Lightning as an Electro-Explosive Hazard

Australian Army Context

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SCOPE

- Introduction and Purpose
- Refresher on EEDs
- Basics of lightning
- Historical incidents
- Existing standards and policy
- How can we manage the risk
- The way forward







INTRODUCTION

- Lightning is a high-energy, unpredictable ignition source capable of initiating Electro-Explosive Devices (EEDs) without warning.
- It also poses a silent threat to EO, irrespective of whether EEDs are installed.
- Lightning strikes are inevitable. Our focus must be on ensuring the risks they pose to our systems are identified, controlled, and managed effectively.

PURPOSE

- Create awareness about lightning as a Electro-Explosive Hazard (EEH).
- Showcase Army's existing controls.
- Identify areas where we could do better.

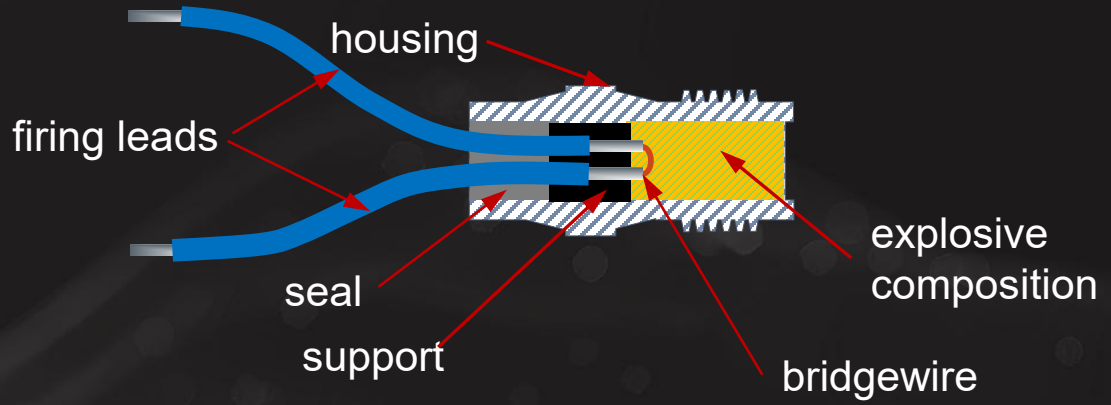
REFRESHER ON EEDs

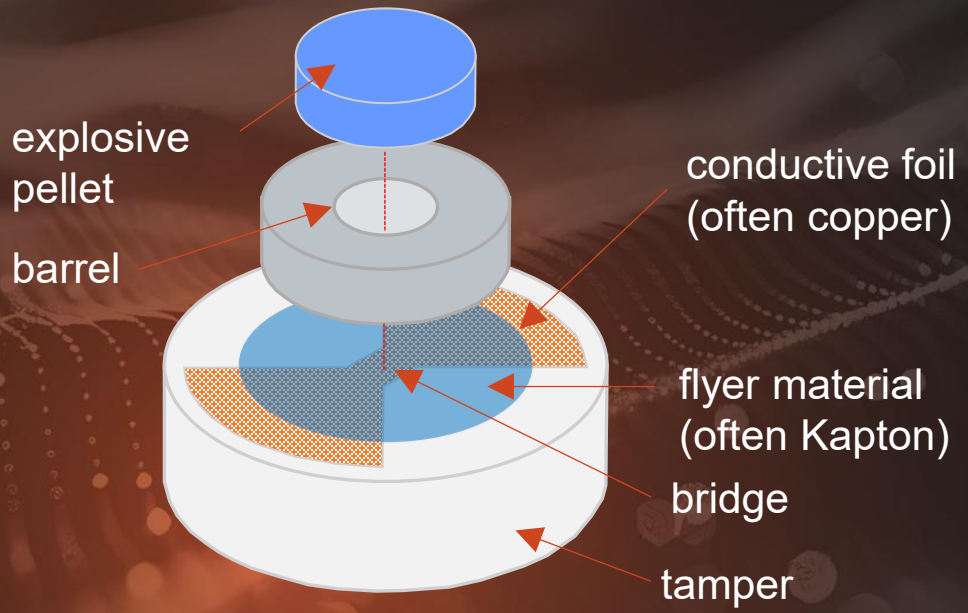
- Electro-Explosive Devices (EEDs) are used to initiate energetic materials using an electrical signal.
- When an unintended electrical signal is induced, the EED may initiate prematurely (safety consequence), or be damaged creating a ‘dud’ (performance consequence [sometimes also safety consequence]).
- EED Types:
  - Low Voltage → (hot) bridgewire, thin-film bridge, conducting composition initiator, semiconductor initiator, carbon bridge
  - High Voltage → exploding bridgewire, exploding foil (or slapper) initiator, arc (plasma discharge) initiator
  - Optically Initiated → laser-initiated devices

REPRESENTATIVE LOW & HIGH VOLTAGE EXAMPLES

(Hot) Bridgewire EED

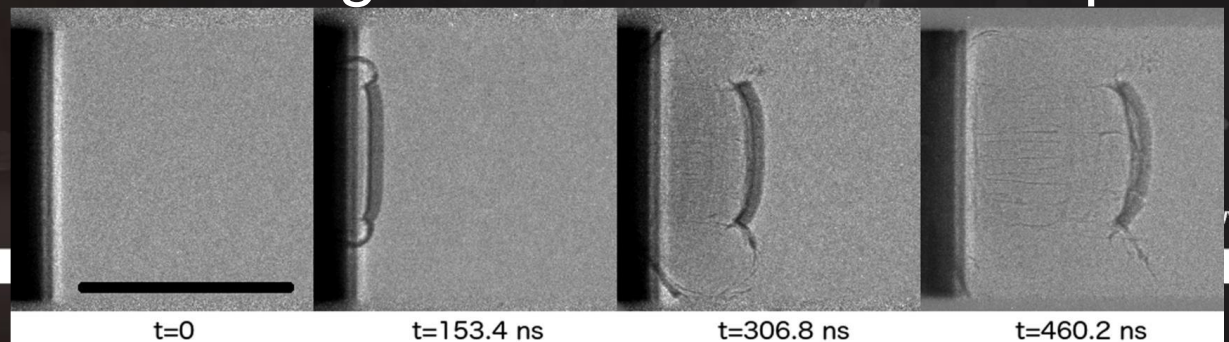
- Used where size, power supply, or cost is a limitation
- Quite vulnerable to different types of EEH





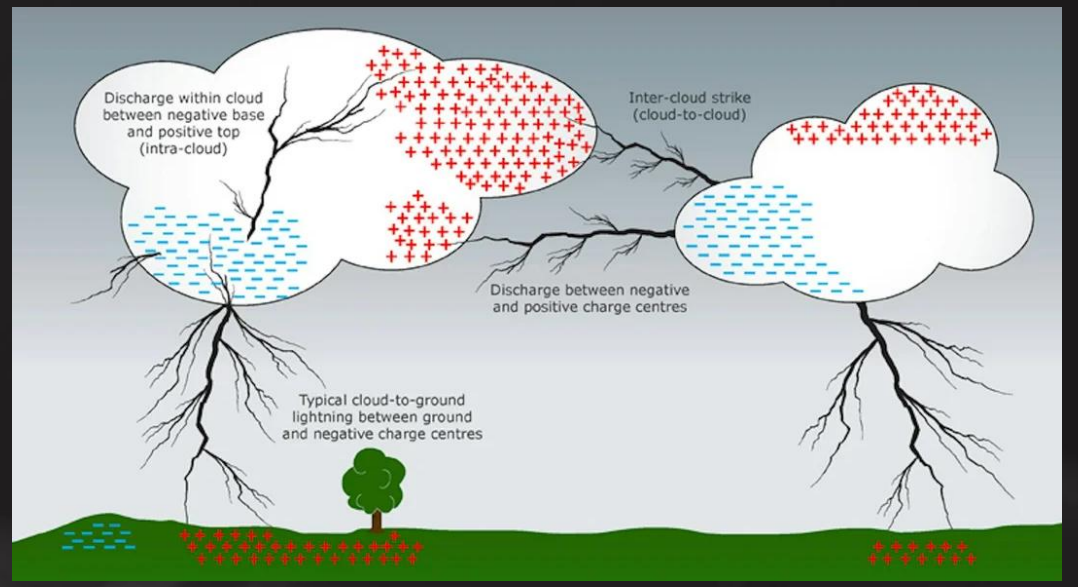
Exploding Foil Initiator ("Slapper")

- Very resistant to EEH
- Can be prone to dudding
- Needs specialised firing sequence making it most suitable in complex EO

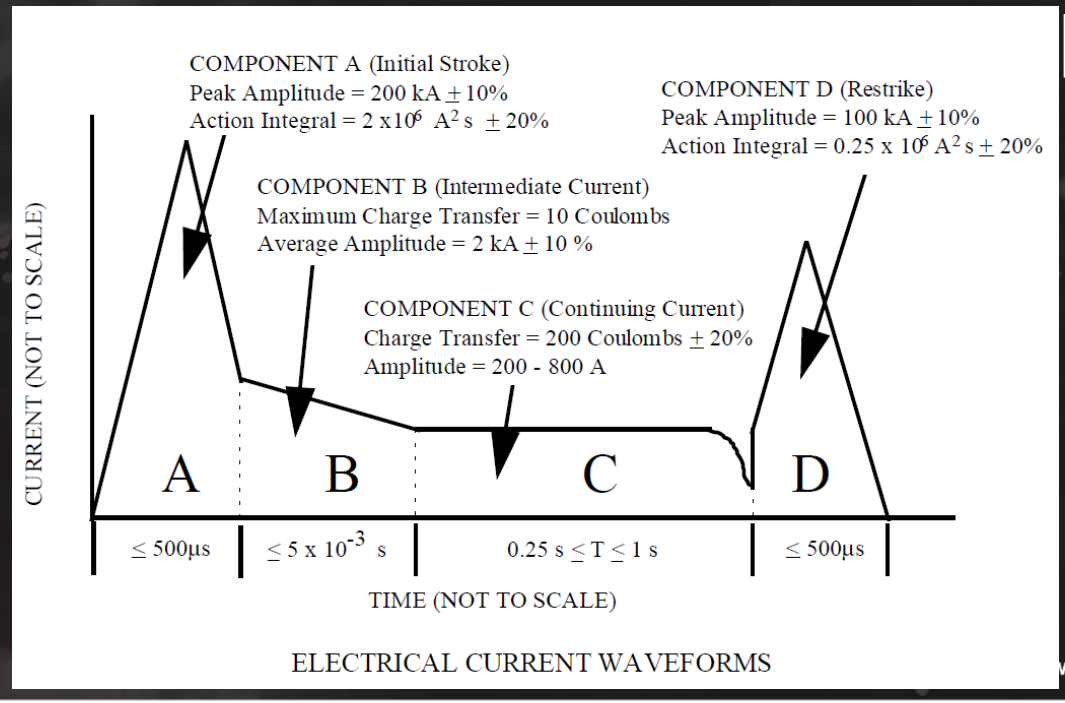


BASICS OF LIGHTNING

- Lightning is produced as a result of charge separation within the atmosphere.
- Cloud-to-ground, cloud-to-cloud, and intra-cloud







[1]

EFFECTS OF LIGHTNING

Direct Effects

- A direct lightning strike can inject extremely high currents leading to:
  - initiation of EEDs
  - direct ignition of sensitive explosive materials
- May be partially mitigated by conducting pathways along the platform surface for installed EO

Indirect Effects

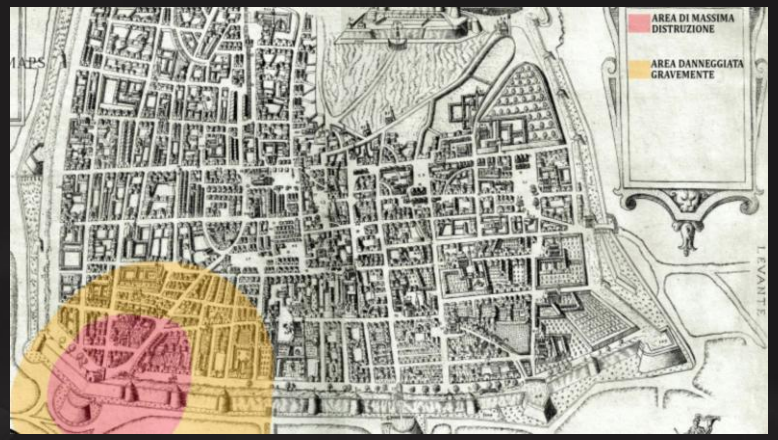
- Lightning generates intense electromagnetic fields that can:
  - induce voltages and currents in wiring, cables, and firing circuits
  - cause unintended activation of EEDs even without direct contact
- Important out to distances of up to 11km (depending on the type of EED) [2].
- May be partially mitigated by shielding when stored within metal boxes.



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HISTORICAL INCIDENTS

- There are multiple records of lightning initiating gunpowder stockpiles across Europe in the 1700s and 1800s.
  - 1769, Brescia, Italy. 90 tonnes of gunpowder. Killed over 400 people. [3]
  - 1807, Luxembourg City. 12 tonnes of gunpowder. Killed 32 people. [4]
  - 1856, Rhodes Greece. 300 tonnes of gunpowder. Killed over 200 people. [5]





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HISTORICAL INCIDENTS (CONTINUED)

- In 1926, lightning struck a temporary magazine at the Lake Denmark Naval Ammunition Depot (adjacent to Picatinny Arsenal) containing 775,000 lb of TNT, causing an explosion and fire. [6]
- The fire spread to a neighbouring magazine containing over 1.6 million lb of TNT.
- Over 4 days, the subsequent explosions and fires initiated 2.4 million lb of TNT, killed 19 people, and destroyed 187 of the 200 buildings at the site. [7]





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HISTORICAL INCIDENTS (CONTINUED)

- The mining industry reports an average of more than two lightning-related unplanned detonations per year in the United States [8].
- From 1978 to 1993, lightning caused 40 unplanned detonations of explosives in mines.
- The same study indicated that EM pulses from lightning can set off electric detonators over 20 km away.





EXISTING STANDARDS AND POLICY

- **MIL-STD-464 Electromagnetic environmental effects (E3) requirements for systems**
  - *“Ordnance shall meet its operational performance requirements after experiencing a near strike in an exposed condition and a direct strike in a stored condition.”*
  - *“Ordnance shall remain safe during and after experiencing a direct strike in an exposed condition”*
- **TOP-1-2-511A Test Operating Procedure for E3**
  - Specifies that ordnance is to be tested against Direct Strike and Near Strike Lightning. Uses test parameters from MIL-STD-464C.



EXISTING STANDARDS AND POLICY

- **AECTP-250 Electrical and electromagnetic environmental conditions**
  - Provides the current waveform and voltages for idealised lightning strikes in various environments for testing purposes.

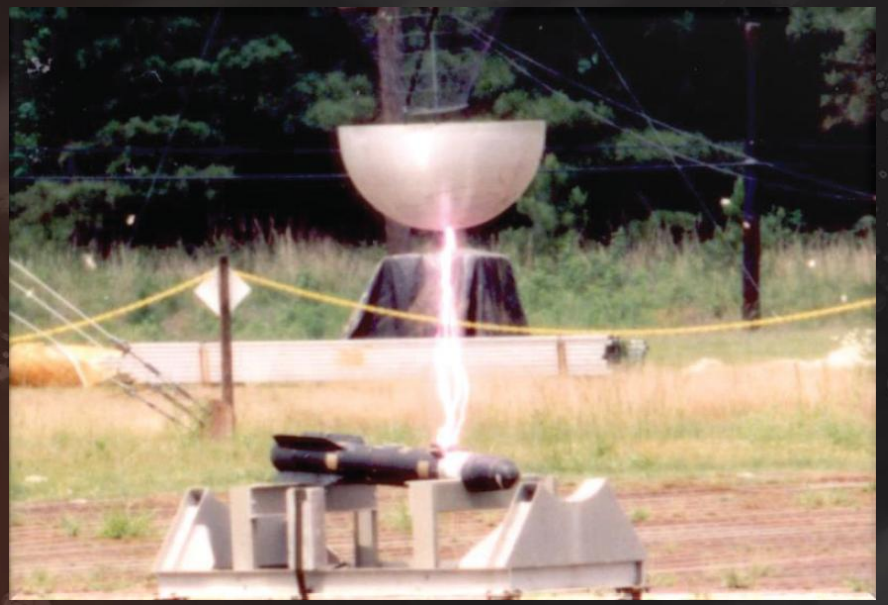


- **AASTP-1 Manual of NATO Safety Principles for the Storage of Military Ammunition And Explosives**
  - *“All permanent storage buildings and workshops for ammunition and explosives should be provided with lightning protection.”*
- **DEOP 101**
  - Details the requirements for lightning protection at fixed sites and stand down procedures for thunderstorms.

DRAFT POLICY

JOTP-063 Lightning Requirements for Ordnance (Direct Strike and Near Strike)







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HOW CAN WE MANAGE THE RISK

- Safety procedures depend on the level of risk acceptance, which varies between training and operations.
  - Training ➔ we often cancel the activity due to lightning
  - Operations ➔ we may proceed at risk, because not proceeding may impose a different risk.

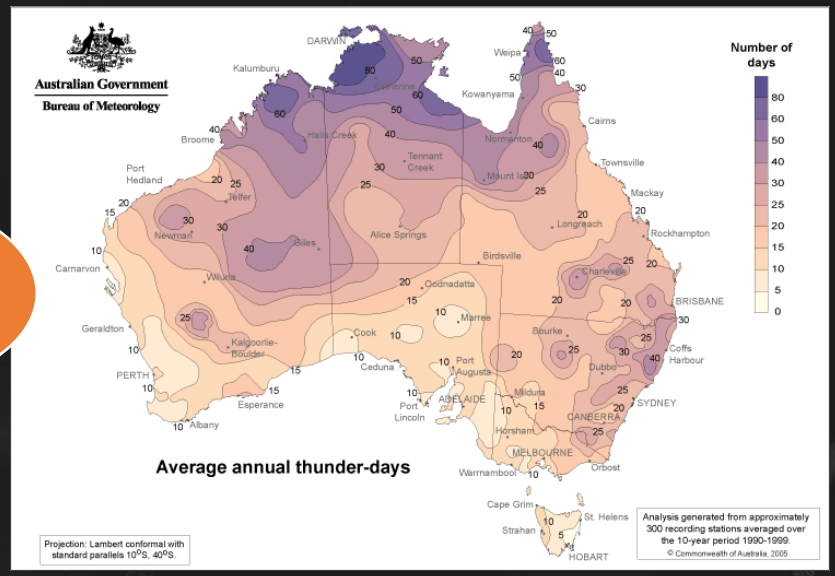
Defence Work Health & Safety Risk Matrix

Likelihood descriptors \ Consequence descriptors		Minor (A) Minor injury or illness that is treatable in the workplace (first aid) OR by a registered health practitioner, with no follow up treatment required.	Moderate (B) Injury or illness causing no permanent disability, which requires non-emergency medical attention by a registered health practitioner OR 10 or more injuries or illnesses categorised as 'minor'.	Major (C) Serious injury or illness requiring immediate admission to hospital as an inpatient and/or permanent partial disability OR 10 or more injuries/illnesses categorised as 'moderate'.	Critical (D) Single fatality and / or permanent total disability OR 10 or more injuries or illnesses categorized as 'major'.	Catastrophic (E) Multiple fatalities OR 10 or more injuries / illnesses categorised as 'critical'.
Almost certain (5)	**Activity**: Expected to occur during the planned activity. Is known to occur frequently in similar activities. **System**: Expected to occur several times a year or often during the system life-cycle. Is known to occur frequently in similar systems being used in the same role and operating environment.	(A5) LOW	(B5) MEDIUM	(C5) HIGH	(D5) VERY HIGH	(E5) VERY HIGH
Probable (4)	**Activity**: Expected to occur in most circumstances, but is not certain. Is known to have occurred previously in similar activities. **System**: Expected to occur one or more times per year or several times in the system life cycle. Is known to occur previously but is not certain to occur.	(A4) LOW	(B4) MEDIUM	(C4) HIGH	(D4) HIGH	(E4) VERY HIGH
Occasional (3)	**Activity**: Not expected to occur during the planned activity. Sporadic but not uncommon. **System**: Expected to occur less than once per year or infrequently during system life cycle.	(A3) VERY LOW	(B3) LOW	(C3) MEDIUM	(D3) HIGH	(E3) HIGH
Improbable (2)	**Activity**: Not expected to occur during the planned activity. Occurrence conceivable but considered uncommon. **System**: Not expected to occur, but possible to experience one or more events during the system life cycle.	(A2) VERY LOW	(B2) VERY LOW	(C2) LOW	(D2) MEDIUM	(E2) MEDIUM
Rare (1)	**Activity**: Not expected to occur during the planned activity. Occurrence conceivable but not expected to occur. **System**: Only expected to occur in rare or exceptional circumstances or no more than once during the system life cycle.	(A1) VERY LOW	(B1) VERY LOW	(C1) VERY LOW	(D1) LOW	(E1) LOW

- Managing the risk of lightning shifts from a purely policy based approach in training to a command decision during operations. Understanding the risks are key to making informed decisions.

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HOW CAN WE MANAGE THE RISK



Lightning detection networks

Weather forecasting

Weather radars

Prediction and detection

Suspension of operations

Stand down criteria

Evacuation of personnel

Exclusion zones

Administrative Controls

RISK REDUCED SFARP

Engineering Controls

Only applicable at permanent EO facilities / depots

Shielding, grounding, bonding

Lightning rods

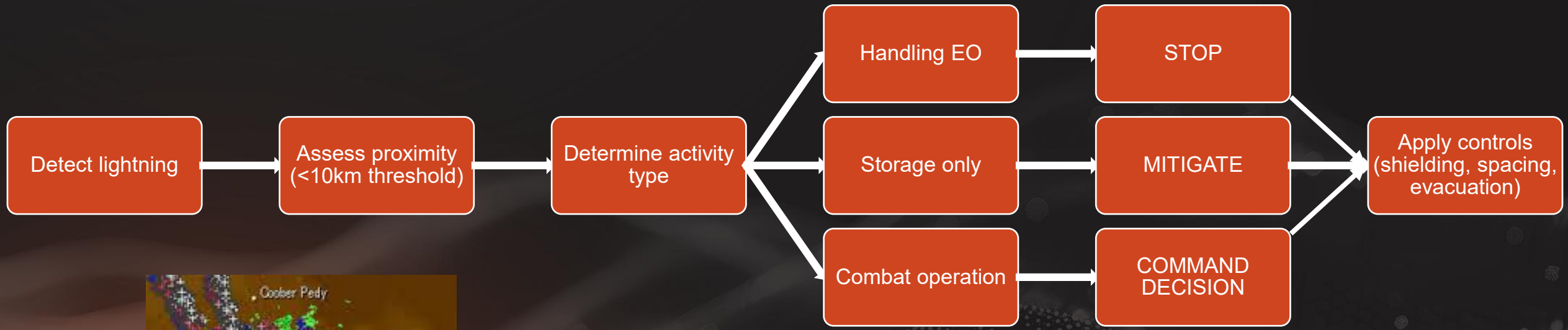
Moving EO indoors

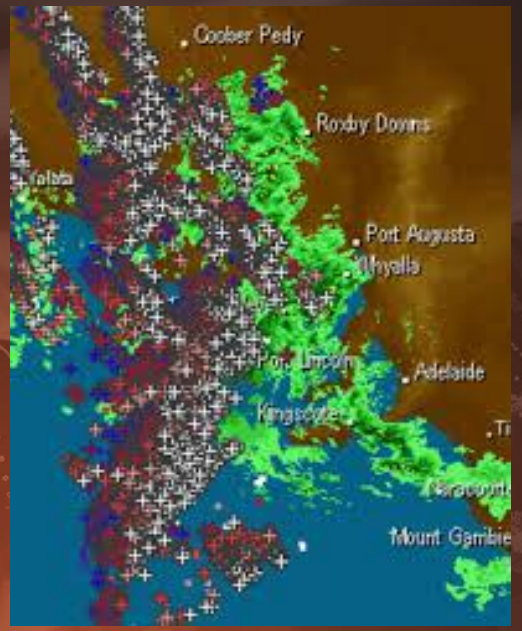
Some of these are not practicable in the field environment

Many of these are not practicable in war

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LIGHTNING RISK DECISION MODEL









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FIELD STORAGE ON OPERATIONS



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FIELD STORAGE ON OPERATIONS



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FIELD STORAGE ON OPERATIONS



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THE WAY FORWARD

Unified Electromagnetic Hazard Approach

- EEH from lightning should be managed along with other EEH sources such as RF, EMP, and ESD.

Decision Framework Development

- Develop clearer lightning decision frameworks to guide commanders on stand-down thresholds and EO handling during storms.

Addressing Capability Gaps

- Improve access to lightning simulation, testing, and validation to ensure EO is compliant.



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QUESTIONS

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