ELECTROMAGNETIC PULSE (EMP) RISK MITIGATION
Disruptive electromagnetic pulses (EMPs) can occur if:
1. A nuclear weapon is detonated (either above or below atmosphere)
2. A non-nuclear Radio Frequency Weapon (RFW) is used
3. A solar coronal mass ejection (CME), etc., causes a Geomagnetic Disturbance (GMD)

Major types of nuclear weapons generated EMP
1. Source Region EMP (SREMP)
   • Mainly a problem associated with a ground-based nuclear detonations
   • Can disrupt power and communications throughout a city and region
2. High-altitude EMP (HEMP)
   • Can cause infrastructure disruption over multiple states with a single burst
   • May take months or years to repair damage to infrastructure
3. System Generated EMP (SGEMP)
   • Can disrupt/damage satellites via exoatmospheric X-ray fluence
SREMP Risk Background

- Source Region EMP (SREMP) is mainly a problem with ground nuclear detonations, and can be caused by:
  - Portable Nuclear Device (few tons up to kilotons (kt)*)
  - Improvised Nuclear Devices (IND)
  - Transportable weapon (up to megatons, delivered by car, missile ...)

- If a nuclear bomb goes off at ground level, it may cause:
  1. Loss of power (due to SREMP and blast effects)
  2. Induced fires (due to SREMP and thermal pulses)
  3. Electronics disruption (mainly due to SREMP)
  4. Blast wind and overpressure
  5. Radioactive Fallout

* kt = kiloton = 1,000 tons = ~ 2.2 million pounds. For nuclear weapons, the equivalent of 2.2 million pounds of TNT
Hypothetical 10 kiloton SREMP
100’ Ethernet Cable Upset/Damage

Computers, phone, and other equipment connected via Cat5 (whether Ethernet, phone, or video) within 13 mile radius (inner ring) may be damaged; outer ring shows range where equipment may be disrupted. Note that disruption can extend well past Baltimore.
Cellular handsets may be damaged within 0.8 mile radius if turned on. Handsets that come into the area later may not work due to cellular backhaul infrastructure damage or disruption.
Hypothetical 10 kiloton SREMP
Cordless Phone Power Adapter

Based on DHS/NCC testing, loss of function is due to damage to AC/DC power adapter supporting handset base.

Cordless phone power adapters within 73 mile radius may be damaged.
SREMP Summary

1. SREMP is well understood due to over 2,000 nuclear tests worldwide
2. Likely to disrupt regional electronics
3. May severely disrupt nearby cities, infrastructures, and bases
4. SREMP can cause major fires, especially in cities
5. SREMP disruption of electronics is likely to greatly exceed other surface burst effects (like blast) in total area disrupted
6. HEMP protection is not likely to adequately protect against SREMP
7. SREMP may cause more electronics damage than HEMP in a city near burst; in a large attack, may cause more damage than HEMP
High-altitude Electromagnetic Pulse (HEMP) Overview

Orange  Teak  Kingfish  Checkmate  Starfish Prime
High-altitude EMP (HEMP) E1, E2, & E3

1. **E1** is the fast (less than microsecond) and powerful pulse that can destroy computers and communications equipment and disrupt power grids

2. **E2** occurs from 1 microsecond out to 1 second and is generated by gammas produced by weapon neutrons and is less powerful than the E1 pulse
   - The main risk with the E2 component is that it immediately follows the E1 component, which may have damaged the lightning protection devices that would normally also have protected against E2

3. **E3** is a slow pulse that arrives after 1 second and can last several minutes
   - E3 can penetrate the ground and water
   - E3 is similar to the EMP caused by a significant solar geomagnetic storm
   - E3 can produce damaging surge currents in long electrical conductors like power lines or undersea cables
HEMP – E1, E2, & E3 described

Early Time (E1)  Intermediate Time (E2)  Late Time (E3)

- Prompt Gamma Signal
- Neutron Gamma Signal
- MHD Signal
- Lightening at 10 meters
- Scattered Gamma Signal

E(t) [kV/m]

Time (s)

Distributed Nets

Long Power and Comms Lines, like Undersea Cables

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Electromagnetic Spectrum Comparisons for E1, lightening, and IEMI* threats

* IEMI = Intentional Electro-Magnetic Interference (narrowband and wideband are IEMI)
The July 1962 “Starfish Prime” high altitude nuclear burst as seen through heavy cloud cover from Honolulu about 900 miles away. Aurora effects were observed for as long as 7 to 14 minutes in some areas.

The Starfish Prime air-glow aurora as seen at three minutes from a surveillance aircraft.
1945: Enrico Fermi predicted EMP with the first nuclear detonation at ground level
   • Even with shielding, some test equipment failed and records were lost
1962: U.S. “Starfish Prime” High-altitude EMP (HEMP) Test
   • At midnight (9 July) over Johnston Island, a 1.4 MT device was detonated at 400 km
     (~ 250 miles) altitude; a ~ 14 kV/m EMP resulted at Johnston Island
   • At 100 nanoseconds, Hawaii experienced what some reported as 5.6 kV/m
     • Blew fuses supporting ~ 300 street lights in Oahu (about 900 miles away)
     • Damaged a microwave link that then shut down telephone service between
       Kauai to the other Hawaiian islands
     • Other: some car ignition systems fused and burglar alarms went off
     • Artificial radiation belt of trapped electrons damaged many satellites
       • Solar panels degraded; many satellites failed (within days to months)
       • HF radio was disrupted for minutes to hours in the region

A similar detonation over the central USA today could potentially shut down the power grid
and communications, etc., in large regions for months or longer
EMP – Lessons from Soviet history
Oct 1962  K-3 HEMP Test over Kazakhstan

300 kiloton burst at 290 km altitude

Overhead Power and Communications Lines Damaged

Overhead power transmission lines

Puncture, temporary disconnection of transmission line

Loss of communications; many examples

Power supply breakdown

1000 km

Ground zero

600 km

Malfunction of radio-location

Long line problems due to EMP "long tail"

Overhead communications lines

Backup Diesel generators found damaged, “later”

Overhead communications lines

Spark gaps breakdown

600 km

600 km

Result – USSR decided to protect their infrastructure from EMP. They put their top scientists on this EMP project.

Amplification location unit

Power supply breakdown

Signal cable line

600 km

400 km

Safety devices burning

Figure adapted from presentation by General Loborev, Director, Central Institute of Physics and Technology, EUROEM Bordeaux, June 1994

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HEMP E1 area coverage by Height of Burst (HOB)
E1 can cause arcing within equipment

- High-level pulses can cause arcing
E1 can cause component damage

• High-level pulses coming into systems can explode parts
Examples of Radio Frequency Weapons

- JOLT IRA Hyperband Emitter
- Large Truck Mounted NB HPRF/M Source
- CHAMP Weapon
- Pickup truck Radar HPRF/M Source
- UWB Pulser and Impulse Radiating Antenna
- Diehl DS110B EM Weapon
EMP Mitigation Conclusions

• Risk of not protecting critical infrastructures is profound
  • One HEMP burst can severely disrupt continental U.S. infrastructures
  • One SREMP burst can severely disrupt infrastructures within a 100 miles

• Significant, low-cost EMP protection can be implemented quickly
  • For example, cell sites could be HEMP protected for < 5% of cost/site

• EMP protection guidance is needed for more than just HEMP
  • Key satellites need System Generated EMP (SGEMP) protection
  • Key facilities need SREMP protection, if near a major city or possible target

• Need to implement EMP protections for all critical infrastructures, not just communications (such as power, water, transportation …)

• President’s Executive Order 13865 will help expedite EMP mitigation