REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
17-October-2019	Final	

4. TITLE AND SUBTITLE
Joint Ordnance Test Procedure (JOTP)-054
Guidelines for the Design of Low Voltage Command-Arm (LVCA) Distributed Fuzing Systems

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHORS

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
DOD Fuze Engineering Standardization Working Group
U.S. Army CCDC Armaments Center
ATTN: FCDD-ACE-Z / Building 6
Picatinny Arsenal, NJ 07806-5000

8. PERFORMING ORGANIZATION REPORT NUMBER
JOTP-054

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Policy and Standardization Division (CSTE-TM)
US Army Test and Evaluation Command
6617 Aberdeen Boulevard
Aberdeen Proving Ground, MD 21005-5001

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Same as item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT

Distribution Statement A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Defense Technical Information Center (DTIC),

This in the initial release of the document. There are no previous versions of this document.

14. ABSTRACT
This document provides guidance on the design of distributed fuzing systems that utilize low voltage electrical signals to properly arm the fuze for subsequent detonation.

15. SUBJECT TERMS

Low Voltage Command Arm   fuzes   distributed fuzing systems   arming environments

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**B. ABSTRACT**	**C. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
Unclassified	Unclassified	Unclassified	SAR	17	

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DEPARTMENT OF DEFENSE

JOINT ORDNANCE TEST PROCEDURE (JOTP)-054

GUIDELINES FOR THE DESIGN OF LOW VOLTAGE COMMAND-ARM (LVCA) DISTRIBUTED FUZING SYSTEMS

DOD Fuze Engineering Standardization Working Group (FESWG)

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Joint Ordnance Test Procedure (JOTP)-054
Guidelines for the Design of Low Voltage Command-Arm (LVCA) Distributed Fuzing Systems

<table>
<tr><td>DOCUMENT COMPLETION DATE:

6 November 2019</td><td colspan="2">TITLE AND SUBTITLE:

Joint Ordnance Test Procedure (JOTP)-054
Guidelines for the Design of Low Voltage Command-Arm (LVCA) Distributed Fuzing Systems</td></tr>
<tr><td colspan="2">PREPARING ACTIVITY:

DOD Fuze Engineering Standardization Working Group
U.S. Army CCDC Armaments Center
ATTN: FCDD-ACE-Z / Building 6
Picatinny Arsenal, NJ 07806-5000</td><td>SPONSORING ACTIVITY:

Policy and Standardization Division (CSTE-TM)
US Army Test and Evaluation Command
6617 Aberdeen Boulevard
Aberdeen Proving Ground, MD 21005-5001</td></tr>
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<tr><td colspan="3">COORDINATION DRAFT REVIEWED BY:
This document was coordinated with the following Standardization Offices: AR, AS, EA, MC, MI, MR, OS, TE, AF-2, AF-70, and AF-99. In addition, the document was also coordinated with the Joint Weapon Safety Working Group and select Subject Matter Experts (SMEs).

ASSIST COORDINATION DATE: 14 June 2019</td></tr>
<tr><td colspan="3">IMPLEMENTATION PLAN:

1. This document was generated to describe acceptable architectures and signal format addressing safety design of distributed fuzing systems that utilize low voltage electrical signals to properly arm the fuze for subsequent detonation.

2. This document has been developed by the DOD Fuze Engineering Standardization Working Group (FESWG) for use by the Service Safety Review Authorities in evaluating low voltage command-arm (LVCA) distributed fuze architectures for an acceptable level of safety for service use.
3. In all cases, the Service Safety Review Authorities will review the LVCA architecture and any applicable safety and risk analyses for compliance with this document.</td></tr>
<tr><td colspan="3">APPROVING AUTHORITY:

Thierry Chiapello
Executive Director, DoD Explosives Safety Board</td></tr>
</table>

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DEPARTMENT OF DEFENSE
JOINT ORDNANCE TEST PROCEDURE

Joint Ordnance Test Procedure (JOTP)-054 17 October 2019
DTIC AD No.

GUIDELINES FOR THE DESIGN OF LOW VOLTAGE COMMAND-ARM (LVCA) DISTRIBUTED FUZING SYSTEMS

Approved for public release; distribution unlimited.

1. SCOPE.

a. This document provides guidance on the design of distributed fuzing systems that utilize low voltage electrical signals to properly arm the fuze for subsequent detonation. The primary purpose of this document is to describe acceptable architectures and signal format, addressing safety design and basic suitability for service use. This document is applicable to distributed in-line fuzing systems; however, the concepts may apply to out-of-line fuzing systems that remotely process the arming environments. Additional architectures and signal formats, beyond those presented in this document, may be acceptable based on unique program specifications to further support suitability for service use.

b. This document applies to fuzes, Safe and Arm devices (S&As), and Ignition Safety Devices (ISDs). (NOTE: The term “fuze” as used throughout this document is interchangeable with the terms “S&A” and “ISD”.) Exclusions include nuclear weapon systems and associated trainers, flares and signals dispensed by hand-held devices, and pyrotechnic countermeasure devices. This document does not replace the basic fuze or ISD safety requirements of MIL-STD-1316, MIL-STD-1901, or MIL-STD-1911. When feasible, every effort should be made to collocate safety features in accordance with MIL-STD-1316. When operational requirements preclude collocation of safety features, use of an acceptable low voltage command-arm (LVCA) architecture may be used if such architecture is agreed upon by the Service Safety Authorities (SSA) and acceptable rationale is provided.

c. This document has been developed by the DoD Fuze Engineering Standardization Working Group (DoD FESWG) for use by the Army Fuze Safety Review Board (AFSRB), the Army Ignition System Safety Review Board (ISSRB), the Air Force Nonnuclear Munitions Safety Board (NNMSB), and the Navy Fuze and Initiation System Technical Review Panel (FISTRP).

d. The SSA will review fuze, S&A, and ISD designs for acceptability using the guidance contained herein. Individual services may issue regulations or instructions which impose additional design safety criteria. Each program is encouraged to engage the appropriate SSA to determine the applicability of the guidance as well as any pertinent conditions and/or additional requirements. Continued dialogue should occur with the SSA as the design matures to facilitate the safety certification/concurrence process.

2. DEFINITIONS.

a. Low Voltage Distributed Fuzing/Ignition Architecture. A configuration and/or architecture in which elements that influence validation of arming environments are not collocated with the elements that enable safety features.

b. Environment. A specific physical condition to which the fuze and/or ignition system may be exposed.

c. Environmental Signal. The electrical representation of an environment sensed via transducer or sensor.

d. Sensor. A component or series of components designed to detect and respond to a specific environment.

e. Strong Data Typing. A fault tolerant technique wherein a discrete or variable data is represented by a bit pattern that is unique for each valid value and cannot be confused with any other valid value even as a result of up to a four bit error.

f. Virtual Environment: A unique electrical signal derived or translated from a physical environmental signal sensed by the fuzing system. It is NOT a direct sensor output.

3. REFERENCED AND RELATED DOCUMENTS.

a. REFERENCED DOCUMENTS.

(1) MIL-STD-461, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.

(2) MIL-STD-464, Electromagnetic Environmental Effects Requirements for Systems.

(3) MIL-STD-1316, Fuze Design, Safety Criteria for.

(4) MIL-STD-1901, Munition Rocket and Missile Motor Ignition System Design, Safety Criteria for.

(5) MIL-STD-1911, Hand-Emplaced Ordnance Design, Safety Criteria for.

b. RELATED DOCUMENTS.

(1) MIL-STD-331, Fuze and Fuze Components, Environmental and Performance Tests for.

(2) DoD JOTP-051, Technical Manual for the use of Logic Devices in Safety Features.

(3) DoD JOTP-052, Guideline for Qualification of Fuzes, Safe and Arm (S&A) Devices, and Ignition Safety Devices (ISD).

(4) DoD JOTP-053, Electrical Stress Test.

(Copies of these documents are available online at https://assist.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

4. REQUIREMENTS.

The words "should" and "preferred" in the text expresses a recommendation or advice on implementing this guidance. The customer expects that such recommendation or advice be followed unless sufficient rationale are provided to do otherwise. The word "must" in the text is used for a legislative or regulatory requirement (e.g., health and safety) with which both the customer and the fuze developer shall comply. It is not used to express a requirement of the specification. The word "will" in the text is used for the future tense. It does not express a requirement of the specification. The word "may" in the text expresses a permissible practice or action. It does not express a requirement of the specification. Plain text (i.e., text not containing the above key words) is used to state facts and to describe existing capabilities or features. Such text does not express a requirement of the specification.

4.1 Arming Control Unit (ACU)

4.1.1 The ACU should directly sense, process, and validate any physical arming environments that are to be converted into Virtual Environments (VEs). The ACU should translate the physical arming environment(s) into VEs and transmit all VE signal(s) to each Remote Firing Module (RFM).

4.1.2 Based on system requirements, the ACU may maintain an active link with all RFMs that are in use after the fuze system is properly armed.

4.1.3 The ACU is intended to provide all power and ground references for the RFMs, including Arm Power where practical.

4.1.4 There should be no inadvertent transmission of VE signals by the ACU during or after exposure to credible stressing electrical stimuli and electromagnetic environments. The ACU will be tested or evaluated in accordance with JOTP-53 (“Electrical Stress Test”), MIL-STD-461, and MIL-STD-464.

4.2 Remote Firing Module

4.2.1 Power to the safety critical features in the RFM should be applied as late in the launch sequence or operational deployment as practical.

4.2.2 The RFM should contain all required arming switches. Refer to Appendix A for examples of potential acceptable architectures.

4.2.3 It is preferred that the dynamic signal for driving the high voltage transformer be generated within the RFM.

4.2.4 Timing/Sequencing of the VE signals should be validated within the RFM.

4.2.5 There should be no inadvertent activation of any safety features during or after exposure to credible stressing electrical stimuli and electromagnetic environments. The RFM will be tested or evaluated in accordance with JOTP-53 (“Electrical Stress Test”), MIL-STD-461, and MIL-STD-464.

4.2.6 A minimum of two unique and independent VE arming signals should be validated at the RFM for arming of the fuze system. Robust physical environmental signals (i.e., raw sensor data) may be validated at the RFM in lieu of VE arming signals.

4.3 Environmental Signals/Commands

4.3.1 All environmental signals and VE signals must be robust such that the signal is not susceptible to inadvertent generation and subversion by credible environments anticipated in the lifecycle.

4.3.2 Each VE signal should be generated by independent and dissimilar logic circuitry that is physically and functionally partitioned. The degree of dissimilarity should be sufficient to ensure that any credible common cause failure mode susceptibility will not result in an inadvertent arming signal transmission in other logic devices and circuits.

4.3.3 The guidance outlined in 4.3.1 also applies to the processing of the received arming signal at the RFM and subsequent activation of any safety features contained within.

4.3.4 Virtual Environment Messaging

4.3.4.1 Each safety-critical VE message should be implemented as a dedicated, one-way communication line. All non-safety critical messages (e.g., polling, mission data, message acknowledgement, etc.) should be transmitted/received on a separate communication line.

4.3.4.2 Transmission of the VE message will only occur when its associated physical arming environment has been validated.

4.3.4.3 The preferred method is to dynamically generate the VE message based on events that occur throughout an arming environment.

4.3.4.4 Where generation of the VE message is not practical, pre-stored VE serial messages may be utilized. The pre-stored VE message must be further distinguished by a minimum of two additional validation methods (Reference Table A-1) or features in order to prevent subversion of safety features by credible environments.

NOTE: The method of 4.3.4.4 is considered a significant risk for acceptable implementation. Where operational requirements dictate the use of this method, sufficient justification will need to be provided. Consult with the SSA prior to implementing this method.

4.3.4.5 The Bit Error Rate (BER) of the received VE message should be less than or equal to $1x10^{-6}$.

4.3.4.6 Each VE message should use strong data typing and be unique and unambiguous, from any and all other VE messages.

a) Error detection schemes (e.g., parity, checksums, CRCs, etc.), if incorporated, must be distinct from any safety-critical message to the extent possible so as to not compromise the integrity of the message.

b) Error correction schemes will not be permitted.

4.3.4.7 Tolerance to corrupt/invalid data should be characterized through analyses and tests. The analyses and test methodologies will be provided to the appropriate SSA for approval. For reference, a list of potential data failure modes is shown in Table 1.

Table 1: Data Failure Modes

Failure Mode	Definition
Inadvertent Release	A class of failures whereby a message is sent that is not a result of deliberate, planned actions
Incorrect Sequence	Messages are not received in the correct order
Early Arrival	The message is received correctly before it is expected
Late Arrival	The message is received correctly later than expected
Repetition	The same message is sent all the time (i.e., babbling idiot)
Deletion	All or part of the messages or message content is missing
Insertion	A message is received unintentionally and is perceived as the correct address (e.g., data from the wrong source)
Corruption	One or more data bits are changed in the message
Masquerade	A non-safety-related message could be interpreted as a safety-related message
Inconsistency	Two or more receivers have a different view of the transmitted data or the receivers may be in different states

Appendix A

Notional Distributed Fuzing Architectures

A.1 Fundamental Architecture

Figure A-1 below outlines a basic block diagram from which a specific detailed design may be developed. All subsequent architectures shown in this Appendix are derivatives of Figure A-1.

Architecture configurations beyond what is presented in this Appendix should be based on Figure A-1 and reviewed by the appropriate SSA early in the design process for acceptability. Please note the following:

- The ACU "Environ Signal Validation" & "VE Generation" blocks and the RFM "VE Validation" blocks may be implemented with discrete components or complex logic.
- Non-Safety Critical Data (e.g., "Mission" Data) and the "Fire" signals are not shown in Figure A-1 due to the application-specific nature of these signals.
- Developers have the option to incorporate specific features of one architecture into another architecture. Examples of this would include controlling power (from Figure A-5) to a Bundle Control Unit (Figure A-4) or incorporating Frequency Shifts (Figure A-2) for both VEs.

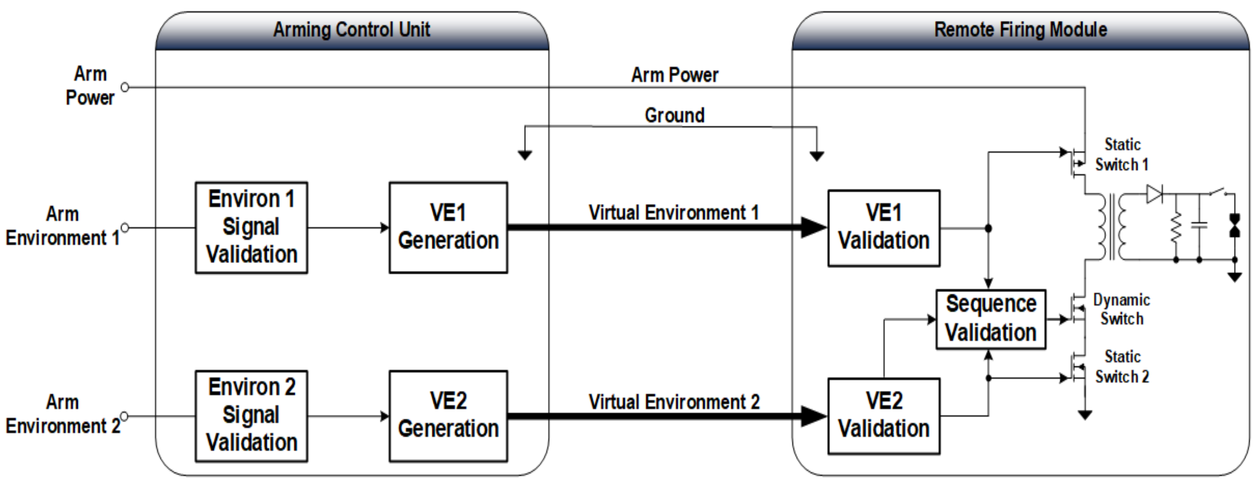

Figure A-1: Fundamental Block Diagram

A.2 Frequency Shift/Serial Data Architecture

The first Virtual Environment is a "Frequency Shift" whereby an initial frequency is sent to the RFM at the beginning of the arming environment (or after detection of the first event) and is "shifted" to another frequency at completion of the arming environment. The RFM must detect this change in frequency within a specific time window for it to be deemed valid. The second Virtual Environment is a serial message dynamically generated in accordance with paragraph 4.3.4.

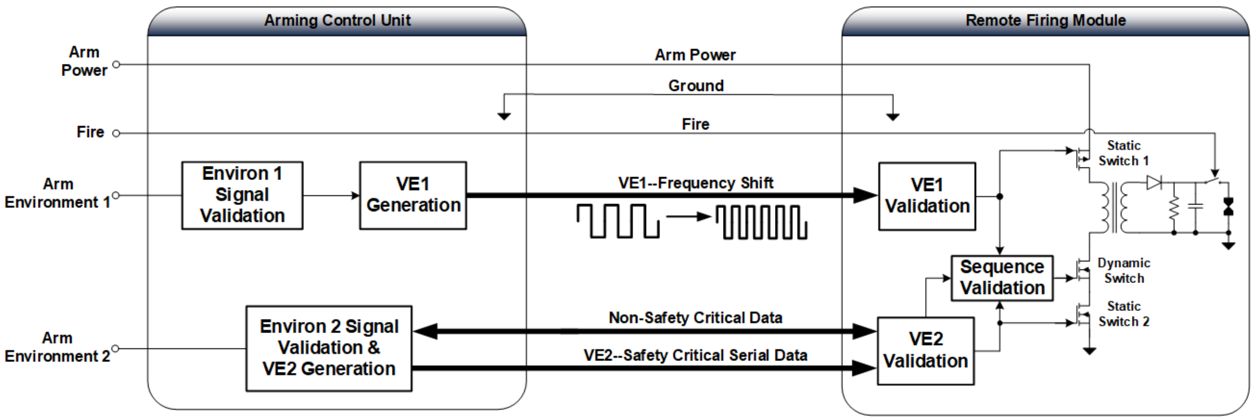

Figure A-2: Frequency Shift/Serial Data Architecture Block Diagram

A.3 Physical & Virtual ("Hybrid") Architecture

This architecture utilizes a Virtual Environment and the "raw" data from a physical arming environment. The safety features are located in both the ACU and the RFM. In lieu of raw sensor data, launch events may be used if such events irreversibly commit the munition to complete the launch cycle. The events must be detected within the expected time window and sequence.

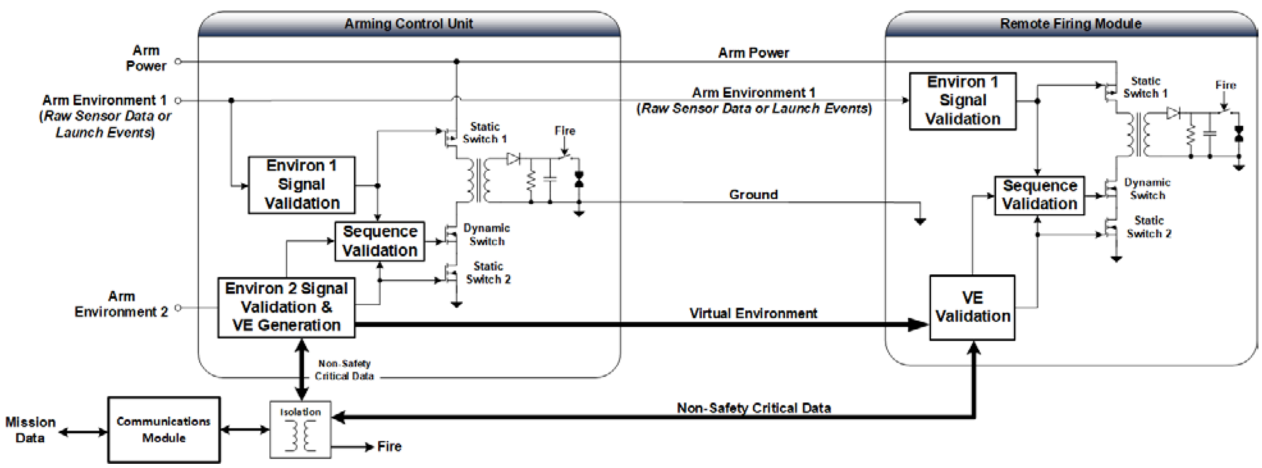

Figure A-3: Hybrid Architecture Block Diagram

A.4 Bundled Control Unit

This architecture utilizes a centralized safety module and distributes the firing voltage to the remote locations. The VEs are communicated between the ACU and Bundle Control Unit (BCU).

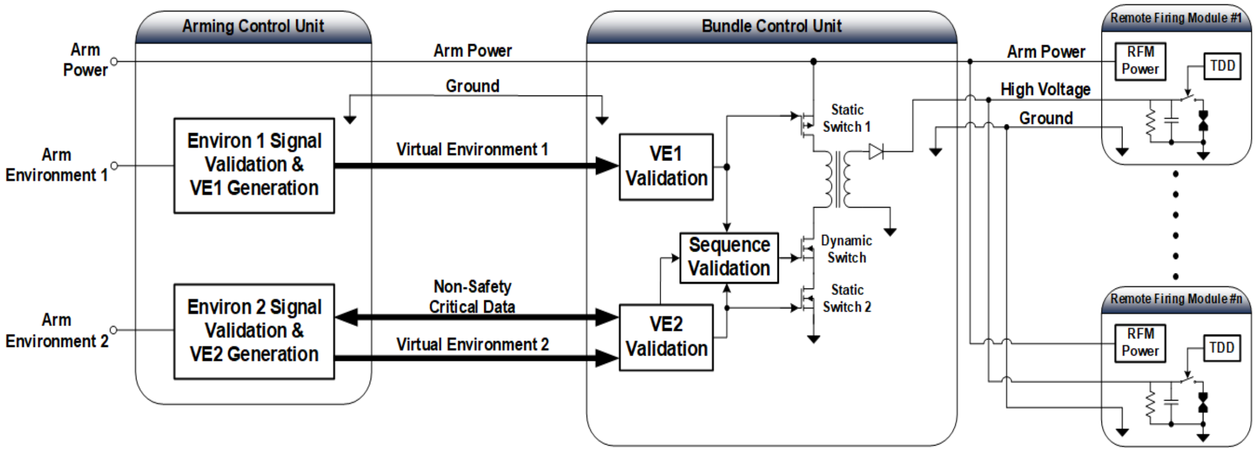

Figure A-4: BCU Architecture Block Diagram

A.5 RFM Power Control

This architecture utilizes a transistor switch to control power to the RFMs. Note that this switch ***is not*** considered a safety feature and ***does not*** contribute towards the prevention of fuze arming.

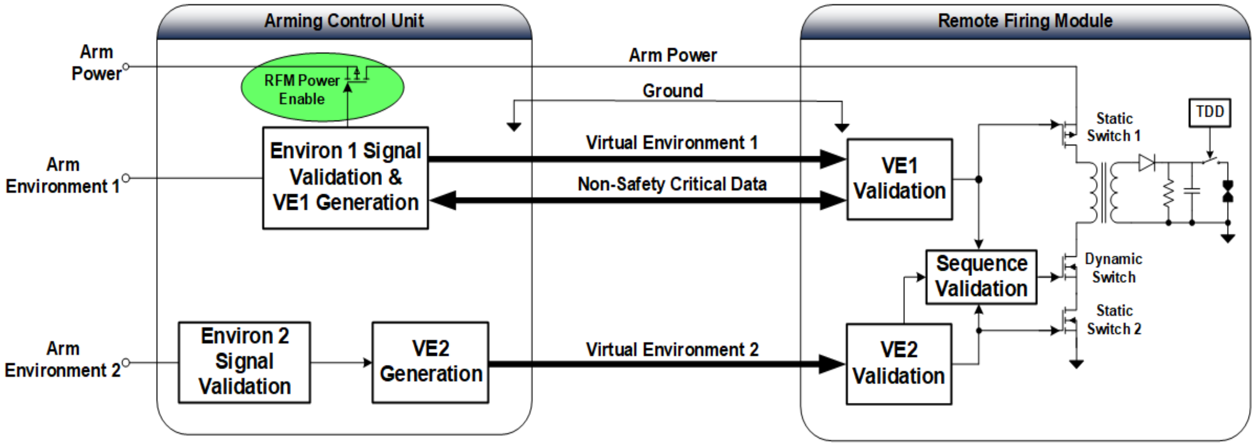

Figure A-5: RFM Power Control Block Diagram

A.6 Single Serial Data Line Architecture

This architecture is not approved for tri-service use and is considered a significant risk for acceptable implementation due to common mode, common cause, and independency failure mode concerns. Where operational requirements dictate the use of this architecture, sufficient justification will need to be provided. Consult with the SSA prior to implementing this architecture.

In this architecture, both Virtual Environments are transmitted over a single serial data line. Since the communication data is safety-critical, several methods may need to be incorporated to mitigate the potential failure modes listed in Table 1. Refer to Table A-1 for recommended mitigation methods.

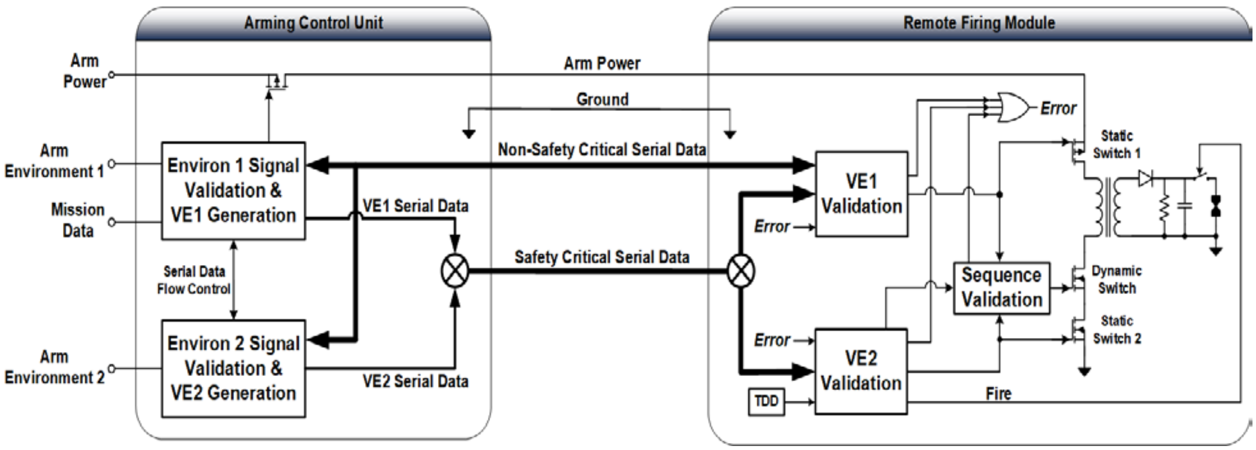

Figure A-6: Single Serial Data Line Architecture Block Diagram

Method / Failure Mode	Sequence number	Time Stamp	Time out	Message Reliability (e.g. CRC)	Feedback Message	Flow Control	Identifiers for sender and receiver	Replication	Alternating messages
Inadvertent Release	•	•	•		•				•
Incorrect Sequence	•	•							•
Early Arrival		•							
Late Arrival		•	•		•				
Repetition	•	•							•
Deletion	•	•			•				•
Insertion	•				•			•	•
Corrupted Message				•	•				•
Masquerade				•	•		•		
Inconsistency						•			

Table A-1: Failure Mode Mitigation Methods

Comments, suggestions, or questions on this document should be addressed to:

Chairman, DOD Fuze Engineering Standardization Working Group, U.S. Army Combat Capabilities Development Command Armaments Center (FCDD-ACE-Z / Building 6), Picatinny Arsenal, NJ 07806-5000
usarmy.pica.ccdc-ac.mbx.afsrb@mail.mil

and

Policy and Standardization Division (CSTE-TM), US Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001, https://www.atec.army.mil/publications/documents.html

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