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HAND-EMPLACED MUNITIONS (HEM), PRINCIPLES FOR SAFE DESIGN

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NORTH ATLANTIC TREATY ORGANIZATION

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

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NATO LETTER OF PROMULGATION

23 September 2020

1. The enclosed Allied Ordnance Publication AOP-4497, Edition A, Version 1, HAND-EMPLACED MUNITIONS (HEM), PRINCIPLES FOR SAFE DESIGN, which has been approved by the nations in the CNAD AMMUNITION SAFETY GROUP (CASG AC/326), is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 4497.

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4. This publication shall be handled in accordance with C-M(2002)60.

Zoltán GULYÁS
Brigadier General, HUNAF
Director, NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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RECORD OF SPECIFIC RESERVATIONS

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CHAPTER 1 INTRODUCTION

1.1. AIM

The aim of this allied publication is to provide general design principles and specific safety criteria applicable to Hand-Emplaced Munitions (HEMs) throughout their life cycles. The requirements are applicable to new design and development of all HEMs, except those listed in Paragraph 1.3, and subject to national ratification instructions.

1.2. GENERAL INTRODUCTION

HEMs and their associated system(s) shall be designed to meet and maintain the degree of safety defined by the staff requirement for all expected and unexpected-but-credible threat and environmental exposures conceivable throughout the life cycle planned for the HEM. Compliance with the criteria listed in this AOP shall be demonstrated by tests or be assessed by analyses or both to the satisfaction of the safety approving authority of the developing nation.

1.3. EXCLUSIONS

The following munitions are excluded from this agreement:

(1) Nuclear weapon systems and their associated training aids.

(2) Flares and signals dispensed by hand-held devices.

(3) Pyrotechnic countermeasure devices.

(4) Demolition materials, devices or charges which are covered under STANAG 2818.

(5) Networked Munitions.

(6) Hand emplaced munitions which the NSAA agrees do not present sufficient hazard as to require a safety system.

1.4. DEFINITIONS

The term Hand-Emplaced Munition (HEM) applies to a munition that is manually emplaced at, or hand-thrown to, a point of intended function, and that requires user action both to begin its operation and to achieve safe separation. Examples include some mines, grenades, and pyrotechnic devices.

Specific terms used in this AOP are listed in Annex A, while Appendix 1 to Annex A lists terms and definitions related to possible states that both a Target Sensor and a Safety and Arming Device (SAD) can adopt within an HEM.

All other terms are defined in the NATOTerm database (https://nso.nato.int/natoterm/content/nato/pages/home.html?lg=en).
Other International sources may be used to compliment but not replace the NATO agreed definitions.

1.5. WORDING CONVENTIONS

1. “Shall” indicates the application of a procedure or specification is mandatory.

2. “Should” indicates the application of a procedure or specification is recommended.

CHAPTER 2 GENERAL DESIGN REQUIREMENTS

2.1. GENERAL CONSIDERATIONS

The objective of using the requirements listed in this agreement is to optimize the safety of HEMs. The related documents imposed by and referenced in this AOP should be used, when applicable, during the development of Hand-Emplaced Munitions. Adherence to and implementation of the safety design principles discussed in those documents is assumed.

a. Whenever feasible, and where environments exist that can be used to arm the device (enable safety features), HEM designs are to conform to the requirements of STANAG 4187.

b. A system safety program based on the requirements of AOP-15 shall be implemented during the development of the HEM. The intent of that safety program shall be to ensure compliance with applicable design criteria and to control safety risk through early project attention to safety design criteria. Methods for ensuring compliance shall be based on accepted system safety analytical techniques applied as part of an iterative design process. The analyses and studies carried out under that system safety program shall consider all environmental influences, logistic conditions, and life cycle phases anticipated for the HEM.

c. A methodical evaluation shall be conducted to confirm that the principles for safe design given in this AOP have been effectively implemented. If the NSAA approves a less than fully compliant HEM for service use, then the basis for its approval shall be clearly documented..

2.2. SYSTEM DESIGN SAFETY APPROACH

The following general requirements apply to the design of an HEM within the scope of this document.

1. Life Cycle Exposure Profile

In concert with the conceptual design of the HEM, an environmental and threat exposure profile shall be defined. The profile shall establish exposure conditions and limits the HEM is likely to encounter throughout its life cycle from manufacturing to use or disposal. The profile shall be used in assessing hazards associated with the HEM.

2. Analyses

The following analyses shall be conducted to identify hazardous conditions associated with the HEM. The analyses shall be conducted with appropriate

timeliness in the development process to permit control of identified hazards by the most effective means.

(1) A preliminary hazard analysis shall be conducted in accordance with AOP-15. That analysis shall focus on conditions and personnel actions that may occur throughout the life cycle of the HEM. It may be carried out on conceptual and incomplete design information. It is intended to be used in the establishment of design, test and evaluation requirements for the HEM.

(2) System and major component hazard analyses shall be carried out to identify credible single point and other failure modes and to estimate the HEM's safety failure rate. Techniques such as Fault Tree Analysis and Failure Modes Effects and Criticality Analysis may be used in performing component and system hazard analyses. These analyses evaluate the safety of the HEM design in order to estimate the probabilities of a single system failing over its anticipated life cycle, including those due to manual operations. These probabilities shall not exceed the following rates:

(a) Prior to Commencement of the Arming Sequence. The probability of arming, or functioning irrespective of arming, between manufacture and the intended commencement of the arming sequence shall not exceed one in a million.

(b) During and after arming. The probability of unintentional functioning of the HEM during or after arming shall be acceptable to the NSAA.

(3) Where electronic logic (software) is shown to directly control or enable one or more safety features, a detailed analysis and testing of the applicable software, following the appropriate guidelines (such as AOP-15 or AOP-52), shall be performed to ensure that no design weaknesses, credible software failures, or credible hardware failures propagating through the software can result in compromise of the safety features. If Application Specific Integrated Circuits, Programmable Gate Arrays, or similar devices, are used, the analyses shall include a determination of the safety criticality of these devices to the arming and functioning of the system. Detailed safety analyses and tests shall be performed on those devices shown to be safety critical or directly influence safety critical functions to determine their contribution to the safety failure rate.

3. Fail-Safe Design

To the greatest extent feasible, the HEM shall incorporate design features that render the HEM incapable of attaining or maintaining an armed state and of functioning upon the failure, improper assembly, omission, or out-of-sequence operation of components.

4. Design for Survivability

The HEM shall be designed to minimize the violence of a reaction and of subsequent collateral damage when it is subjected to credible environments such as temperature extremes, shock and vibration, and fragment or bullet impact. The HEM shall use the least sensitive energetic materials available that meet the operational requirements. If possible, the use of primary explosives shall be avoided. The HEM shall be evaluated in accordance with STANAG 4439.

5. Electrical/Electromagnetic Environments

The HEM shall be designed such that, in its normal life cycle configurations, it shall not exhibit unsafe operation, nor shall any explosive component unintentionally function, during and after exposure to electromagnetic energy including lightning. Immunity from arming or firing due to electromagnetic forms of energy shall be demonstrated by analyses and appropriate tests as necessary, which duplicate or simulate credible life cycle electromagnetic environments (refer to AOP-20). Where electromagnetic environmental effects environments are not specified or known, AECTP 250 may be consulted for determining test parameters. Electromagnetic and electrical environments include: electromagnetic vulnerability (EMV), electrostatic discharge (ESD), electromagnetic radiation (EMR), lightning effects (LE) electromagnetic pulse (EMP), and power supply transients (PST). The HEM shall be tested or analyzed for the following as applicable:

(1) EMV: AECTP 500, Category 508, Leaflet 1, Ordnance Electromagnetic Vulnerability of a complete munitions system containing electronics

(2) ESD: AECTP 500, Category 508, Leaflet 2, Electrostatic Discharge

(3) EMR: AECTP 500, Category 508 Leaflet 3, Electromagnetic Radiation

(4) LE: AECTP 500, Category 508 Leaflet 4, Lightning

(5) EMP: AECTP 500, Category 508, Leaflet 5, Nuclear Electromagnetic Pulse

(6) PST: by appropriate national test and analysis

5. Compatibility of Materials

Explosive components shall meet the material compatibility requirements of STANAG 4147. All materials shall be chosen to be compatible and stable so that under all credible life cycle conditions, none of the following shall occur in an unarmed HEM:

(1) Premature arming or initiation.

(2) Dangerous exudation or ejection of material.

(3) Deflagration or detonation of the lead or booster.

(4) The formation of dangerous or incompatible compounds Material which could contribute to the formation of more volatile or more sensitive compounds should not be used. If used, then the material shall be treated, located or contained to prevent the formation of a hazardous compound.

(5) A compromise of the safety, de-arming, sterilisation or self-destruct features, e.g., by electro-chemical reaction.

(6) Production of unacceptable levels of toxic or other hazardous materials.

6. Design for Demilitarization and Disposal

The designs for HEM shall meet the requirements of STANAG 4518.

7. Human Factors Engineering

The HEM design shall emphasize human factors engineering to eliminate or control hazards associated with manual operations. The safety assessment of HEM shall identify all credible human errors and where possible, these shall be mitigated by design. If this is not possible, these hazards shall be mitigated by procedure and training.

(1) Design Simplicity. The design of the HEM shall be as simple as possible to minimize operator error.

(2) Design Ruggedness. The design of the HEM shall be rugged enough to permit exposure of the HEM to both the normal and credible accident environments and handling stresses anticipated in its life cycle with no deterioration or degradation of its safety system.

(3) HEM Assembly and Setting. The HEM shall be designed so that it cannot be assembled in the armed condition or in a condition that compromises the intended level of safety. Where disassembly is a requirement, the design shall be such that the HEM may be dismantled safely and be capable of reuse unless otherwise specified by operational requirements. If the state of the HEM is to be checked or set after assembly of the HEM, such checking or setting shall be positive and unambiguous, and shall not degrade safety.

(4) Manually Operable Safety Features. Manually operable features critical to system safety shall be designed to minimize inadvertent or unintended operation. Unless otherwise specified in the requirements document, operation of the first safety feature shall be reversible.

(5) Operational Status Indicator. The HEM safety system shall provide the user a positive indication of its operational status, compatible with the

intended environments where the HEM will be handled. The operational status indicator shall discriminate between safe and any lesser condition of the HEM's safety system and shall provide unambiguous notification to the observer. Indicator failure shall not result in a false non-armed condition indication.

(6) Human Error. To the greatest extent practical, human errors which could have a catastrophic effect shall be mitigated by either an indicator or a warning label.

8. Design for Quality Control and Inspection During Manufacture

HEM shall be designed and documented to facilitate the application of effective quality control and inspection and test procedures in accordance with AQAP-2110. The design of the HEM shall incorporate features that will facilitate the use of inspection procedures and test equipment to ensure that all critical design characteristics have not been compromised. All critical design characteristics (for example: dimensions, material properties, heat treatments, and fabrication operations) shall be identified by the safety assessment and a method to ensure that these characteristics are within acceptable limits shall be incorporated during manufacturing and assembly of the HEM.

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CHAPTER 3 DETAILED DESIGN REQUIREMENTS

3.1 REQUIREMENTS APPLICABLE TO ALL HEM DESIGNS

a. Safety Features

The safety system of an HEM shall contain at least two independent safety features, each of which shall prevent unintentional arming. Enabling of each safety feature shall require a separate, distinct, and verifiable action. Those actions must be performed in a specific sequence for arming to be permitted. After the first action is taken, the HEM shall be capable of being restored to its original condition.

b. Arming or Firing-Control Delay

HEMs shall incorporate a method for obtaining safe separation. An arming delay provides the highest level of safety and shall be used wherever feasible. A firing-control delay may be used to obtain safe separation if operational or functional requirements dictate. However, prior approval of the NSAA for this must be obtained and the firing-control delay shall be fail safe.

The design of HEM shall reduce to a minimum single point failure modes for arming delays or firing-control delays. The time window associated with these single point failures shall be reduced to a minimum and shall exist only at or near the expiration of the intended arming delay.

c. HEM Setting.

Inadvertent alteration of the arming time or function time shall be prevented.

d. Stored Energy

The HEM shall not use stored energy for enabling or arming if sufficient energy can be derived from environments or levels of environmental stimuli present only during or after HEM deployment. If sufficient energy cannot be so derived, stored energy may be used with the following restrictions:

(1) Installation of any stored energy component(s) into the HEM shall be delayed as long as feasible in the manufacture-to-deployment logistic cycle, and

(2) The design of the HEM prohibits release of the stored energy except as a result of user-enabled actions performed in a specific sequence.

Examples of stored energy are batteries, charged capacitors, compressed air devices, explosive actuators, and loaded springs.

e. Electrical Firing Energy Dissipation

For electrically initiated explosive trains in HEMs, the design shall include a provision to deplete the firing energy after expiration of the munition's armed life, or safety system failure, or whenever the HEM is returned to the non-armed condition. The time required to dissipate the firing energy shall be reduced to the minimum allowed by operating requirements for the munition. The means of dissipation shall be designed to preclude single point and common-mode failures, and to ensure that the overall safety of the munition is not degraded before the munition is armed.

f. Self-Destruction, Sterilisation, De-arming

Self-Destruct may take one of two forms: self-functioning or self-disruption. If required in the system requirement document, a self-destruct, sterilisation, and/or de-arming feature may be included. None of these features shall increase the probability of hazards to the users throughout the lifecycle of the munition over those that exist without such a feature. Self-destruction shall not be initiated prior to achieving safe separation distance or equivalent functional delay.

g. Anti-Tamper

The use of anti-tamper features shall not reduce the safety to the user.

Anti-tamper features that pose a potential unintentional hazard shall be deactivated after expiration of the munition’s armed life.

h. Explosive Ordnance Disposal (EOD)

Features shall be incorporated in the HEM in accordance with national policies that facilitate its being rendered safe by EOD tools, equipment and procedures, even if sterilization or self-destruction features are incorporated.

i. Explosive Materials

Explosive materials shall be selected as follows:

(1) Assessment and Qualification of Explosives. Explosives shall be assessed and qualified for their intended role (e.g., primary explosive, lead charge, booster explosive, high explosive (main charge), etc.) in accordance with the requirements of STANAG 4170.

(2) Safety in Storage and Use. Explosive compositions shall be chosen, so that the system is safe and remains so under the specified conditions of storage and use.

(3) Sensitiveness. The sensitiveness of the explosives shall not increase significantly during the entire service life of the HEM beyond the level at which they were approved for service use.

(4) Qualification and Sensitiveness of Explosive Materials Used in Non-Interrupted Explosive Trains. Only those explosives materials qualified in accordance with the requirements of STANAG 4170 as acceptable booster explosives are permitted to be in a position leading to the initiation of a high explosive main charge without interruption. The explosive material used in HEMs shall not be altered by any means likely to increase its sensitiveness beyond that at which the material was qualified.

(5) Assessment of Detonating Explosive Components. Detonating explosive components in HEMs shall be assessed in accordance with the requirements of and pass the tests specified in STANAG 4363.

j. Use of Interrupted Explosive Trains

When the explosive train contains primary explosives or explosives other than those allowed by Chapter 3, paragraph 3.1.i.(4) and 3.1.i.(5), the train is to be interrupted and the following requirements shall apply:

(1) At least one interrupter (barrier, shutter, slider, rotor) shall isolate the primary explosive and/or explosives that do not meet the requirements of Chapter 3, paragraph 3.1.i.(4) and 3.1.i.(5), from subsequent elements of the explosive train. The interrupter(s) shall be directly locked mechanically in the safe position by at least two independent safety features until the start of the arming sequence.

(2) The interrupter shall prevent propagation of an explosive event to any acceptor explosive element, contained within the explosive train after the interrupter, until the required safe separation or equivalent delay has lapsed. The explosive train interruption shall be evaluated by the Primary Explosive Component Safety Test as given in STANAG 4157 and AOP-20.

(3) Designs in which the primary explosive is positioned such that safety is completely dependent upon the presence of an interrupter shall include positive means to prevent the HEM from being assembled if the interrupter is excluded or if the interrupter is in the unsafe position.

k. Use of Non-interrupted Explosive Trains

Explosive train interruption is not required when only those explosive materials allowed by Chapter 3, paragraph 1.i.(4) and 1.i.(5), are used in the train. In these circumstances the following shall apply:

(1) At least two safety features shall enable at least 3 energy breaks.

(2) At least one energy break shall be capable of preventing arming in a static mode if any or all of the energy breaks are left out or malfunction. This requires at least one energy break to function in a dynamic mode.

(3) At least one energy break shall function in a static mode.

(4) Independent control of energy breaks shall be exercised to the maximum extent possible; a minimum of two separate logic devices shall be employed.

l. Electrical Initiators and Electroexplosive Devices (EEDs)

(1) Shall be characterised in accordance with STANAG 4560 and that information shall be made available to the NSAA.

(2) Shall be qualified to specific test procedures and pass/fail criteria established or approved by the NSAA.

(3) Electrical initiators used in non-interrupted explosive trains shall:

a. Not be capable of being detonated by any electrical potential of less than 500 V applied directly to the initiator.

b. Not be capable of being initiated by an electrical potential of less than 500 V when applied to any accessible part of the HEM after final assembly.

c. EED No-Fire Threshold Safety Margins. In any safety and arming system in which safety is dependent on preventing the unintentional functioning of an EED, a minimum safety margin between the no-fire threshold (NFT) stimulus and the stimulus that could be induced by electrical or electromagnetic interference shall be demonstrated to and accepted by the NSAA.

m. Arming and Initiation

Designs shall ensure that:

(1) Independent safety feature controls (e.g., logic) are physically separated and implemented using different component types to minimise the potential for common cause failures.

(2) The safety of the HEM shall not be degraded by Built-In-Test (BIT) or other In-Service Tests employed to verify the integrity of the HEM.

n. Safety Critical Computing Systems.

The safety design requirements and guidelines as stipulated by the NSAA shall be complied with. Requirements for safety logic features are as follows:

(1) Information Transfer.
Information passed between a logic controller or sensor and a safety and arming system shall be transferred by a defined logic route dedicated to that transfer only.

(2) Interpretation of Information.
Information received by the safety and arming system shall be capable of being verified as a valid command to begin a sequence of events resulting in the removal of a safety feature. False or corrupted data shall not cause the removal of a safety feature.

(3) Computing Systems.
Non-embedded software shall not be used. If a computing system with embedded software is used to perform the logic function, then it shall be designed to facilitate a safety assessment to the satisfaction of the NSAA.

o. Hardware Excluding Computing Systems.

If the logic function is performed by totally dedicated hardware to give unequivocal interpretation, the hardware systems shall use components in which all the logic states can be identified, verified and validated. The design selected shall be approved by the NSAA.

p. Assembly.

Where HEM safety is primarily achieved by separate storage and handling of the main charge and the initiating system explosives, such separation shall be maintained until on-site assembly and mating shall be delayed as late as possible in the assembly process.

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CHAPTER 4 SAFETY ASSESSMENT AND APPROVAL

4. 1 ASSESSMENT AND APPROVAL OF HEMs FOR SAFETY AND SUITABILITY IN ACCORDANCE WITH AOP-15.

a. Assessment

Assessment shall be a judgment made by the safety approving authority of the developing nation based upon consideration of the results of all analysis and testing results. In making the judgment, the results of analyses, developmental testing, testing of subassemblies of the HEM and tests performed for reasons other than safety, such as for obtaining performance and reliability data, shall be considered.

b. Approval

Designs shall be certified by the NSAA for compliance with this AOP. New designs, modifications to approved designs which affect safety, and new applications of previously approved designs shall be presented with supporting evidence to the NSAA for safety evaluation and certification of compliance.

c. Non-Compliance

If a design does not comply with one or more requirements of this AOP, but is certified as safe and suitable for service by a NSAA, a detailed description of the non-compliance and the rationale upon which that safe and suitable certification is based on shall be recorded as part of the NSAA decision. This document shall be made available to other NATO nations justifiably requiring this information.

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ANNEX A – DEFINITIONS

A.1. INTRODUCTION

For the interpretation of AOP-4497 the following specific definitions apply in addition to those in NATOTerm. Definitions relating to the possible states that a HEM's safety and arming system may adopt are given at Appendix 1 to this Annex.

a. **Anti-Tamper Devices**. (Also known as Anti-Handling Devices) Devices included in a munition to prevent moving, deactivating, exploiting or reverse engineering. This may be done by self-functioning, sterilizing, or self-disrupting the munition.

b. **Armed.** Hand emplaced munitions are considered armed when any firing stimulus can produce functioning of the munition.

(1) When the HEM's safety system employs explosive train interruption (see 7.j), it is considered armed when the interrupter(s) position is such that the probability of propagation of the explosive train is > or = 0,005 at the 95% single sided lower level of confidence.

(2) When the HEM's safety system employs a non-interrupted explosive train (see 7.k), it is considered armed when the stimulus available for delivery to the initiator equals or exceeds the initiator's Maximum Non-Initiation Threshold (MNIT) Stimulus.

c. **Arming Delay.** The time elapsed from the final commitment to the arming process until the armed condition is attained.

d. **Booster and lead explosives**. Booster and lead explosives are compounds or formulations used to augment and transmit detonation, respectively.

e. **Commitment to Arm**. Actions carried out, following which the HEM will irreversibly arm.

f. **Common Cause Failure**. The failure of two or more components due to a single cause. For example two or more components may fail due to the single cause of heating. The mode of failure may or may not be the same.

g. **Common Mode Failure**. The failure of two or more components in the same mode. For example two or more components such as switches may fail in a single mode such as open circuit. The cause of failure may or may not be the same.

h. **Credible environment.** An environment to which a device may be exposed during its life cycle (manufacturing to target or disposal). Credible environments include, but are not limited to, electromagnetic fields, line voltages, heating and cooling to temperature extremes, humidity, vibration, shock and pressure due to drops, bullet and fragment impact and nearby detonations. Combinations of environments that can be expected to occur must also be considered within the context of credible environments.

i. **De-armed.** An HEM which has been returned to an unarmed condition having previously been armed.

j. **Deployment.** The actions that are required to prepare and use a Hand-Emplaced Munition.

k. **Disposal.** The tasks, actions or activities performed on no longer required munitions to destroy, recycle or otherwise redistribute the residual materials in a safe, non-toxic, cost effective, practicable and environmentally responsible manner.

l. **Embedded Software**. Software residing in the computer in 'Read Only' memory.

m. **Enable.** To remove or deactivate safety features which prevent arming.

n. **Energy Break.** A component, e.g., a switch, which prevents the accumulation of arming or firing energy on the firing capacitor in a non-interrupted explosive train.

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

p. **Explosive train** The detonation or deflagration train (ie., transfer mechanism), beginning with the first explosive element (e.g., primer, detonator) and terminating in the main charge (e.g., munition functional mechanism, high explosive, pyrotechnic compound).

q. **Fail-Safe.** A design feature of an HEM which renders the munition incapable of arming and functioning upon malfunction of safety feature(s) or exposure to an out-of-sequence arming process or operation of components.

r. **Firing-control delay**. The time elapsed from achievement of the armed condition to the time when controls on the delivery of a firing stimulus are removed.

s. **Firing Stimulus**. A stimulus that will initiate the first explosive element in the explosive train in a HEM. The first element could be explosive or pyrotechnic.

t. **Hand Emplaced Munition (HEM).** A munition that is manually emplaced at, or is hand thrown to, a point of intended function and that requires user action both to begin its operation and to achieve safe separation. Examples include antitank mines, mine clearance devices, grenades and pyrotechnics. Some HEM may be in the form of a non-lethal munition.

u. **Initiator.** The component or components which convert the firing energy resulting in initiation of the first explosive or pyrotechnic element, even in the case of a distributed system where the energy conversion may occur at some distance and in a physically different module from the explosive or pyrotechnic element. The first explosive or pyrotechnic element of the explosive train will always be considered as part of the initiator. Examples of Initiators include but are not limited to:

(1) Exploding Bridgewire (EBW) devices.

(2) Semi-Conductor Bridge (SCB) initiators.

(3) Laser diodes, the first component of the explosive or pyrotechnic train, and the in between (transfer) components.

(4) Exploding Foil Initiators (EFI), including the bridge and explosive component.

(5) Stab detonators.

v. **Independent Safety Feature.** A safety feature that is not affected by the function or malfunction of any other safety feature.

w. **Interrupted Explosive Train.** An explosive train in which the explosive path between the primary explosive and the lead and booster explosives is physically separated until arming.

x. **Interrupter.** A physical barrier which prevents the transmission of an explosive or burning effect between elements in an explosive train.

y. **Logic Route**. The mapping of all functional paths that can be taken through a system operation.

z. **Maximum Non-Initiation Threshold (MNIT) Stimulus**. The energy stimulus at which the probability of functioning the initiator is 0,005 at the 95% single-sided lower level of confidence. Stimulus refers to the characteristic(s) such as current, rate of change of current (di/dt), power, voltage, or energy which is (are) most critical in defining the no-fire performance of the initiator.

aa. **No-Fire Threshold (NFT) Stimulus.** The energy stimulus at which the probability of functioning the initiator is 0,001 at the 95% single-sided lower level of confidence.

bb. **Non-Interrupted Explosive Train**. An explosive train that has no physical interruption of the explosive elements.

cc. **Primary Explosives**. Sensitive materials used to initiate a detonation or burning reaction.

dd. **Safe Separation**. A minimum distance between the deployed HEM and the user, beyond which the hazards to personnel and the delivery system resulting from functioning of the HEM are acceptable.

ee. **Safety Critical Computing System.** A computing system containing at least one Safety Critical Function.

ff. **Safety failure.** A failure of the HEM's safety system to prevent unintentional enabling, arming or functioning.

gg. **Safety Feature**. An element or combination of elements of a safety and arming system that prevent unintended arming and functioning.

hh. **Safety system.** The aggregate of safety features and devices of the HEM and the procedures associated with its use that eliminate, control or mitigate hazards from the HEM throughout its life cycle.

(1) Sensitiveness. A measure of the ease with which an explosive may be ignited or initiated by a prescribed stimulus (an inverse measure of the safety of an explosive against accidental initiation).

(2) Shall. Indicates a provision that is mandatory.

kk. **Should.** Indicates a provision that, although not mandatory, is highly desirable, and, if it cannot be met, then the reasons shall be stated.

ll. **Software**. The non-hardware elements of a system which include computer programming operating systems, programming languages, data bases and associated documentation.

mm. **Sterilise (Sterilization).** A design feature that permanently prevents the HEM from functioning.

nn. **Stored Energy**. The capability of a component to deliver energy in addition to any external energy required to initiate its function. Examples of stored energy are springs under load, batteries, charged capacitors, compressed gas devices and explosive actuators.

APPENDIX 1 TO ANNEX A - SENSOR \ HEM SAFETY AND ARMING SYSTEM TERMS AND DEFINITIONS

1. INTRODUCTION

a. It has proven necessary to clarify the wide spectrum of possible states that both a Target Sensor and a Safety and Arming Device (SAD) can adopt within an HEM. Table 1 below describes the situation regarding the status of both the sensor and either an interrupted or non-interrupted SAD with the labels assigned for the status of the Target Sensor and the SAD. These terms are then defined in Tables 2 and 3. This table was originally developed to describe the various states that an intelligent mine (one that could be turned "on" and "off" for safe passage) might be in. It was decided to include this as it describes one or more states that all fuzed munitions can be expected to be in during their life cycle and use, whether they contain target sensors or not.

b. It is emphasised that the terms and definitions apply to the states that can be adopted within all types of HEM. For most HEM systems, not all states are either possible or relevant.

c. When referring to a sensor, “Off” means that the sensor cannot produce an output (e.g., no firing signal).

d. When referring to a sensor, “On” means that the sensor can produce an output (e.g., firing signal).

e. Where charging circuitry is working, the firing capacitor can be expected to have a charge less than the Maximum Non-Initiation Threshold (MNIT) for only a very short time.

f. Where a firing capacitor has a charge greater than the MNIT, even in the absence of a working charging circuitry, the Electronic Safety and Arming Device (ESAD) is still armed.

g. A de-armed Safety and Arming Device is one which is returned to an unarmed condition having previously been armed.

Table 1 - Identification of Terms:

Ser	Target Sensor	SAD State	Interrupted Safety and Arming Device	Non-Interrupted Safety and Arming Device				Term for system status	
				Power Supply (SAD only)	Static Switches	Dynamic Switch	Firing Capacitor	Sensor	HEM
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
1	Off	Unarmed	Interrupter locked, by at least 2 independent locking devices, in the position designed to prevent initiation of the main charge by the detonator.	Off or not available	Open	Not Oscillating	Not Charged	Inactive	Unarmed
2	On	Unarmed	As Above	On or off	Open	Not Oscillating	Not Charged	Active	Unarmed
3	On	Partially Armed	Interrupter in the position designed to prevent initiation of the main charge by the detonator but not fully locked in place as in serial 1.	On On	Closed Closed	Not Oscillating Oscillating	Not Charged Charged < MNIT	Active	Partially Armed
4	On	Armed	Interrupter in the position designed to allow initiation of the main charge by the detonator.	On	Closed	Oscillating	Charged > MNIT	Active	Armed
5	Functioned	Fired	Fired	Fired				Functioned	Functioned

Ser	Target Sensor	SAD State	Interrupted Safety and Arming Device	Non-Interrupted Safety and Arming Device				Term for system status	
				Power Supply (SAD only)	Static Switches	Dynamic Switch	Firing Capacitor	Sensor	HEM
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
6	Off	Armed	Interrupter in the position designed to allow initiation of main charge ready to fire. Note: the status of the HEM will always be considered armed regardless of the state of the power source, firing capacitor or sensor.	On Off	Closed Closed or open	Oscillating Not oscillating	Charged > MNIT Charged > MNIT	De-Activated	Armed
7	Off	Partially De-Armed	Interrupter returned or progressed to a position designed to prevent initiation of the main charge but not fully locked in place. The SAD can be rearmed.	On or Off On or Off	Closed Open	Not Oscillating Not Oscillating	Charged < MNIT Charged < MNIT	De-Activated	Partially De-Armed
8	Off	De-Armed	Interrupter returned or progressed to an unarmed position and fully locked in place in such a manner that it can be rearmed.	Off	Open	Not Oscillating	Safely Discharged	De-Activated	De-Armed

Ser	Target Sensor	SAD State	Interrupted Safety and Arming Device	Non-Interrupted Safety and Arming Device				Term for system status	
				Power Supply (SAD only)	Static Switches	Dynamic Switch	Firing Capacitor	Sensor	HEM
(a)	(b)	(c)	(d)	(e)				(f)	(g)
9	Off	Sterilised	Interrupter moved from the armed position and returned to the position at which detonator function will not initiate the main charge and is permanently disabled. This may be achieved by functioning the detonator in that position.	Rendered permanently inoperable				Permanently De-Activated	Sterilised
10	NA	Destroyed	SA mechanism armed and main charge functioned after a period of time or environmental condition has been sensed with the purpose of demolishing the munition and leaving no explosive hazard.	Fired and irreparably damaged				Destroyed	Self Functioned
11	NA	Destroyed	SA mechanism (or secondary SA mechanism) armed and subsidiary charge functioned after a period of time or environmental condition has been sensed with the purpose of disrupting the munition without functioning the main charge.	Disrupted	Disrupted	Disrupted	Fired	Destroyed	Self Disrupted

2. DEFINITION OF TERMS RELATED TO SENSORS

a. Shown in the table below are the definitions related to the possible states that a Target Sensor for a fuzing system may adopt.

Table 2 - Definition of Terms Related to Sensors:

Ser	Term	Definition
(a)	(b)	(c)
1	Inactive	Munition sensor not turned on for the first time.
2	Active	Munition sensor turned on, capable of responding to a target and producing an output (e.g., firing signal).
3	Deactivated	Munition sensor turned off, having been turned on, and capable of being returned to the active state.
4	Permanently Deactivated	Munition sensor turned off, having been turned on, but incapable of being returned to the active state.
5	Destroyed	Munition sensor no longer assembled and incapable of being re-assembled and used.

3 DEFINITION OF TERMS RELATED TO SAFETY AND ARMING DEVICES

a. Shown in the table below are the definitions related to the possible states that a SAD for a HEM system may adopt.

b. Safety and Arming Device (SAD). A SAD may be either an Interrupted Explosive Train SAD or a Non-Interrupted Explosive Train SAD

c. Firing Capacitor Energy (FCE). The energy stored in the firing capacitor at any time intended to be applied to the initiator by closure of the firing switch. This energy is not to be confused with that which is stored on any other capacitor used to close a firing switch.

Table 3 - Definitions Related to Safety and Arming Devices

Ser	Term	Definition	
		Interrupted Explosive Train SAD	Non-Interrupted Explosive Train SAD
(a)	(b)	(c)	(d)
1	Unarmed	Interrupter locked, by all safety features, in the original position designed to prevent initiation of the main charge by the detonator.	Firing Capacitor Energy (FCE) shall not be present. All safety features in their original unpowered condition shall prevent accumulation of FCE (power supply to the SAD is off).
2	Partially Armed	The interrupter is in any position where the probability of initiation of the main charge by the detonator is less than 0.005 at the 95% single sided lower level of confidence, but with the safety features not fully applied as in the unarmed state.	FCE is greater than in the unarmed state and/or the Safety Features are not all fully applied. The FCE is less than the MNIT of the initiator.
3	Armed	The interrupter position is such that the probability of propagation of the explosive train is ≥ 0,005 at the 95% single sided lower level of confidence.	The FCE is greater than or equal to the MNIT of the initiator.

Ser	Term	Definition	
		Interrupted Explosive Train SAD	Non-Interrupted Explosive Train SAD
(a)	(b)	(c)	(d)
4	Partially De-Armed	A state in which the SAD, having been armed, is in any configuration where the probability of initiation of the main charge by the detonator is less than 0,005 at the 95% single sided lower level of confidence, but with the safety features not fully applied as in the de-armed state.	After having been armed, the FCE is greater than in the unarmed state and/or not all the Safety Features are fully applied. The FCE is less than the MNIT of the initiator.
5	De-Armed	A state in which the SAD, having been armed meets all of the following: a. Is rendered incapable of functioning the main charge. b. Meets the safety requirements of Chapter 3, Paragraph 3.1.j. c. Can be rearmed.	A state in which the SAD, having been armed meets all of the following: a. Firing capacitor energy shall not be present. b. Meets the safety requirement of Chapter 3, Paragraph 3.1.k. c. Can be rearmed.
6	Sterilised	A state in which the SAD is rendered permanently incapable of functioning the main charge. This shall be accomplished by either removal of the detonator or permanent interruption of the explosive train, or similar means.	A state in which the SAD is rendered permanently incapable of functioning the main charge.
7	Self functioned	The SAD is armed and functioned deliberately, without necessarily sensing a target, with the purpose of functioning the main charge.	The SAD is armed and functioned deliberately, without necessarily sensing a target, with the purpose of functioning the main charge.
8	Self disrupted	The SAD (or Secondary SAD) is functioned deliberately, without necessarily sensing a target, in order to operate a specific mechanism with the purpose of breaking up the munition without functioning the main charge.	The SAD (or Secondary SAD) is functioned deliberately, without necessarily sensing a target, in order to operate a specific mechanism with the purpose of breaking up the munition without functioning the main charge.

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ANNEX B ADDITIONAL SAFETY DESIGN REQUIREMENTS FOR HAND EMPLACED MINE FUZING SYSTEMS

1. The design of safety and arming systems of all mine systems shall comply with the safety design requirements of this AOP. There are additional requirements for mine fuzing or safety and arming systems, for example recovery and redeployment, and these are described in this Annex.

2. The mines (HEM) referred to in this Annex may fire either a direct lethal mechanism or consist of a deployed launcher and sub-munition(s). The safety and arming mechanism in either the deployed launcher or the direct lethal mechanism is referred to as the SAD throughout this Annex. The SAD of a deployed launcher controls the firing of the expelling charge, whereas the SAD of a direct lethal mechanism controls the firing of the warhead. The SAD of any sub-munition shall be designed in accordance with the requirements of the main body of this AOP.

3. Within this Annex, mine fuzing systems are divided into two functional parts:

   a. The Target Sensor. The Target Sensor is a component or series of components designed to detect and respond to a target.

   b. The Safety and Arming Device (SAD). A device that prevents the fuzing system from arming until an acceptable set of conditions has been achieved and subsequently effects arming and allows functioning of the payload.

4. Definitions. Those Definitions set out in the Tables 1, 2 and 3 of Appendix 1 to Annex B are used to describe the states which may be adopted by the Target Sensor and the SAD.

5. Deployment. The target sensor should not be activated until the arming sequence of the SAD has been completed. Where this is not the case the design authority shall demonstrate to the NSAA how the safety requirements of Paragraph 2.2-2 of this AOP are met.

6. Passage of friendly forces.

   a. A system, designed to allow the passage of friendly forces, is recognised to be inherently less safe when set to this operational scenario. For this reason operational requirements shall justify such use and commanders shall be made aware of this hazard. Live munitions should not be used in this scenario during training. The design safety assessment shall demonstrate that the level of this hazard is acceptable to the User and the NSAA.

b. To allow the operational passage of friendly forces (operational passage mode):

(1) The SAD shall be in the unarmed or de-armed state.

(2) The target sensor shall be deactivated.

(3) The firing circuit of a direct lethal mechanism or the launcher, in the case of a deployed launcher and sub-munition, shall be disabled.

(4) The remote command to re-arm shall require the operator to perform at least two different actions in a specific sequence, to generate and send a unique signal. If an external command is used to initiate reactivation, the fuzing system shall validate the command before re-arming and shall not react to an invalid or corrupted command.

(5) Command and control of deactivation and activation of the target sensor shall be independent of the command and control of the SAD so that no common mode failure shall be able to effect the target sensor and the SAD. This shall be demonstrated to the NSAA.

(6) No failure of any part of the fuzing system related solely to re-arming may inhibit partial de-arming, de-arming, sterilisation, self-function or self-disrupt at a later time.

7. Approaching a Mine. If there is a User requirement to approach a mine, the design authority shall demonstrate how this could be achieved with the required safety.

8. Field Maintenance. In order to perform maintenance on a mine, the fuzing system shall be at the unarmed or de-armed state with the target sensor deactivated.

9. Recovery. For a mine to be recovered, the fuzing system shall be at the unarmed state with the target sensor deactivated, or in the sterilised state.

10. Re-deployment. For a mine to be re-deployed the fuzing system must be in an unarmed or de-armed state with the target sensor deactivated.

11. Self-Destruct. Self-destruction of a mine may be accomplished either by Self-Function or Self-Disrupt.

12. Where it is intended to use a mine fuzing system which incorporates a Non-Interrupted Explosive Train SAD, the accumulation of FCE shall be prevented until, and as late as possible, in the engagement sequence.

13. Fail-Safe. The failure of any component of the fuzing system which is not directly involved with de-arming, sterilisation, self-function or self-disrupt shall not compromise these capabilities.

14. End Of Deployed Life. Mines shall either self-destruct or sterilise themselves at the end of their planned life. These actions are intended to minimise the hazard of an unexploded mine. This function shall be included in the design safety assessment to ensure that the incidence of unexploded ordnance is at a level acceptable to the User and/or the NSAA.

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