - Derating Criteria

Alumina substrates shall be derated to 0.5 of the manufacturer's DWV.

C.16 Switches - Derating Criteria

The derating requirements for switches are essentially the same as for relay contacts. The notes below Table C-21 that refer to relay contacts also apply to switches.

Thermal switches developed to MIL-PRF-24236[46] 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 cannot be met, solid-state thermal controls shall be used.

[46] Department of Defense. Switches, Thermostatic, (Metallic and Bimetallic), General Specification for. MIL-PRF-24236D w/Amendment 1. 1 June 2010. May be superseded by update. Available at http://quicksearch.dla.mil/.

C.17 Transistors - Derating Criteria

Table C-25 describes derating criteria for bipolar junction and JFET transistors. Table C-26 lists derating criteria for GaAs FETs. Table C-27 provides derating criteria for metal oxide semiconductor field effect transistors (FETs), small-signal, and power transistors.

Table C-25. Bipolar Junction and Junction-gate Field Effect Transistors

Parameter	Maximum Stress Ratio	Comments
Power[1]	0.5 (0.6 WC)	
Voltage[2]	0.75	
Voltage Transients	0.85	Worst-case turn-on or repetitive transient.
Current	0.75 (0.85 WC)	
Junction Temperature	125°C, or maximum rating − 20°C	Whichever is lower.

[1]Usable power at a given case temperature can be found from the following relationship:

$$P = (T_{Jmax} - T_C)/\phi_{JC}$$

Where:

T_{Jmax} = the maximum allowed junction temperature.
T_C = the device case temperature.
ϕ_{JC} = the thermal resistance from junction to case.

[2]Voltage derating applies to device voltages such as the maximum open emitter collector-to-base voltage (V_{CBO}), maximum open collector emitter-to-base voltage (V_{EBO}), and maximum emitter biased collector-to-base voltage (V_{CEX}) for bipolar junction transistors and the maximum gate-to-drain, maximum gate-to-source, and maximum drain-to-source voltages for FETs. The preceding list is for example only and does not comprise all voltages that must be considered.

Table C-26. GaAs Field Effect Transistor

Type	Parameter	Maximum Stress Ratio	Comments
Low Noise	Voltage	0.75	
	Current[1,2]	0.9	
	Power, Channel	0.5	
	Temperature, Channel	125°C, or maximum rating − 20°C	Whichever is lower.
Power	Voltage	0.75	
	Current[1,2]	0.9	
	Temperature, Channel	125°C, or maximum rating − 20°C	Whichever is lower.

[1]Where the maximum saturation drain current (I_{DS}) rating is not specified, the upper zero gate voltage drain current (I_{DSS}) rating will apply.
[2]Devices may be tested briefly with I_{DS}, not to exceed the maximum rated value. Forward gate current shall be 0.9 of the specified rating or less, or zero if not specified.

Table C-27. Metal Oxide Semiconductor Field Effect Transistors, Small-Signal, and Power Transistors

Parameter	Maximum Stress Ratio	Comments
Voltage, Gate-to-Source, V_{GS}	0.75	
Channel Power	0.5	
Channel Current[1,2]	0.9	
Breakdown Voltage, V_{BGSS}	0.75	
Temperature, Channel	125°C, or maximum rating − 20°C	Whichever is lower

[1]Where the maximum saturation drain current (I_{DS}) rating is not specified, the upper zero gate voltage drain current (I_{DSS}) rating will apply.
[2]Devices may be tested briefly with I_{DS}, not to exceed the maximum rated value. Forward gate current shall be 0.9 of the specified rating or less, or zero if not specified.

C.18 Wire and Cable - Derating Criteria

Table C-28 lists derating information for wire of various gauge and bundle sizes.

Table C-28. 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. Ratings are based on polyalkene-insulated copper wire.
28	1.0	1.8	
26	1.4	2.5	
24	2.0	3.3	
22	2.5	4.5	
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	

[1]Use of wire smaller than AWG #30 is not recommended; however, if it must be used, the maximum current rating for a single wire is 2.16 A/m^2 (2.63 mA/circular mil, 3.348 mA/square mil) of cross-sectional area. Wire smaller than AWG #36 shall require a reliability review and PMPCB approval prior to use and shall not be used in critical applications.
[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 C.3.

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Appendix D

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 is required prior to acceptance of the unit by the procurement agency. This testing is sometimes referred to as Performance Testing (See MIL-STD-810).

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: A stimulus (energy, dose, current, voltage, stress, etc.) level, above the statistical all-fire level (i.e., the statistical all-fire level plus a margin), used in the specification. The specified 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 specified all-fire level is used for all system analyses, LATs, and qualification testing. Sometimes called the guaranteed all-fire level.

Statistical: The minimum stimulus (energy, dose, current, voltage, stress, etc.) level, determined by performing a sensitivity analysis on data gathered from a sensitivity test, at which an ordnance initiation device will fire with a specified reliability and confidence level.

See No-Fire Level.

Antenna: A device capable of radiating or receiving RF 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 RF 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 and ANSI/IEEE 149.[47]

Abbreviated Pattern. A limited sample of the full pattern that represents the full range of the antennas capability.

Attenuation, Radio Frequency (RF): The decrease in the power of an 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 the composite of the RCC tones present on the RF carrier.

Autonomous FTS (AFTS): An independent FTS that replaces or supplements the command destruct system that renders a vehicle non-propulsive. The autonomous FTS determines if a vehicle termination is required based on 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. Examples include ISDSs and ADS.

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.

Roll: An arbitrarily predefined 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.

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.

[47] Institute of Electrical and Electronics Engineers. *IEEE Standard Test Procedures for Antennas*. ANSI/IEEE Std 149-1979. New York: Institute of Electrical and Electronics Engineers, 1975 (reaffirmed 2008).

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 specified minimum total energy contained within a battery as determined by the manufacturer based on a set of specific conditions such as the SOC at start of discharge, discharge temperature, discharge current, and EODV.

Measured Capacity. The total energy contained within a battery determined by testing based on a set of specific conditions such as the SOC at start of discharge, discharge temperature, discharge current, and EODV.

Booster Charge: Ordnance industry term. When an initiating ordnance element does not produce enough energy to initiate a target, an intermediary explosive element or “booster charge,” which is capable of being initiated by the first element and that produces enough energy to initiate the target, may be employed.

Breakwire: A continuity circuit between stages of multistage vehicle, structural vehicle breakpoints, or separation plane interfaces whose breakage is used to initiate FTS actions.

Command Termination System: An airborne system that receives a ground-initiated flight termination control signal that terminates flight of the vehicle. A command destruct system includes all receiving antennas, receiver decoders, explosive initiating and transmission devices, SADs, and ordnance necessary to achieve termination of a vehicle.

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 strength 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. Each device that is required to undergo certification testing has a specified maximum certification period beyond which it must be recertified before it can continue to be used. See Surveillance Test.

Check Channel: A representative tone that is modulated onto the carrier to validate command destruct link integrity.

Circular mil: The area of a circle with a diameter of 1 mil.

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.

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.

Continuity and Isolation: The resistance between any electrical component's terminals that are common (continuity) and those that are not common (isolation).

Continuous Wave (CW) Bandwidth: The FTR CW response at the assigned center frequency versus the 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: 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.

Critical Pressure: The pressure that yields the lowest electrical breakdown voltage for an atmospheric gas and hence the highest vulnerability to arcing between two conductors. This process is governed by Paschen's Law.

dBm: A measure of RF power in decibels relative to a reference value of 1 mW. It is typically easier to directly measure voltage than power so for simple resistive circuits it is common to convert the power ratio into a voltage ratio. For this standard, the reference voltage is that voltage that, when applied across a 50-Ω resistor, yields a power dissipation of 1 mW. For such a circuit, the reference voltage is $V = \sqrt{PxR} = \sqrt{1\,\text{mW x } 50\,\Omega} = 0.224$ V.

Deadfacing: Any method used to ensure that electrical connectors that are planned on being demated during flight become electrically inactive upon demating in order to prevent arcing.

Decibel (dB):

A unit of relative power. The decibel ratio between two power levels, P_1 and P_2, is defined by the relation $dB=10\ Log_{10}\ (P_2/P_1)$. This equation is used, for example, to calculate margin for spectral density random vibration, acceleration, and shock.

A unit of relative voltage, current, or g_{rms}. The decibel ratio between two levels, L_1 and L_2, is defined by the relation $dB=20\ Log_{10}\ (L_2/L_1)$.

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.

Deflagration: Subsonic combustion typically propagated through thermal conductivity. This produces pressures on the order of 7 MPa to 70 MPa and propagation velocities on the order of 400 m/s or less.

Derating: The process of setting the maximum allowable stress levels for electronic piece-parts below the manufacturer's specified limits in order to increase reliability and lifetime.

Detonation: Supersonic combustion propagated through shock compression. This produces pressures on the order of 7 GPa and propagation velocities on the order of 3 km/s to 10 km/s.

Detonator: An initiator designed to initiate high-order explosives.

Deviation Sensitivity: The amount of FM deviation required to cause an FTR to execute a command correctly.

Electroexplosive Device: See Low-Voltage Initiator.

Electronic Safe and Arm: A high-voltage ordnance initiating device that provides electronic interruption and initiation of downstream ordnance with no mechanical safety barriers.

Enhanced Flight Termination System (EFTS): The Enhanced Flight Termination System comprises an RCC standard digital encrypted command system.

Equivalent Level of Safety: A determination that a non-compliance with a component performance requirement does not result in a significant increase in risk to people and property and is accepted for use by the affected range.

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 Bridgewire Initiator : An electrical initiator using a high-voltage discharge through a thin wire or "bridge" causing the wire to vaporize creating a conductive gas that allows an electrical arc to form. The creation of the arc produces heat and a shock wave that initiates the explosive. See high-Voltage Initiator.

Exploding Foil Initiator: An electrical initiator using a high-voltage discharge through a foil creating a "flyer" that impacts on an explosive media resulting in initiation or detonation of the media. Also known as a "slapper" initiator. See high-Voltage Initiator.

Explosive Material Classification: Explosive materials may be classified in a number of different ways including sensitivity to initiation, velocity of propagation, chemical composition, etc. The two primary classifications used in this document are sensitivity to initiation and velocity of propagation.

Classification by sensitivity to initiation:

Primary explosives: Explosives that are relatively sensitive to initiation. Generally initiated by heat or shock.

Secondary explosives: Explosives that are relatively insensitive to initiation. Generally these must be initiated by another explosive.

Classification by velocity of propagation:

Low explosives: Explosives that deflagrate. Low explosives are normally employed as propellants.

High explosives: Explosives that detonate.

Fail-Safe: A method built into flight termination systems that will activate a termination output upon the loss of positive FTS control due to conditions such as loss of power, RF signal, tone, or command message.

Firing Circuit: The electrical energy path between the power source and the initiating device.

Firing Line: A wire or cable that conveys the appropriate stimulus to an initiator.

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 vehicles to receive ground encoded commands and to generate output signals meant to result in termination of the vehicle.

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 use.

Fratricide: When one system or component of a system causes harm or failure to another system or component.

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.

Hang-Fire: A condition that exists when an ignition signal has been sent to a propulsion initiator but ignition of the propulsion system is not achieved.

High-Alphabet Command System: The High-Alphabet Command System comprises an RCC standard “encrypted” analog tone-based command system.

High Explosive: See Explosive Material Classification.

High-Voltage Initiator: A device that begins an ordnance event using an electrical impulse greater than 500 V to directly initiate a secondary explosive. Examples include EBWs and EFIs. See Initiator.

High-Energy Firing Unit: An ordnance initiation component that uses voltages greater than 500 V to fire a high-voltage initiator.

In-Line Explosive: An explosive that is part of an explosive train and that is initiated by an explosive at one end and, in turn, initiates another explosive at the other end.

Initiator: Any single discrete unit, device, or subassembly whose actuation is caused by the application of kinetic, electric, or light energy that in turn initiates an explosive, propellant, or pyrotechnic material contained therein. The term "initiator" does not include complete assemblies that have initiators as subassemblies but includes only the subassemblies themselves.

Interrange Instrumentation Group (IRIG): One of the original standing groups formed by the RCC. The IRIG is a legacy term that has been replaced by individual standing groups such as the Range Safety Group.

IRIG Tones: The term "IRIG Tones" has been replaced by the term "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 at the source looking in the direction of propagation (counterclockwise polarized wave). This definition is consistent with ANSI/IEEE 149.

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 that uses the 95% 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 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. Typically used as a Fail-Safe termination condition.

Loss of Tone: Indicates that a specified tone is not present on the RF carrier or is no longer being decoded. Typically used as a Fail-Safe termination condition.

Low Explosive: See Explosive Material Classification.

Low-Voltage Initiator (LVI): A device that begins an ordnance event using an electrical impulse of less than 50 V. Examples include EEDs and semiconductor bridge initiators. See Initiator.

Margin: Additional design or test levels added to allow a component, subsystem, or system to satisfy 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.

Mil: 1/1000th of an inch. A milli-inch.

Mission Time: The duration of a vehicle's flight time for which the range safety officer has safety responsibility.

Modulation: The process by which a RF carrier is varied IAW 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 10 kHz and the amount of deviation is ±30 kHz.

The carrier is shifting at a rate of 10 kHz and moving a distance of 30 kHz to each side of the center frequency.

No-Fire Level:

Specified: A stimulus (energy, dose, current, voltage, stress, etc.) level, below the statistical no-fire level (i.e., the statistical no-fire level plus a margin), used in the specification, which will not render an initiator inoperative (dudding) or degrade performance. Sometimes referred to as the "No-Damage Level." The specified no-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 specified no-fire level is used for all system analyses, LATs, and qualification testing.

Statistical: The maximum stimulus (energy, dose, current, voltage, stress, etc.) level, determined by performing a sensitivity analysis on data gathered from a sensitivity test, at which an ordnance initiation device will not fire with a specified reliability and confidence level.

See All-Fire Level.

Non-operating Environment: Environments experienced while the component is powered off including manufacturing, storage, shipment, installation and pre-flight 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-flight 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 power, current, or energy level that is used in flight to initiate flight termination ordnance. The operating firing level includes a margin above the all-fire level. For example, for LVIs, the operating current is at least 150% of the guaranteed all-fire current (i.e., a 50% margin on the all-fire current).

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 a component or installation of the component on a 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 that primary power may be applied to electrical or electronic components without maintenance or rework.

Operational Bandwidth: The frequency band over which a properly modulated signal operating frequency can be varied, and an RF component will continue to properly receive and decode the signal.

Optical Coverage: Optical coverage is the percentage of the physical surface area of the cable core insulation covered by a shield. A solid shield would have 100% optical coverage. This typically has a fairly high correlation with the RF shielding efficiency.

Ordnance Interrupter: A device that 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.

Particle Impact Noise Detection (PIND): A nondestructive reliability screening technique that employs a combination of sinusoidal vibration and shock to provide kinetic energy to any loose particles inside a device cavity and an acoustic sensor to detect the noise the particles make as they impact the inner walls of the device.

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 Initiated Device (PID): An ordnance device employing a PI.

Percussion Initiator: A mechanical initiator that uses an external pull force to store potential energy in a spring that, when released, drives a pin into a primer initiating the first element of an explosive train. Examples of this type of device are 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.

Peroxide Voltage: Battery industry term. Initial voltage observed when current load is first applied to a fully charged cell; this voltage is normally higher than the plateau voltage.

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 (perpendicular) 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: Battery industry term. A battery that is not intended to be recharged that is disposed of in controlled conditions when it has delivered all its electrical energy.

Primary Explosive: An explosive that is sensitive to initiation by heat and/or shock. It is capable of building up from a deflagration to detonation in an extremely short distance and time, typically within a few milliseconds. It can also propagate a detonation wave in an extremely small diameter column. The resulting detonation shock wave may be used to initiate a secondary high explosive. Examples include mercury fulminate, lead styphnate, lead azide, and diazodinitrophenol (DDNP). See Explosive Material Classification.

Primer: A device containing impact sensitive ordnance material used to ignite an explosive or pyrotechnic. See Percussion Initiator.

Production Lot: Unless otherwise specified in the detail specification, a production lot of parts refers to a group of parts of a single-part type; defined by a single design and part number; produced in a single production run by means of the same production processes, the same tools and machinery, the same raw material, the same manufacturing and quality controls, and to the same baseline document revisions; and tested within the same period of time. All parts in the same lot have the same lot date code, batch number, or equivalent identification.

Propellant: A material that deflagrates to produce pressurized gas. See Pyrotechnic Ordnance.

Propellant Actuated Device (PAD): An ordnance device that employs the pressurized gas produced by burning a propellant to perform mechanical work.

Pyrotechnic Ordnance: A type of low explosive that produces gas, light, heat, or pressure and is used primarily to provide mechanical energy or to ignite primary explosives. Pyrotechnic ordnance does not typically produce enough energy to directly initiate secondary explosives.

Q:

The standard aerodynamic symbol for dynamic pressure.

The standard symbol for the dynamic quality factor or transmissibility that determines the qualitative behavior of a simple damped oscillator. It is used in calculating the SRS. The value is unitless with a magnitude equal to the inverse of two times the damping ratio.

Dynamic Amplification Factor? (from structural dynamics)

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. This testing is sometimes referred to as Endurance Testing (See MIL-STD-810).

Quieting Sensitivity: The minimum signal input to an FM receiver that is required to give a specified output signal-to-noise ratio under specified conditions.

Range Safety Officer: A generic title used in this document to designate the person responsible for the real-time, pre-flight, and flight 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 DoD, civil government, commercial; and foreign government agencies.

RCC Tones: A group of 20 standard tone frequencies that are specified in RCC Standard 319-14, Supplement. These tones are used to encode commands for standard tone-based flight termination receivers.

Redundancy: The existence of two or more components, circuits, assemblies, or systems that serve the same objective. The goal of physical redundancy is to provide maximum practical separation, difference in orientation, etc. between redundant components in order to increase breakup survivability.

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 Power: The amplitude of the RF signal.

RF Receiving System: A group of components that provide vehicle antenna radiation characteristics to satisfy radio command coverage requirements. The RF receiving system may include power splitters, combiners, hybrids, coaxial cables, and other passive components. The RF receiving 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.

Safe and Arm Device: An ordnance initiation component that provides mechanical interruption (safe) or alignment (arm) of the explosive train and/or electrical interruption (safe) or continuity (arm) of the firing circuit.

Secondary Battery: Battery industry term. A rechargeable battery.

Secondary Explosive: An explosive that 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 booster charges and bursting charges. Sometimes called "non-initiating high explosives." Examples include pentaerythritol tetranitrate (PETN), Research Department explosive (RDX), trinitrotoluene (TNT), and hexanitrostilbene (HNS). See Explosive Material Classification.

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.

Semiconductor Bridge Initiator (SCB): See Low-Voltage Initiator.

Sensitivity Test / Sensitivity Analysis: This comprises a statistical test and data analysis methodology that is used in this document to determine ordnance maximum no-fire and minimum all-fire stimulus. This does not constitute a firing reliability test or analysis. See Statistical All-Fire / No-Fire levels.

Service Life: The period extending from the date of completion of LATs of an item to a date when it is no longer acceptable for use. For the purpose of this document the service life covers both storage life and operating life.

Service Life Extension Test: A test or sequence of tests used to extend the service life of an item.

Signal Strength Telemetry Output (SSTO): A telemetry output voltage from an FTR that is directly proportional to the power of the RF signal that the FTR is receiving. The FTR uses its automatic gain control voltage as the basis for SSTO voltage. This output signal is usually scaled from 0 to 5 Vdc and may be referred to as the automatic gain control, signal strength telemetry (SST), or SS/TLM. The preferred initialism is SSTO.

Sound Pressure Level (Lp or SPL): A measure of acoustic power in decibels relative to a reference value of 20 µPa.

Square mil: The area of a square with 1-mil sides.

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 propellant-actuated devices. See Initiator and Pyrotechnic Ordnance.

Standard Leak Conditions (SLC): For the purposes of this document the standard leak conditions are defined by a temperature and partial pressure of the standard reference gas on the high-pressure side of the leak of 25°C (“room temperature”) and 100 kPa absolute (1 Atm, 760 mm Hg), respectively and a partial pressure of the standard reference gas on the low pressure side of the leak of less than 133 Pa absolute (0.001 Atm, 1 mm Hg).

Storage Life: That period of time during which the item can remain in storage under specified environmental conditions without having its operability affected. The service and storage life clocks start at burn-in or acceptance test.

Surveillance Test: A test or sequence of tests that is performed periodically over the service life of a unit to verify continued functionality. Sometimes referred to as an Age Surveillance Test.

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 that, when received and decoded, will cease the flight profile of an airborne vehicle.

Threshold RF Sensitivity: The 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.

Up-Rating: The process of qualifying an electronic piece-part to operate outside of the manufacturer's specified limits. This process is strongly discouraged.

Voltage Standing Wave Ratio (VSWR): In any transmission line the total line voltage at any location and time is the sum of the forward voltage wave and any voltage wave being reflected back down the line due to imperfections in the transmission medium or an impedance mismatch between the transmission line and the load. The VSWR is the ratio of the sum and the difference of the maximum amplitudes of the forward and reflected waves. An ideal VSWR of 1:1 occurs when there is no reflected voltage wave. This also means that all of the RF power introduced at one end of the line will be coupled to the next device with no losses. A VSWR of Infinity:1 occurs for both open circuit and short circuit terminations of a transmission line.

Waiver: Waivers document non-compliances to performance requirements that result in significant risks to mission personnel or public safety and require formal acceptance by the range commander.

Watchdog Circuit: A watchdog circuit is one that is designed to monitor the operation of a digital processor and to reset it in the event of a specified failure condition.

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Appendix E

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