Australian Government
Department of Defence
Guided Weapons and
Explosive Ordnance Group

Electrically Initiated EO in a Dynamic Electromagnetic Environment

Strategies for Ensuring Effective Interoperability

Mr Thinus Neethling
EEH Desk Officer | SME
Directorate of Engineering, GWEO Systems Division

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- Installed EO
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- A Layered Interoperability Framework
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Introduction

Interoperability Definition

"…the ability of different forces to operate safely and effectively together in joint or combined operations."

- An emphasis on using a wide selection of electrically initiated Explosive Ordnance (EO), on a wide selection of platforms in ever-changing Electromagnetic Environments (EMEs).
- Intentional RF/electromagnetic radiation considered as an Electro-explosive Hazard (EEH) and the focus of this presentation.

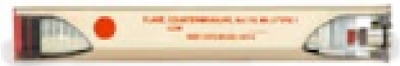
Electrically Initiated EO

- Electrically initiated EO has one or more Electro-explosive Devices (EEDs) installed inside them, to fulfill a range of different functions.

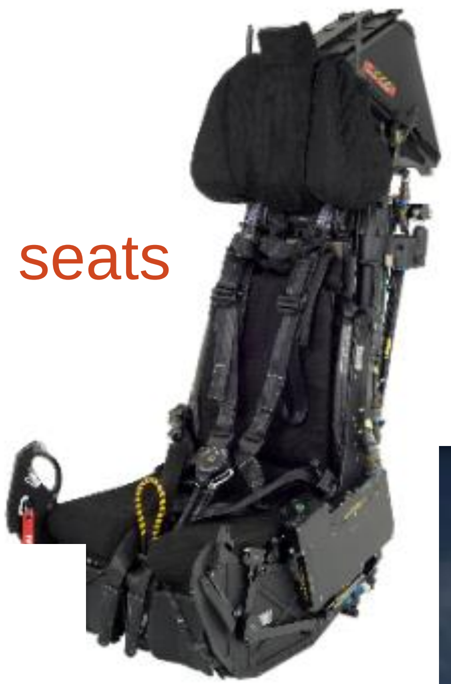
  - ➢ Gun Ammunition ≥ 20mm
  - ➢ Mortars
  - ➢ Fuzes
  - ➢ Guided Missiles
  - ➢ Torpedoes
  - ➢ Rockets
  - ➢ Bombs

Other Electrically Initiated EO

- Mines & Mine Disposal Systems
- Grenades
- Demolition Stores
- Countermeasures
- Special Function Cartridges
- Pyrotechnics
- Installed EO (next slide)

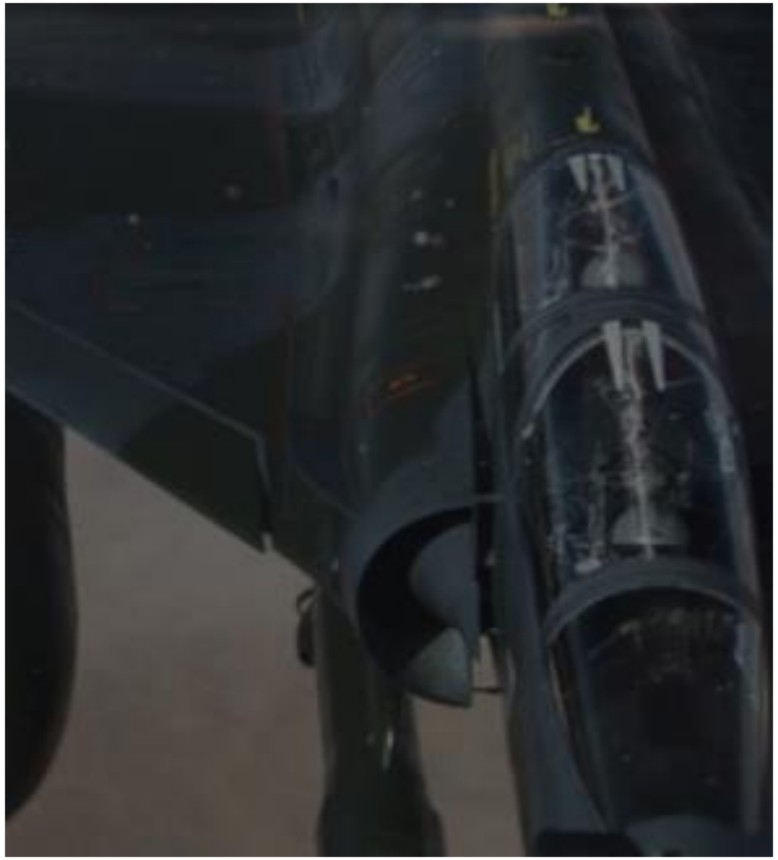


Installed EO



Ejection seats

Automatic aircraft fire extinguisher systems

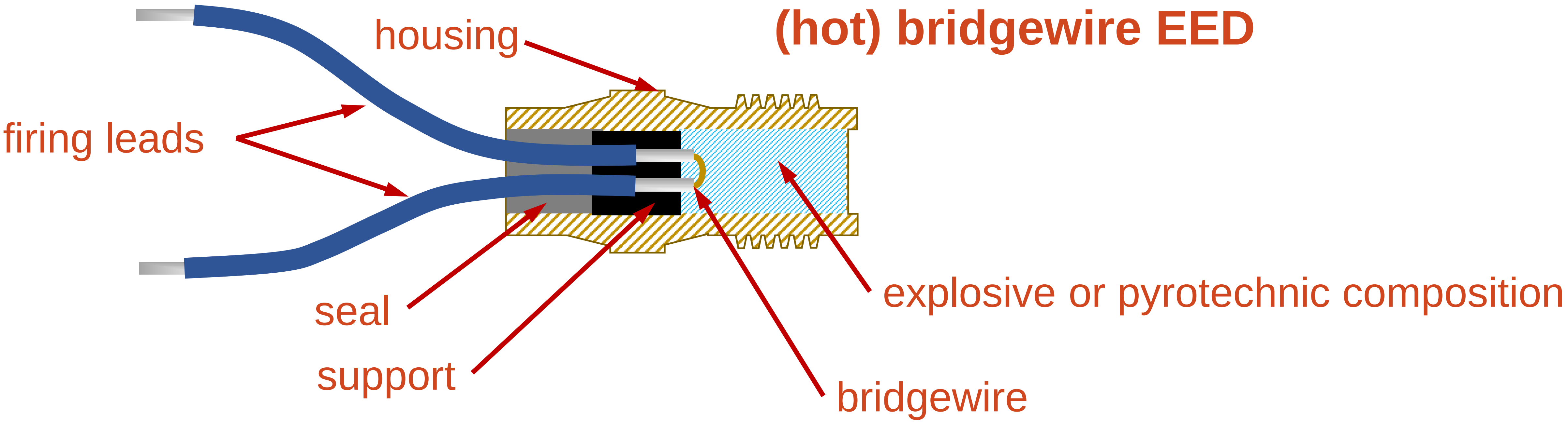


Pyrotechnic chain for emergency canopy severance
(https://pyroalliance.ariane.group/en/defence-activities/aircraft/)

Water-activated release mechanisms

Pyrotechnic chain for emergency fuel tank release
(https://pyroalliance.ariane.group/en/defence-activities/aircraft/)

The Normal Bridge Heating Mechanism



- When an electrical current of suitable amplitude and duration is applied across the resistive bridgewire (BW), it starts to heat to the point where the localised critical temperature of the explosive or pyrotechnic composition is reached. Initiation of the EED follows.

Hazards of Electromagnetic Radiation to Ordnance (HERO)

- EEDs are susceptible to being inadvertently initiated when exposed to any form of EEH such as electromagnetic radiation.
- Examples of HERO incidents that occurred in Australia include:
  - ➢ tracking flare on Jindivik target aircraft functioned after the aircraft had landed at Nowra (early 70s)
  - ➢ 30mm DIRECTION DES ÉTUDES ET FABRICATIONS D'ARMEMENT (DEFA) round exploded in an aircraft ammunition loading bin at RAAF Williamtown (late 70s)
  - ➢ uncommanded functioning of helicopter’s winch cable cutter EED, while the helicopter was on the deck of an FFG Class ship (early 90s)

Reference: *P. Dimsey, EEH Assessment - Study Into Defence Requirements, AEA Report No. R98419/1 of Feb 2000*

The Interoperability Objective

- In a Defence context, the interoperability concept applies to vast array of operations.
- The Overarching Challenge: Ensuring the ongoing S3 status of all electrically initiated EO in a dynamic EME.
- A challenge for all Services & our Allies, affecting a wide range of complex and non-complex EO in different configurations, with different EEDs, across different EO lifecycle phases.
- Nature and complexity of the challenge is ever-changing and non-trivial.

Reference: Chapter 3 – Australian Force Structure, Interoperability and Intelligence, https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Completed_Inquiries/jfadt/usrelations/chapter3

A Dynamic Electromagnetic Environment (EME)





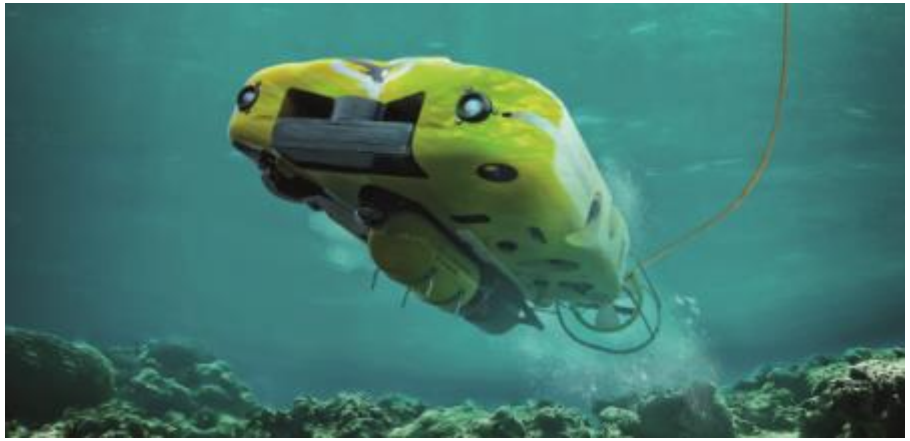


Storage & Transportation of EO

Handling & (Un)loading Phases

Platform-loaded Phases





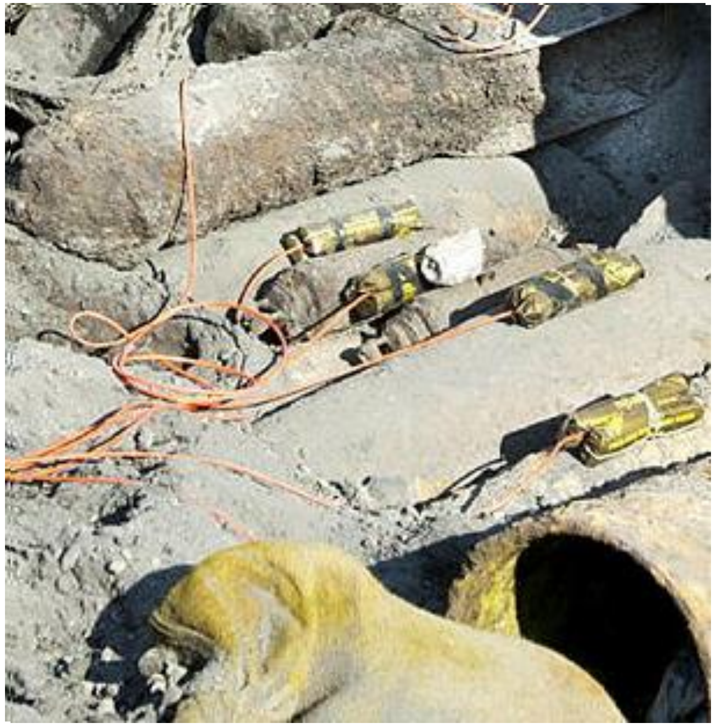
Flo Joe kelpie-cross bomb sniffer. Former graduate of the Explosive Detection Dog School at Holsworthy Barracks, NSW

Post-launch Phases

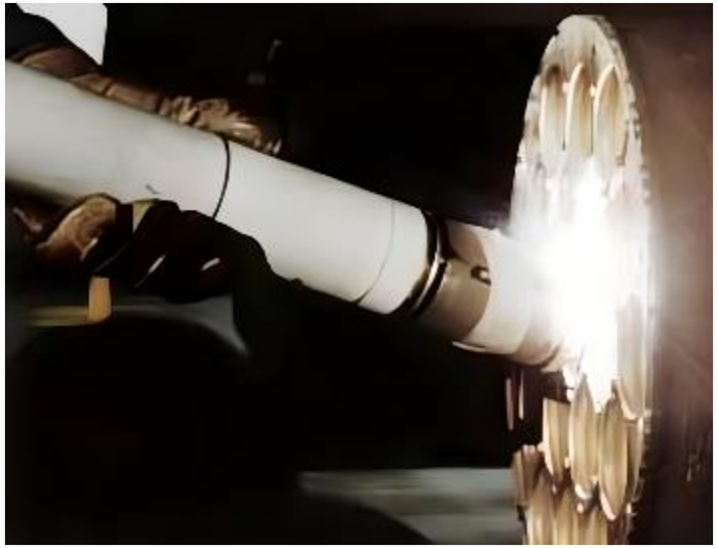
Staged EO

- The phase where the ordnance has been prepared for loading and is pre-positioned in a designated staging area, until the actual loading operation begins.

(Hand) Emplaced EO



Other Hazardous Scenarios



RF-induced arcing during HERO testing.

HF whip & crane cable. Arcing from the crane's hook.

RF jammer in operation near an Improvised Explosive Device (IED).

References: *MIL-HDBK-240A, HERO Test Guide of 10 March 2011, . Keys, Radiation Hazards (RADHAZ) Presentation, Joint Spectrum Center, E3 & Spectrum Engineering Division, OS35, Defence Information Systems Agency of 13 Jan 23*

Robert Bozarth, HERO Overview, NSWCDD Q52 Electromagnetic & Sensor Systems Department, not dated, [Approved for Public Release; Unlimited Distribution]

A Layered Interoperability Framework

- EED Design
  - best practices for the design of EEDs IAW MIL-DTL-23659E, for example;
  - generally the end-user has little, to no say, during the EED design phase;
  - expectation for high quality EEDs, with predictable and repeatable performance;
- EED Qualification & Characterisation
  - characterisation used to derive the critical parameters of an EED via statistical analysis e.g. to derive no-fire threshold data.
  - qualification process is more involved including environmental stress screening, radiographic testing, shock and vibration testing, among others.
- EO Design & EED Selection
  - generally, selection made from available EEDs to satisfy certain design criteria;
  - EO design is multi-faceted and EED selection and firing circuit design is only a small portion thereof;
  - design decisions concerning E3 should be incorporated early on;
  - no single fault or failure of any nature may result in initiation of an EED;

A Layered Interoperability Framework - Continued

- EO Test & Evaluation (T&E)
  - a rigorous T&E program is essential to ensure that all design specifications are met;
  - scope of T&E program needs to be comprehensive;
  - Electromagnetic Environmental Testing (E3) testing, which includes HERO testing, is only a part of the overall EO T&E program;
  - HERO testing is used to derive the Maximum Allowable Environment (MAE) to which EO can be exposed to, during different EO lifecycle phases;

US Air Force (USAF) Safety Office released a mandate, requiring all USAF weapons platforms be subjected to E3 testing.

B-52 Bomber being prepped for HERO testing at Benefield Anechoic Facility, Edwards AFB

Image Reference: https://www.afmc.af.mil/News/Photos/igphoto/2001691061/mediaid/1693838/, Photo by Ethan Wagner, VIRIN 170109-F-JG201-014

A Layered Interoperability Framework - Continued

- Bespoke Test & Evaluation
  - includes RADHAZ surveys, which may be specific to a particular platform, location, building, or scenario, catering for some combination of EO;
  - measuring and characterising a particular EME due to a unique set of RF emitters;
  - bespoke HERO testing e.g. where EO needs to be in close proximity to EO;
  - special testing e.g. RF-induced currents in loop-type structures e.g. cranes.
- Hazard Control Measures
  - Management of the operational EME;
  - Well-proven hazard control measures, including EMCON, use of Safe Separation Distances, HERO doctrines (Army) etc.
- Packaging
  - RF shielding effectiveness of ammunition boxes/containers not commonly known;
  - additional layer of packaging required e.g. Type I MIL-PRF-81705 barrier material.

A Layered Interoperability Framework - Continued

- Training & Creating EEH Awareness
  - a firm level of knowledge about EEH is essential to meeting the interoperability objective;
  - requires critical thinking and informed decision-making;

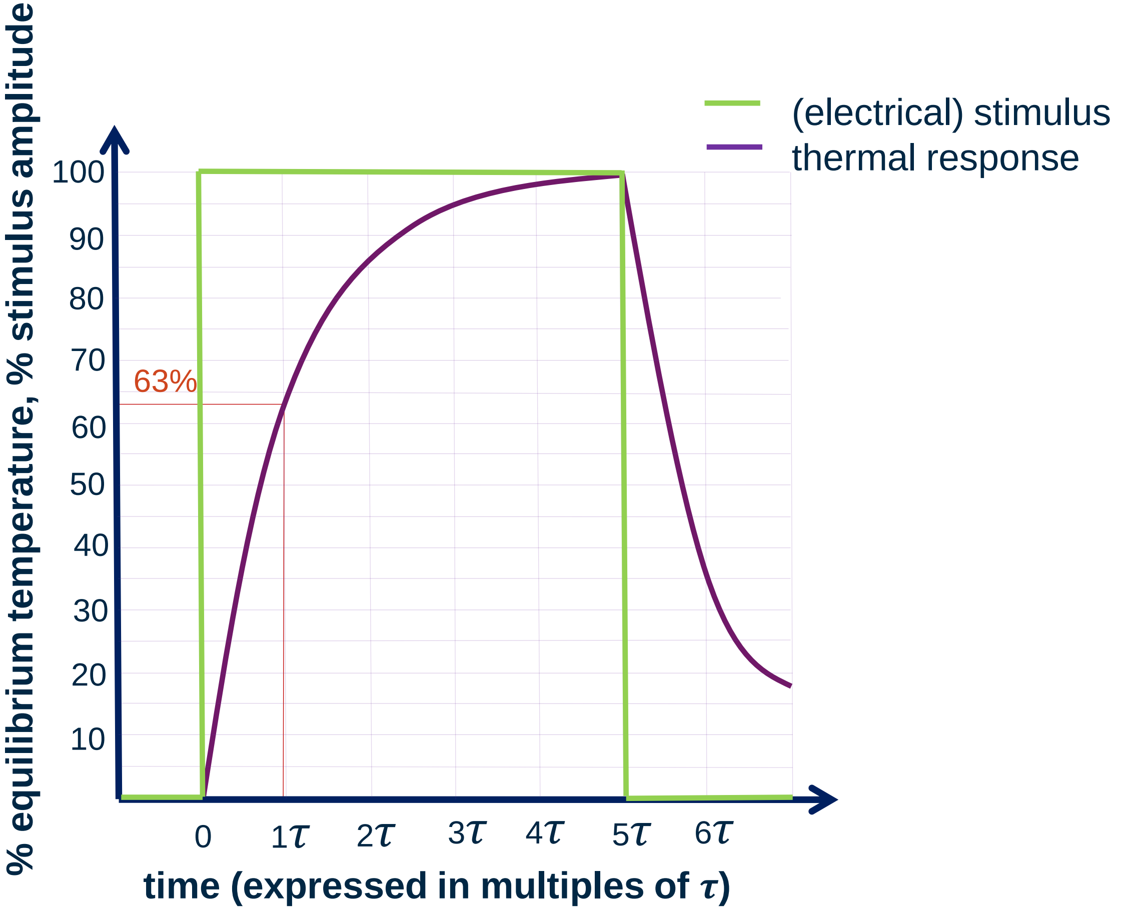
Example: Restrictions for landing of US Army attack helicopters aboard the *USS Eisenhower*, 1994.

- EO installed on the attack helicopters had not been certified for exposure to the ship's unique EME.
- A critically important radar on the ship had to be disabled.
- Emission Control (EMCON) is an effective hazard control measure, however, prevented utilisation of a critically important capability.
- Need to balance requirements of spectrum users, their use of the EME and the RF susceptibility of Electrically Initiated EO.

Reference: *M. Lucchese, Dr. C.L. Golliday Jr., Dr. A.N. Joglekar, Operational Evaluation of Electromagnetic Environmental Effects (E3), New DOT&E Policy Calls for More systematic Assessment of E3, Program Manager (PM) Online Magazine of May-June 2000*

New or Emerging HERO Concerns

- Electromagnetic heating of energetic materials.
  - 2013 incident, non-electric signal flares and smoke signal flares;
  - implications for the scope of HERO testing e.g. expand to include all EO with energetic compositions;
- Peak-power sensitivity of BW EEDs.
  - BW EEDs not traditionally seen as peak-power or pulse sensitive;
  - thermal time constants (τ) typically in excess of 10ms, <u>but there are exceptions</u>;
  - next-generation radars with longer pulse widths are of concern.



Other HERO Challenges

- HERO Control for Cross-deck Operations
  - sharing resources between naval vessels e.g. hosting aircraft of foreign allies;
  - Helicopter Operations from Ships other Than Aircraft Carriers (HOSTAC);
  - requires effective use of SRAD codes and TRAD codes to calculate and impose safe separation distances.

HERO Developments

- Development of Safer EEDs.
  - due to the nature and application of EEDs, R&D and the IP are well-guarded;
  - information is somewhat limited;
  - opto-pyrotechnics receiving particular attention:
    - contain no primary explosives;
    - energetic compositions are isolated from electrical stimuli like ESD and electromagnetic radiation;
  - energy from semi-conductor laser diode, transmitted via an optic fibre to an optical sensitiser in contact with an energetic material;

"This advanced technology is particularly suited to extreme environments including severe electromagnetic environments."

- laser driven flyer plate technology – optic equivalent of an electrically initiated exploding foil initiator or 'slapper' detonator

Reference: *Nexter Ammunition Catalogue of 2018, https://www.knds.fr/sites/default/files/2023-01/Nexter_Arrowtech_Ammunition.pdf*

HERO Developments - continued

- Integrated Pyrotechnic MEMS-based Safe and Arming Devices (SADs)
  - concept was first introduced in 2000;
  - development efforts have focused on higher functional integration;
  - recent design example (i.e. July 2023) consists of an Energetic Semiconductor Bridge (ESCB) detonator, and a SAD with built-in isolation mechanisms, and a micro-detonation train;
  - claims of improved safety and reliability of micro-scale explosive train;
- Real-time, Intelligent Spectrum Sensing
  - provides greater RF situational awareness;
  - monitor EMCON compliance;
  - complement RADHAZ control measures;
  - ‘mask triggering’ used to identify and capture any signal that exceeds a predetermined threshold;

HERO Developments - continued

- EED Characterisation via *Neyer D-Optimality Test*
  - test method was first described and published in 1994;
  - gaining popularity as an improved means of testing a batch of manufactured EEDs;
  - for characterising all-fire and no-fire thresholds of EEDs with higher confidence;

New Standards

- MIL-STD-464D released in 2020
  - significant E-field increases across several frequency bands;
  - evidence of testing against the new standard is quite recent;
  - takes some time to design EO against the requirements of a new standard;
  - should generally yield better HERO-hardened designs;

- MIL-HDBK-240 released in 2022
  - makes provision for testing EO components and sub-systems e.g. sectioned EO.
  - adopted a standard *factor-of-five* extrapolation limit i.e. when $E_{test} < E_{criteria}$
  - allows for limited testing up to 1GHz for handling & (un)loading of EO, against the Restricted E-fields of MIL-STD-464(D).

Conclusion

- HERO risks exist throughout the lifecycles of a wide range of different EO items.
- Risks due to numerous intentional RF emitters, which may be mobile, which potentially have high power outputs, potentially within 3m of EO items etc.
- There are a lot of opportunities and reasons for mishaps to occur, but various extant hazard controls have proven effective.
- New and emerging HERO concerns are driving the need to augment extant hazard controls.
- Effective interoperability framework relies on integrity of different layers, plus the knowledge, awareness and actions personnel.
- New HERO developments aid in bolstering the layered interoperability framework, for using EO in ever-changing EMEs.

Questions?

Contact Details

Thinus Neethling FIEAust CPEng NER APEC Engineer IntPE(Aus) RPEQ, QinetiQ Fellow
Electro-explosive Hazards Desk Officer / Subject Matter Expert

(Contractor to Defence: K39 Consulting)

M: 0468 300 971 **| e-mail:** marthinus.neethling@defence.gov.au