The "Default" HERO Susceptibility Trace

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Key question

- When there is no item-specific HERO test data, does the default susceptibility trace provide a safe and proportionate answer, or merely the safest available assumption?

SCOPE

- Operational decisions
- HERO Susceptibility Trace
  - Advantages and disadvantages
- Non-complex EO
- EED evolution
- HERO Testing
- A data informed decision support tool

Key question

- When should the default HERO trace be accepted, challenged or supplemented?
  - No item-specific HERO data are available.
  - The default trace provides an immediate conservative baseline.
  - The operational cost of applying it may be significant.

- The answer depends on what the trace represents, the EO configuration and the available evidence.

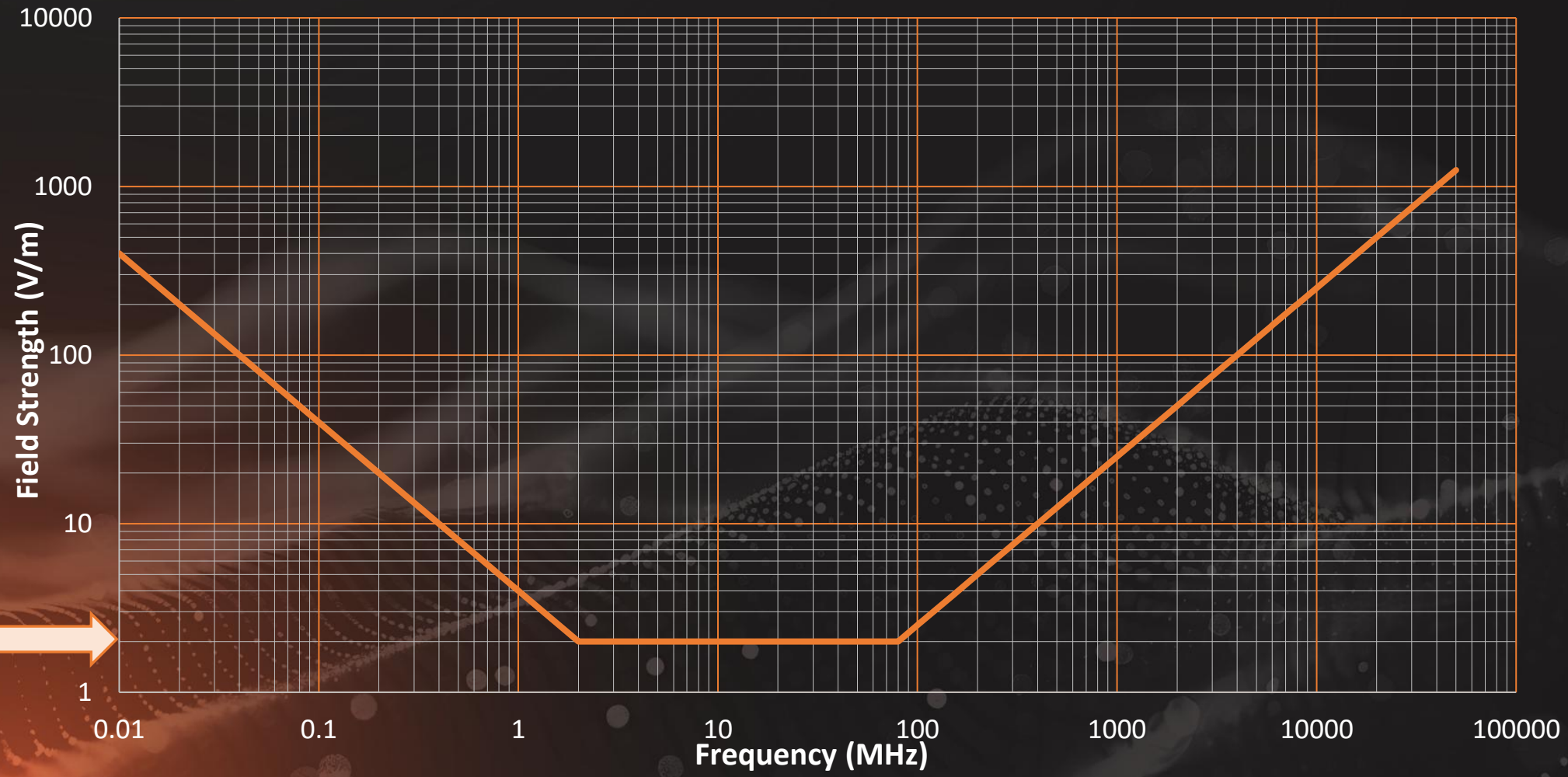
The default susceptibility traces

- What are the default traces?
  - a frequency-dependent Maximum Permissible RF Environment (MPRE);
  - a conservative screening or bounding baseline;
  - an assessment tool for use when better evidence is unavailable.

  - *“prepared on the basis of worst-case conditions for all HERO SUSCEPTIBLE and HERO UNSAFE ORDNANCE and may be used in determining the maximum RF environment for any ordnance system when specific Maximum Allowable Environment (MAE) susceptibility data are not available or for ordnance that has not been HERO evaluated”*

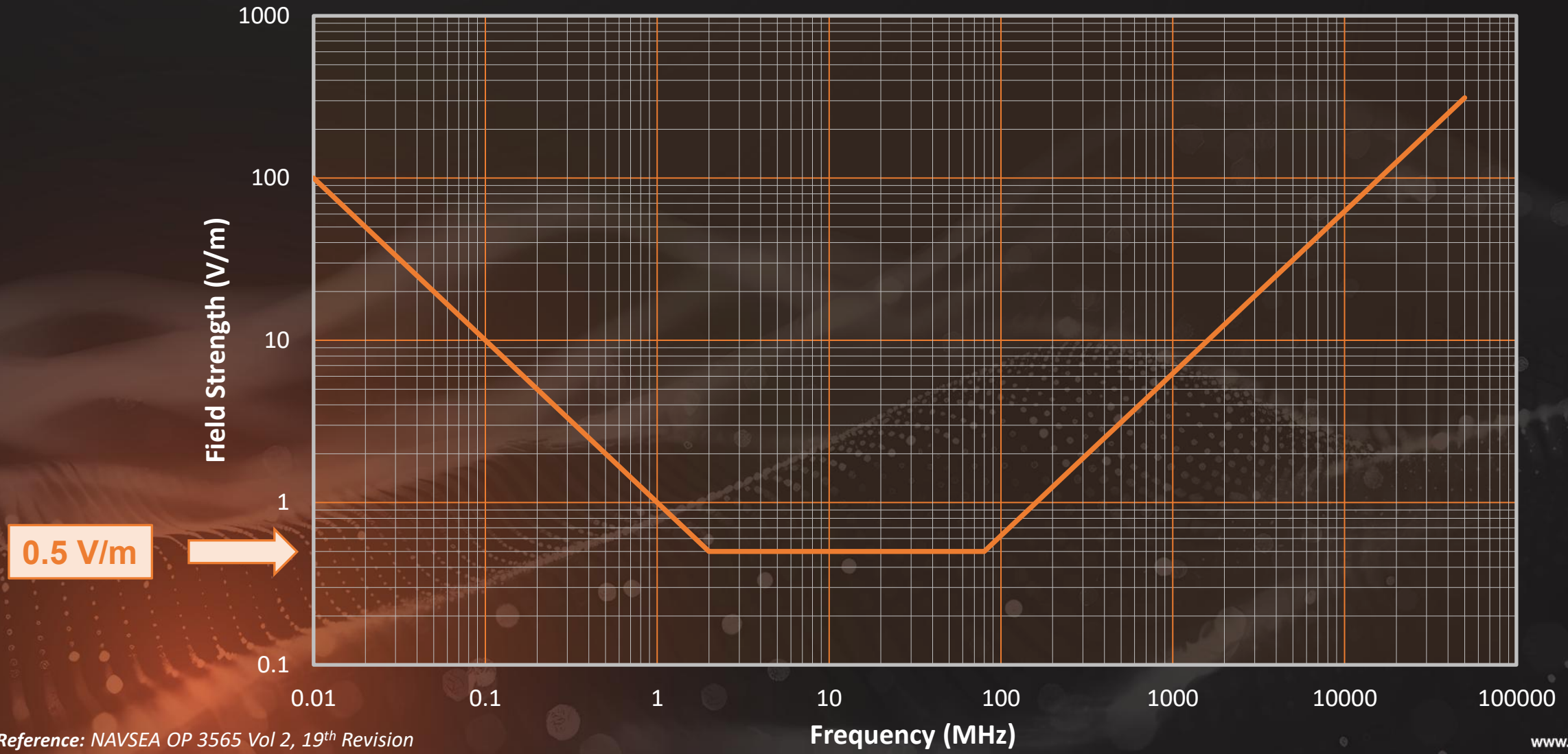
    NAVSEA OP 3565 Volume 2, Rev. 19

DEFAULT TRACE FOR HERO SUSCEPTIBLE EO



Reference: *NAVSEA OP 3565 Vol 2, 19th Revision*

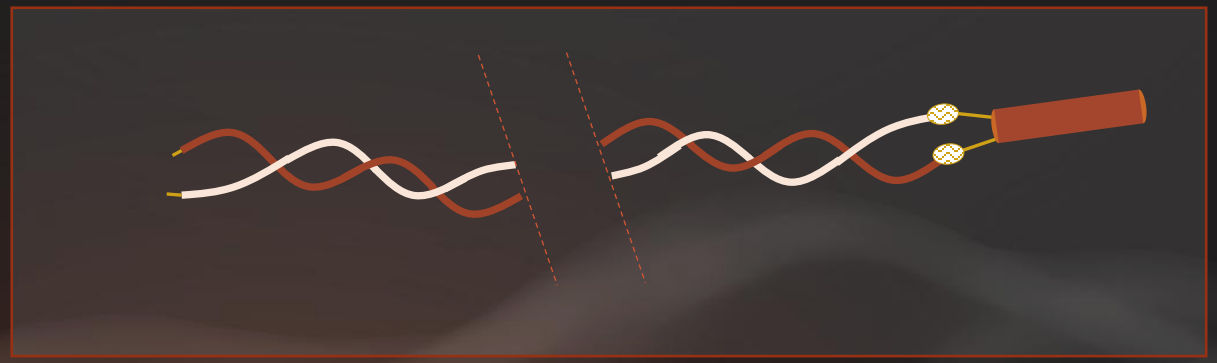
DEFAULT TRACE FOR HERO UNSAFE EO



Reference: *NAVSEA OP 3565 Vol 2, 19th Revision*

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REPRESENTATIVE CIRCUIT FOR HERO SUSCEPTIBLE EO





- No-fire Threshold Power (NFTP) = 54 mW
- Double-pole 20 m firing circuit.
- Lead separation & ground plane spacing ≤ 80 mm
- Margin: 6 dB

Reference: *DEOP 115 Page 109 / 200 Para 16*

The Problem with the default HERO traces

- Conservative and generalised
- The trace represents a Maximum Permissible RF Environment (MPRE) envelope derived from:
  - aggregated tri-service (US Army, Navy, Air Force) test data (worst case scenarios from the three services)
  - conservative modelling assumptions, and
  - worst-case coupling scenarios.

The Problem with the default HERO traces

- The trace:
  - Embeds significant safety margins, and
  - Intentionally collapses complex RF coupling phenomena into a single frequency-dependent field strength threshold
  - Is based on the bridgewire EEDs thermal ignition model and has not kept pace with modern EEDs

Why Modern EED Challenge Legacy Assumptions

Legacy: Hot Bridgewire EED	Modern EEDs
RF-induced current produces resistive heating.	Semiconductor junction rectification.
Heating is related to bridge temperature or induced current.	Energy concentration at specific frequencies.
The relevant comparison is against a no-fire threshold.	Response to modulation, pulse structure or peak field.
Susceptibility is treated primarily as a thermal energy problem.	Frequency-dependent response of filters, protective components and electronic firing circuitry
	Failure mechanisms that may not correlate directly with bridgewire heating.

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO) TESTING

- Formal HERO testing represents the ‘gold standard’ for deriving the Maximum Allowable RF Environment, to which electrically initiated EO can be exposed to.
  - ➢ Referred to as the **RF Susceptibility** of the EO item
- ‘Electrically initiated EO’ implies that the item is fitted with one or more Electro-explosive Device (EED).

HERO TESTING – BRIEF OVERVIEW

- EEDs with known characteristics are instrumented for temperature measurement via a sensor (against the EED's bridge), optic-fibre cable and test instrumentation.
- EO item under test is subjected to different E-fields, across a range of frequencies defined in MIL-STD-464D Table 9.
- An incident E-field results in a temperature increase at the bridge, which is translated to an induced current, $I_{induced}$.
- The induced current due to a certain E-field is compared with the No Fire Threshold Current (NFTC) of the EED.
- Appropriate E-fields can hence be identified to ensure that an appropriate margin between $I_{induced}$ and the NFTC are maintained.

IMAGE OF HERO TEST SETUP (HIGH-COMPLEXITY EO ITEM)

- System Under Test (SUT) is a high-value item.
- Highly complex system.
- Contains multiple EEDs, with different functions and firing consequences.



Image created with M365 Copilot

IMAGE OF HERO TEST SETUP (MEDIUM COMPLEXITY EO ITEM)

- Cost of EO item is significantly lower.
- Contains minimal number of EEDs e.g. 1-2 for a mortar fuze.



NON-COMPLEX EO

- Simple igniter & detonators are shown, with twisted pair or wrapped firing leads.
- Among others, the RF susceptibility of these devices is affected by:
  - Lead length.
  - Twisted-pair geometry and any untwisted sections.
  - Frequency of the RF source.
  - Electrical sensitivity of the bridgewire e.g. No Fire Threshold Power
  - Safety Margin
  - Mounting configuration and nearby conductive structures.



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RF SUSCEPTIBILITY OF NON-COMPLEX EO

- For most EO (medium to complex), where the EED is essentially enclosed, the RF susceptibility is well-defined via a HERO test.
- **Non-complex EO** present a unique challenge, because they usually have accessible firing leads, connected straight to a detonator or igniter.
- Any interaction with the non-complex EO item may affect its RF susceptibility:
  - touching the firing leads
  - changing the lengths of the firing leads e.g. additional lengths of firing cable
  - changing the spacing between twin core wiring
  - changing the distance of the firing cable above ground e.g. introducing pick-up loops.
- The RF susceptibility of non-complex EO is potentially dynamic.

USE OF 3D COMPUTATIONAL EM SOFTWARE

- CST Cable Studio
  - ➢ Used to simulate complex cable bundles e.g. twisted pairs and shielded cables with arbitrary routing.
- Simcenter FEKO (Cable Modelling Module)
  - Excellent for calculating RF coupling into twisted pair bundles and for predicting induced currents at a certain load e.g. EED.
- Ansys EMC Plus (formerly EMA3D® Cable) with an integrated multi-conductor transmission line solver.
  - ➢ The two EM solvers co-simulate to allow for a complex cable harness to be accurately modelled inside complex geometry.

USE OF ELECTROMAGNETIC ANALYSIS SOFTWARE

- Electromagnetic Analysis Software (EAS) Tool
  - UK RF Hazard Assessment Software.
  - Based on procedures of Ordnance Board (OB) Pillar Proceeding P101 - Principles for the Design and Assessment of Electrical Circuits Incorporating Explosive Components, Issue 2.
  - Originally designed to be performed manually.
  - EAS written to automate the procedures.
  - Simulations based on a physical EED circuit model, with a defined No Fire Threshold Power, margin and empirical test data derived from constructed circuits.

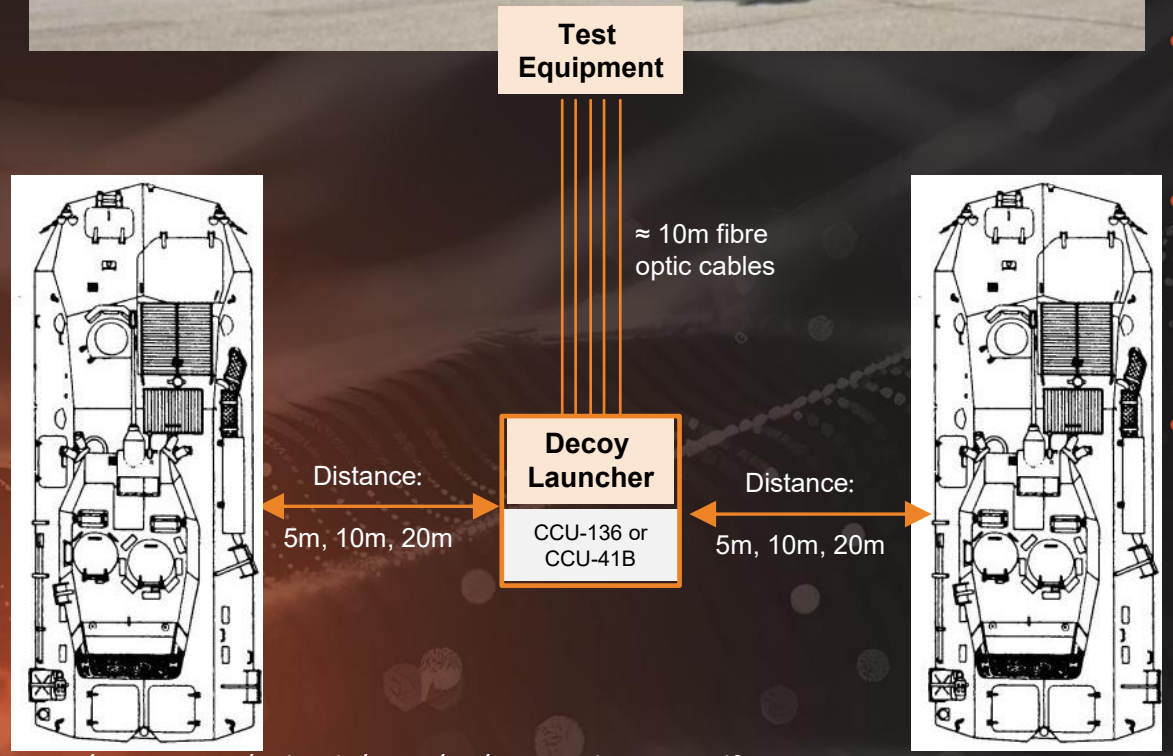
A Data Driven Approach

- Driven by
  - Operational need and use scenario
  - EO nature and complexity
  - Hazard proportionality

- Informed by engineering judgement

Example: Tailored HERO Testing





- During (Canadian) army tactical evaluation manoeuvres, Light Armoured Vehicles (LAVs) operate in close proximity to chaff & flare decoy launchers.
- The original SSD of 50m from any VHF radio was too restrictive.
- The EEDs were instrumented to recreate the actual installation as close as possible.
- Led to a reduction in safe separation distance from 50m to 5m!

Reference: *https://fiso.com/wp-content/uploads/2018/07/apn_eedtesting.pdf*

A Tailored Approach

- Use the default traces; where we must
- HERO test where we can
- This approach will meet safety requirements while improving operational freedom of action
  - Operational need and use scenario
  - EO nature and complexity
  - Hazard proportionality

Conclusion

Use the default trace where evidence is absent. Replace assumption with evidence where the decision warrants it

- The HERO traces remain valid conservative screening baselines when better evidence is unavailable
- It is not device specific and should not automatically be treated as universally bounding
- For non-complex EO conductor configuration may dominate the coupling path
- Where operational consequences justify it, representative analysis, testing and environmental measurement can support a safer and more proportionate limit.

QUESTIONS

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