Australian Government
Department of Defence
Capability Acquisition and Sustainment Group

An Overview of Helicopter-borne ESD as an Electro-explosive Hazard in the ADF

Mr Thinus Neethling
EEH & Fuze Desk Officer
Directorate of Engineering
Explosive Materiel Branch (EMB)

Defending Australia and its National Interests
www.defence.gov.au

Foreword

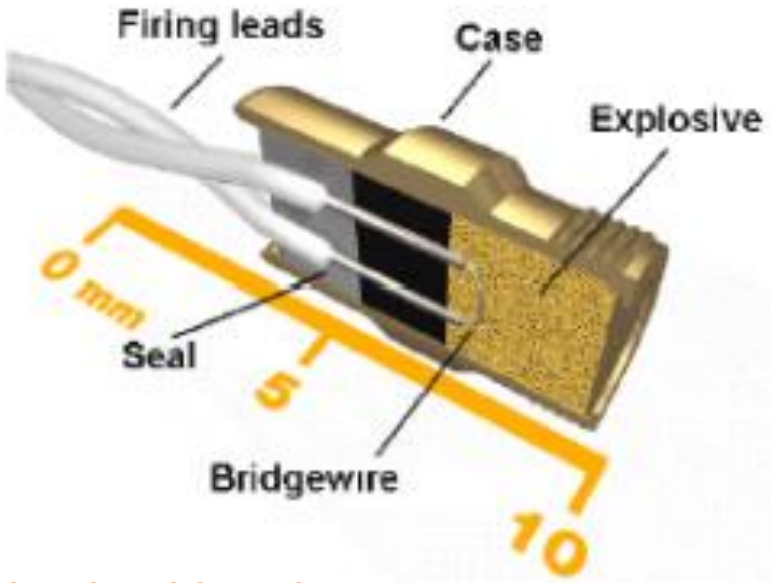
- My paper provides a holistic perspective on Helicopter-borne Electrostatic Discharge (HESD) as an Electro-explosive Hazard (EEH) and how this hazard is controlled within Defence.
- This presentation covers only a number of key HESD topics and aims to raise awareness about this form of EEH, more broadly.
- Peruse my paper, with the same title as this presentation. Useful, as it consolidates wide-ranging HESD topics, in more detail.

Agenda

- Introduction
- HESD (Circuit) Parameters
- Charging Mechanisms
- Lightning Hazard During VERTREP Operations
- Aircraft Configuration and Weather Conditions
- HESD Exposure Scenarios
- Scope of HESD Susceptible Items
- HESD Hazard Controls
- Aircraft Design Aspects
- HESD Test Requirements & Equipment
- *Status Quo* Concerning HESD Testing
- Conclusion

HESD as an Electro-explosive Hazard

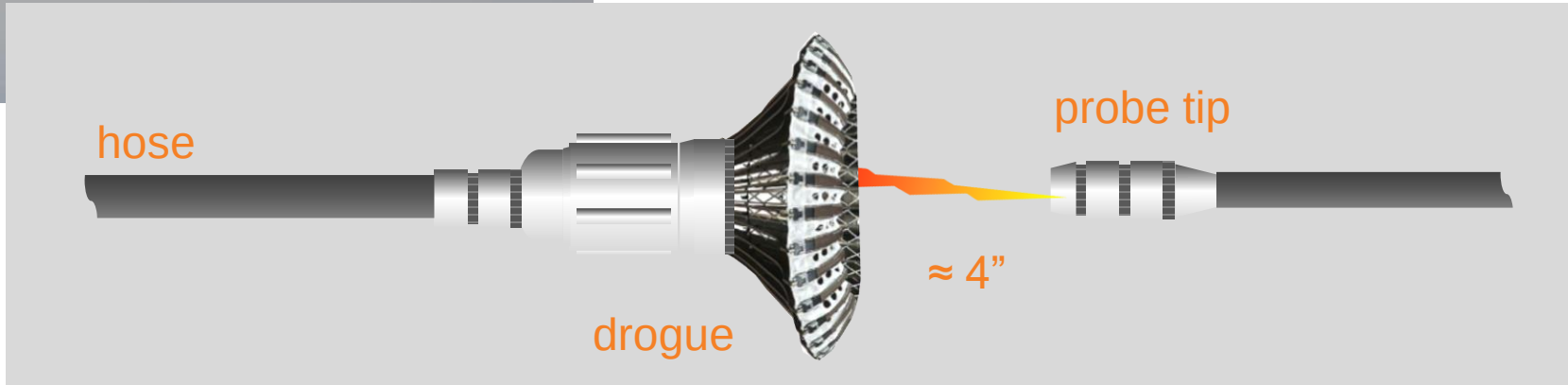
- An HESD current has the ability to initiate an electro-explosive device (EED) within an explosive ordnance (EO) item.
- Consequences may be catastrophic.



(Hot) Bridgewire EED

Introduction

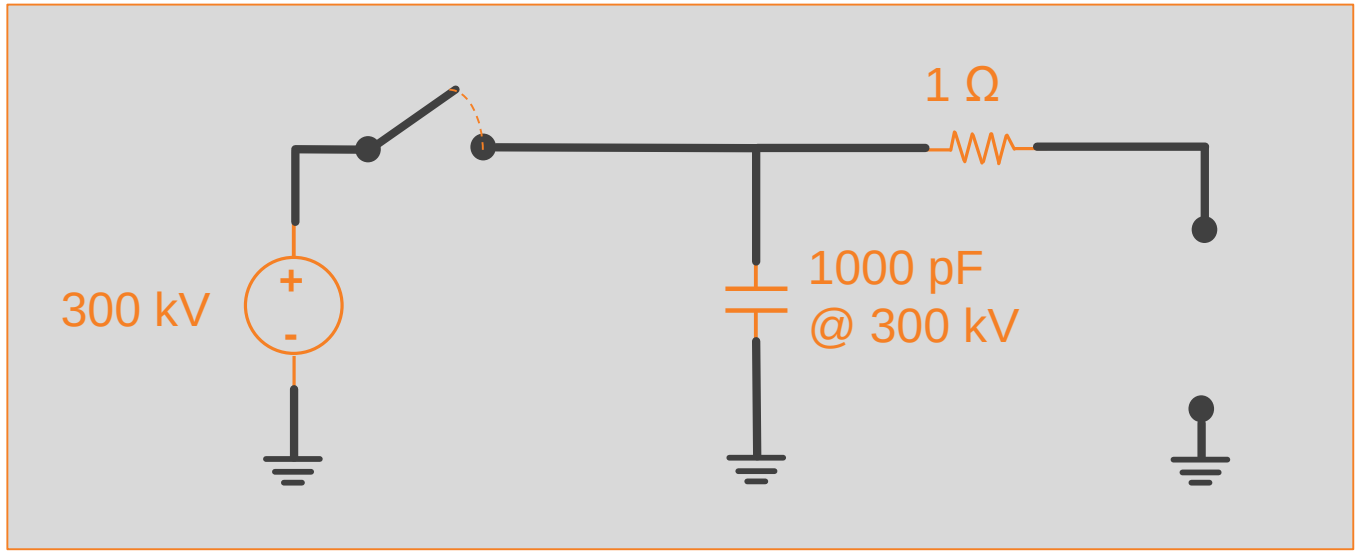
- Various pilots have seen arcs, several inches long between the probe tip and receptacle.
- At 3 kV/mm air begins to break down, which implies an estimated distance of 100 mm (or 3.94 inches) at 300 kV.

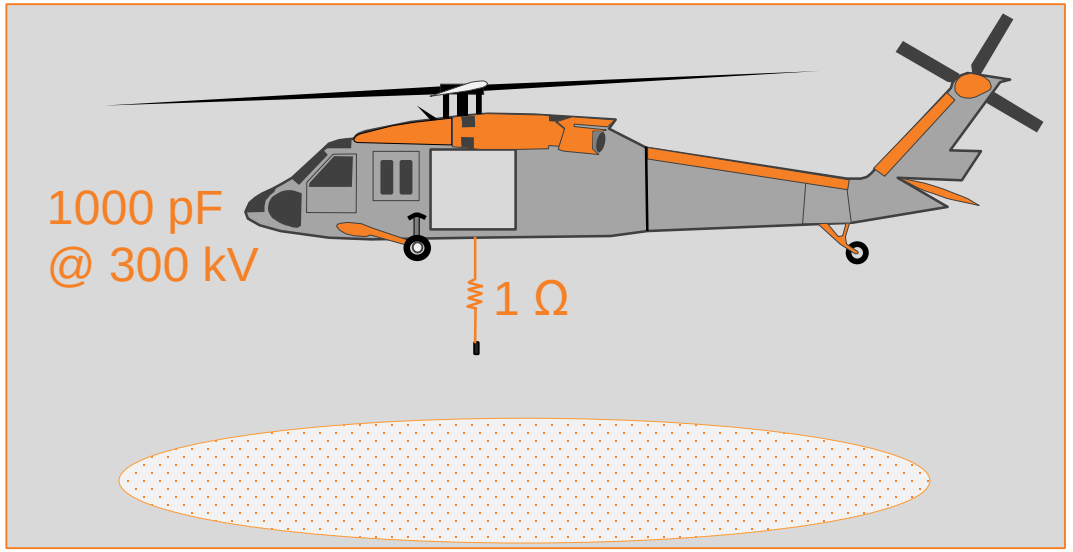


Reference: https://www.lockheedmartin.com/en-us/news/features/2020/combat-rescue-helicopter-program-successfully-executes-major-test-milestone-aerial-refueling.html

HESD Circuit Parameters

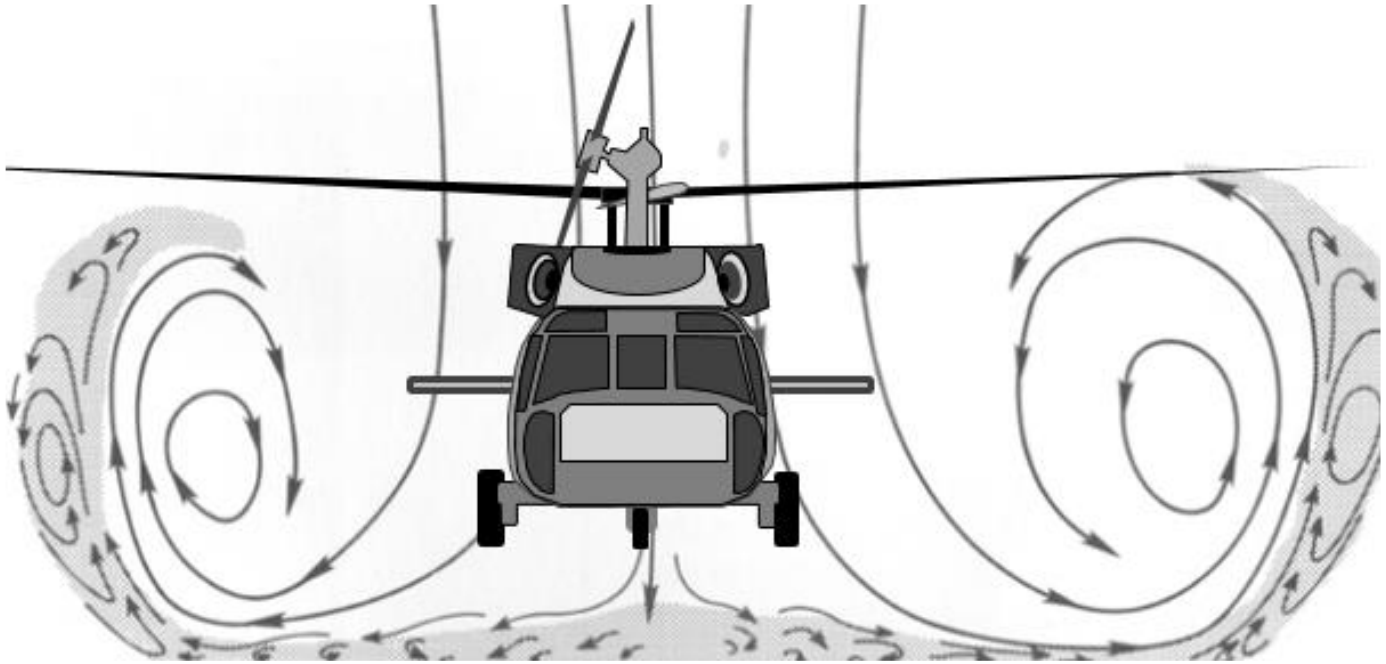
Parameter	Value
Electrostatic Potential	*300 kV ± 500 V*
Helicopter Capacitance	*1000 pF ± 5%*
Series Discharge Resistance	*≤ 1Ω*
Circuit Inductance	*< 20 μH*





HESD Charging Mechanisms

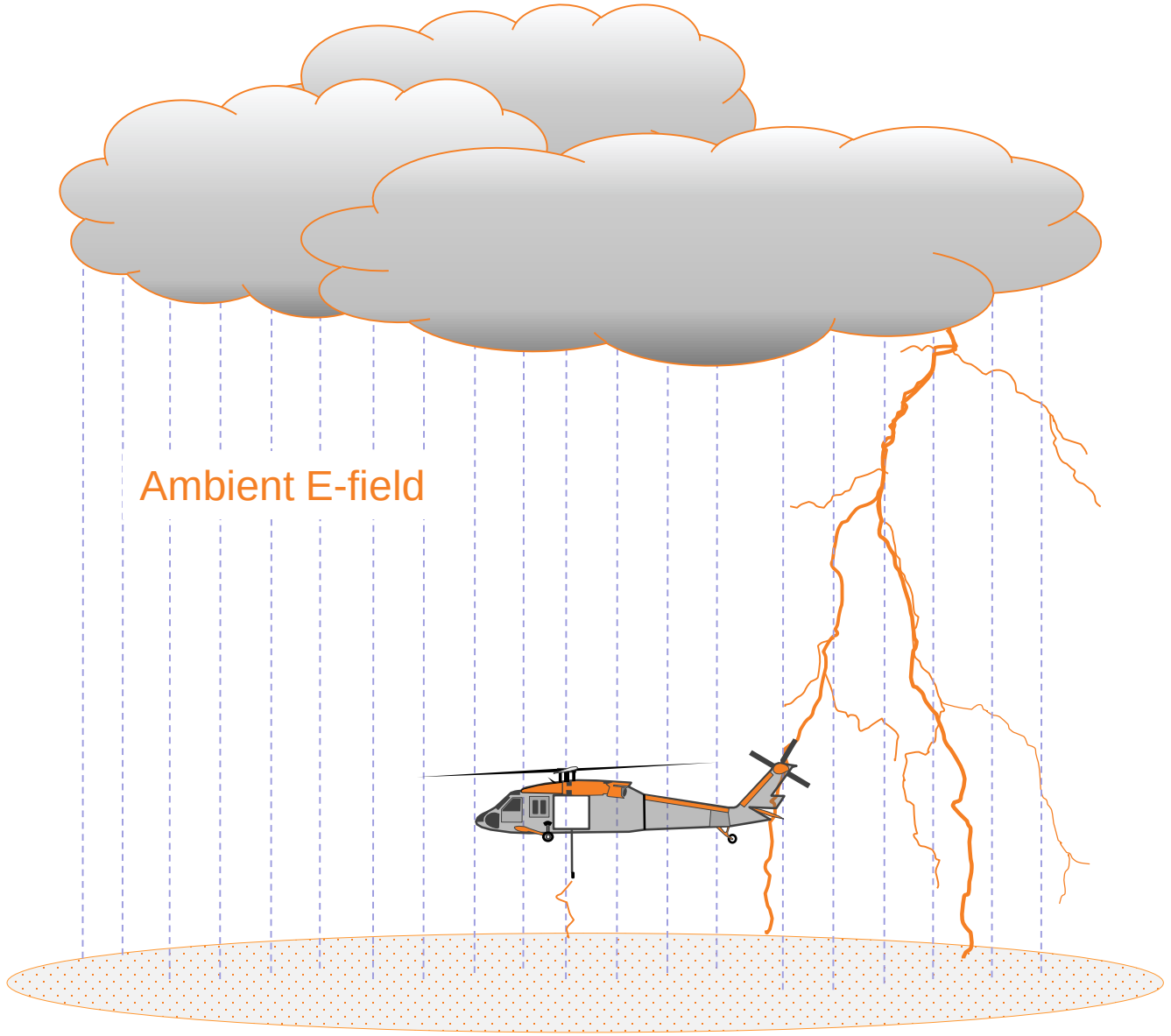
- Engine charging: ionised exhaust gases, of a particular polarity, leave the aircraft charged with the opposite polarity.
- Precipitation static (or P-static): includes all effects due to rain, snow, ice, sand and dust in the atmosphere.
- Induction: due to exposure to (and being present in) an ambient electric field of a charged cloud.



Helicopter downwash brings particulates in contact with rotor blades and aircraft surfaces.

Lightning Hazard during VERTREP & Vertical Lift

- Conductive airframe in an ambient E-field causes a local field concentration that is conducive to the formation of electrical streamers.
- Aircraft ‘attracts’ lightning and forms part of the path for the lightning current to reach the earth.
- Particularly hazardous to personnel, EO and sensitive cargo in that current path.



Effect of Aircraft Configuration & Weather Conditions

- Natural factors that impact the electrostatic potential on the aircraft:
  - combination of temperature and relative humidity
  - presence of wind & wind speed
  - presence, type and density of particulates
  - ambient electric field in presence/absence of clouds
- Factors relating to the aircraft and its configuration that impact the electrostatic potential on the aircraft:
  - size / surface area
  - rotor speed
  - presence / absence of ESD wicks
  - conductivity of airframe, use of composite materials with conductive mesh
  - hovering, earthed vs not earthed, rotors locked but engines running, rotors running
  - dynamic tyre resistance (landed aircraft)

Operational HESD Exposure Scenarios

- Vertical Replenishment (VERTREP) & Vertical Lift.
- Engines Running, Rotors Locked Rearming, of an earthed aircraft.
- Simultaneous Rotors Running Rearming (SRRR), of an earthed aircraft.
- Hot tube (un)loading, of an operating non-earthed aircraft.
- Bare, man-carried scenarios i.e. carried into or from the helicopter.
- External Carry.

An MH-60R firing an Advanced Precision Kill Weapon System, Laser-guided Rocket

Scope of HESD Susceptible EO Items

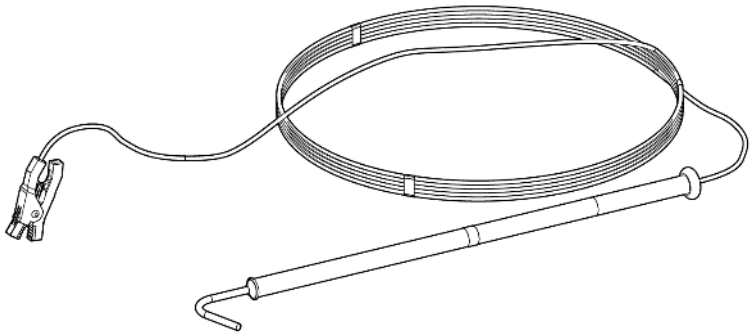
- Top-level requirements for HESD testing (of packaged items for VERTREP) concerns all devices that contain energetic material including electrically initiated devices (EIDs), EEDs and percussion initiated devices that are not in a Faraday cage.
- Bare energetic materials also apply.
- An EID is considered as a higher level EO sub-assembly that is installed with a discrete EED.

HESD EO Commodity Category
Small / Medium / Large Calibre Ammunition
Non-Lethal Ammunition
Air Launched Missile/Rocket
Man Carried Missile/Rocket
Surface Launched Missile/Rocket
Pyrotechnics
Man Emplaced Ammunition
Fuze and Ignition Systems
Underwater Systems

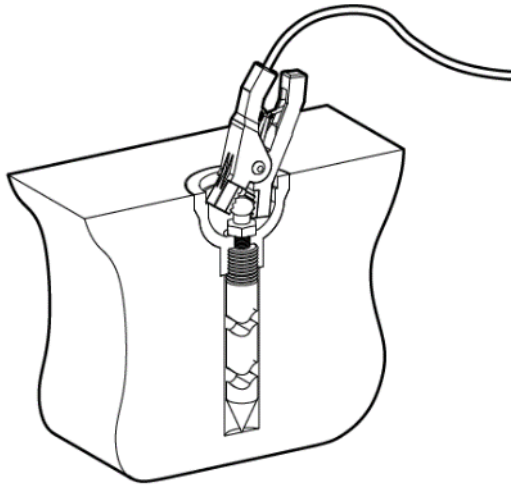
HESD Hazard Controls

- **Aim:**
  - control/direct the path of an HESD current;
    - prevent current path through electrically initiated EO
  - reduce and *zero* the electrostatic potential
  - establish & maintain an earth connection for as long a possible
  - protect personnel against an HESD current
- **How:**
  - consider environmental conditions that are more conducive to electrostatic charge build-up on the aircraft
  - shield EO and installed EEDs within approved, protective packaging
  - during VERTREP, the earth connection is made above the sensitive load, to establish a dedicated HESD path that excludes the sensitive load
  - connect the aircraft to earthing receptacles (or ground spikes, in Army context) via earthing cables
  - personal protective equipment for personnel

Use of an Earthing Wand during VERTREP



Earthing wand, cable and clamp.

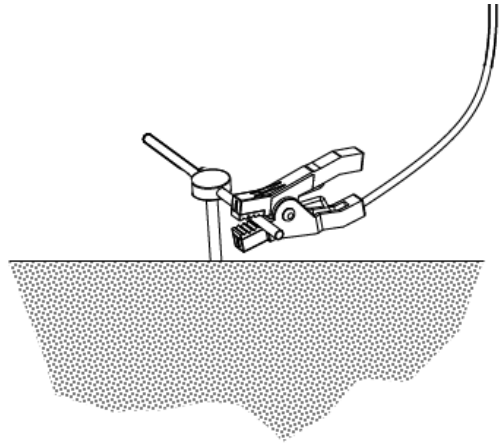


Earthing receptacle.

Use of an Earthing Wand during Vertical Lift

Ground crew maintains visual contact with approaching helicopter in preparation for cargo lift.

A static ‘probe’ is used to discharge static electricity from a UH-60 Black Hawk before the cargo is hooked up to the helicopter.



Ground stake for field use.

Photo Credits: US Army

Aircraft Design Aspects

- P-static discharge wicks shown on the *stabilator and trailing* discharge wicks shown at the landing gear.

Reference: http://www.navy.mil/view_image.asp?id=34700

or https://commons.wikimedia.org/wiki/File:SH-60B_Seahawk2.jpg

Aircraft Tyres

- MIL-DTL-5041 Rev. L covers requirements for tyres intended for use on military aircraft.
- Electrical resistance per Society of Automotive Engineers (SAE) ARP6404: mean electrical resistance needs to be < 10 MΩ.

- Dissipation of ESD not mentioned in MIL-DTL-5041 Rev. L, but in an earlier revision i.e. Rev. H
- Service bulletin *US Tire Manufacturers Assoc., ATSB Vol. 7 No. 2 of 2020* warns against reliance on tyres to dissipate static electricity (and reiterates that a mechanical means shall always be used to earth the aircraft).
- *Michelin* reiterated the stance on ESD in June of 2021.

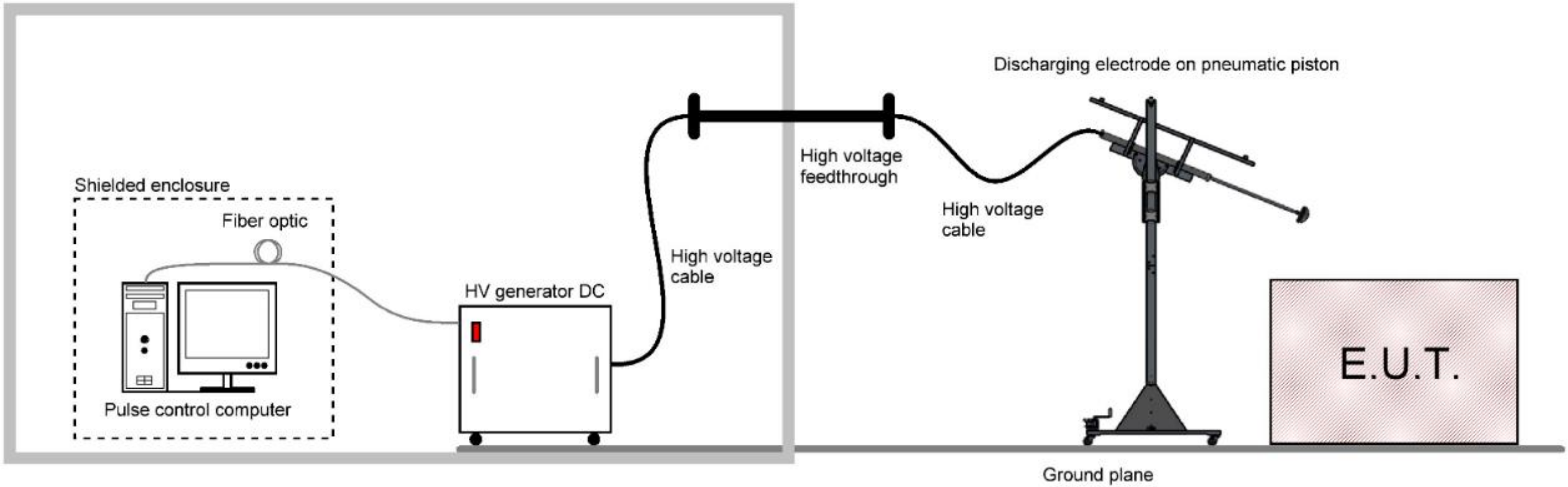
HESD Test Requirements (per JOTP-062)

- Detailed test requirements not covered.
- A minimum of four (4) of the required ten (10) samples must receive incrementing/decrementing voltage testing, as prescribed hereafter:

  Sample #1: +50 kV ▸ +100 kV ▸ +150 kV ▸ +200 kV ▸ +250 kV ▸ +300 kV
  Sample #2: +300 kV ▸ +250 kV ▸ +200 kV ▸ +150 kV ▸ +100 kV ▸ +50 kV
  Sample #3: -50 kV ▸ -100 kV ▸ -150 kV ▸ -200 kV ▸ -250 kV ▸ -300 kV
  Sample #4: -300 kV ▸ -250 kV ▸ -200 kV ▸ -150 kV ▸ -100 kV ▸ -50 kV

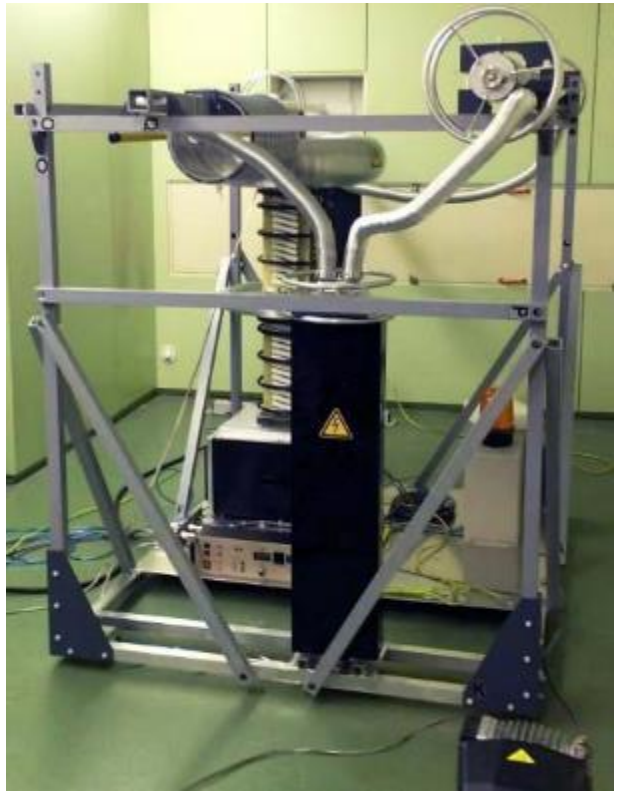
- If samples 1 to 4 pass testing, then the remaining samples may be tested at ± 300 kV only.
- <u>Performance Requirements:</u>
  - no safety or operability/performance failures during or after HESD tests
  - reset or re-powering is considered a failure, whilst momentary upsets that auto-correct are allowed

HESD Test Equipment



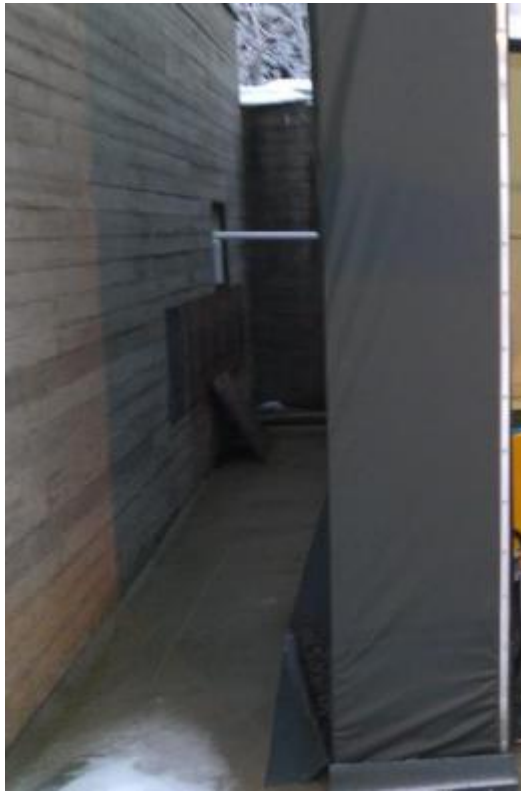
Images provided by Montena Technology SA, Switzerland. See https://www.montena.com/ for more detail.

300 kV Test Setup



HV DC Generator

HV Cable & Feedthrough



HV Cable & Feedthrough between building and tent

Discharging electrode on pneumatic piston

Images provided by Montena Technology SA, Switzerland. See https://www.montena.com/ for more detail.

Status Quo concerning HESD Testing

- No evidence to suggest HESD testing in the past on EO in the ADF.
- Strong reliance on HESD test reports from OEMs.
- Few test reports show testing against the full scope & rigour of JOTP-062.
- Strong reliance on theoretical EEH assessments where HESD is concerned.
- Assessments are limited to EIDs.
- Full scope of HESD susceptible items need to be considered.
- Gaps in understanding and quantifying the HESD hazard, compensated for by strict (effective) HESD hazard control measures.

Conclusion

- 300 kV test limit is reasonably conservative. Not likely to be experienced, unless in the most extreme of weather conditions.
- Emerging requirements & capabilities - and the broader scope of HESD susceptible items will likely drive the need for actual HESD test data, to better inform risk assessments and for making better-informed decisions.
- At the dawn of a new Sovereign Guided Weapons and EO (GWEO) Enterprise, it is essential to reiterate the need for a local HESD test and evaluation capability - to compliment the manufacturing of GW and EO in Australia.

Questions?

Contact Details

Thinus Neethling FIEAust CPEng NER APEC Engineer IntPE(Aus) RPEQ
Electro-explosive Hazards & Fuze Desk Officer

QinetiQ **|** Level 5, 30 Makerston Street **|** BRISBANE QLD 4000
T: (07) 3031 0269 **|** **M:** 0408 850 503 **|** **e-mail:** marthinus.neethling@defence.gov.au