HEMP/IEMI Update:
The Threat and Concerns
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Terminology

High Power Electromagnetics (HPEM) used in the IEEE EMC Society for many years to define:

- EM fields from nearby lightning ground strikes (LEMP)
- EM fields near an electrostatic discharge (ESD)
- EM fields from radars at airports or at navy facilities (HIRF)
- EM fields from switching events in high voltage substations
- Electromagnetic pulse (EMP) fields from nuclear bursts
- Intentional electromagnetic interference (IEMI) environments

Terminology

Electromagnetic Pulse (EMP)

- An umbrella term identifying two forms of damaging high power electromagnetic signals

High-altitude Electromagnetic Pulse (HEMP)

- Damaging electromagnetic signals (>50,000 volts/meter) emitted from a nuclear detonation in outer space at any altitude above 18 miles (30 km)
  - ***Note: No damaging near field or radiation effects***

Intentional Electromagnetic Interference (IEMI)

- Damaging/disruptive and/or data altering electromagnetic signals caused by the malicious use of electromagnetic weapons (non-detonation, within targeted footprints)

Terminology

Coronal Mass Ejection (CME)

- Coronal mass ejection (CME) or a high speed stream of the solar wind, containing magnetic particles, originating from a region of weak magnetic field on the Sun’s surface

Geomagnetic Storm (GS)

- A geomagnetic storm is caused by a CME **(completely distinct from EMP)** causing a temporary disturbance of the Earth's magnetosphere caused by a solar wind shock wave and/or cloud of magnetic field which interacts with the Earth's magnetic field.

Terminology

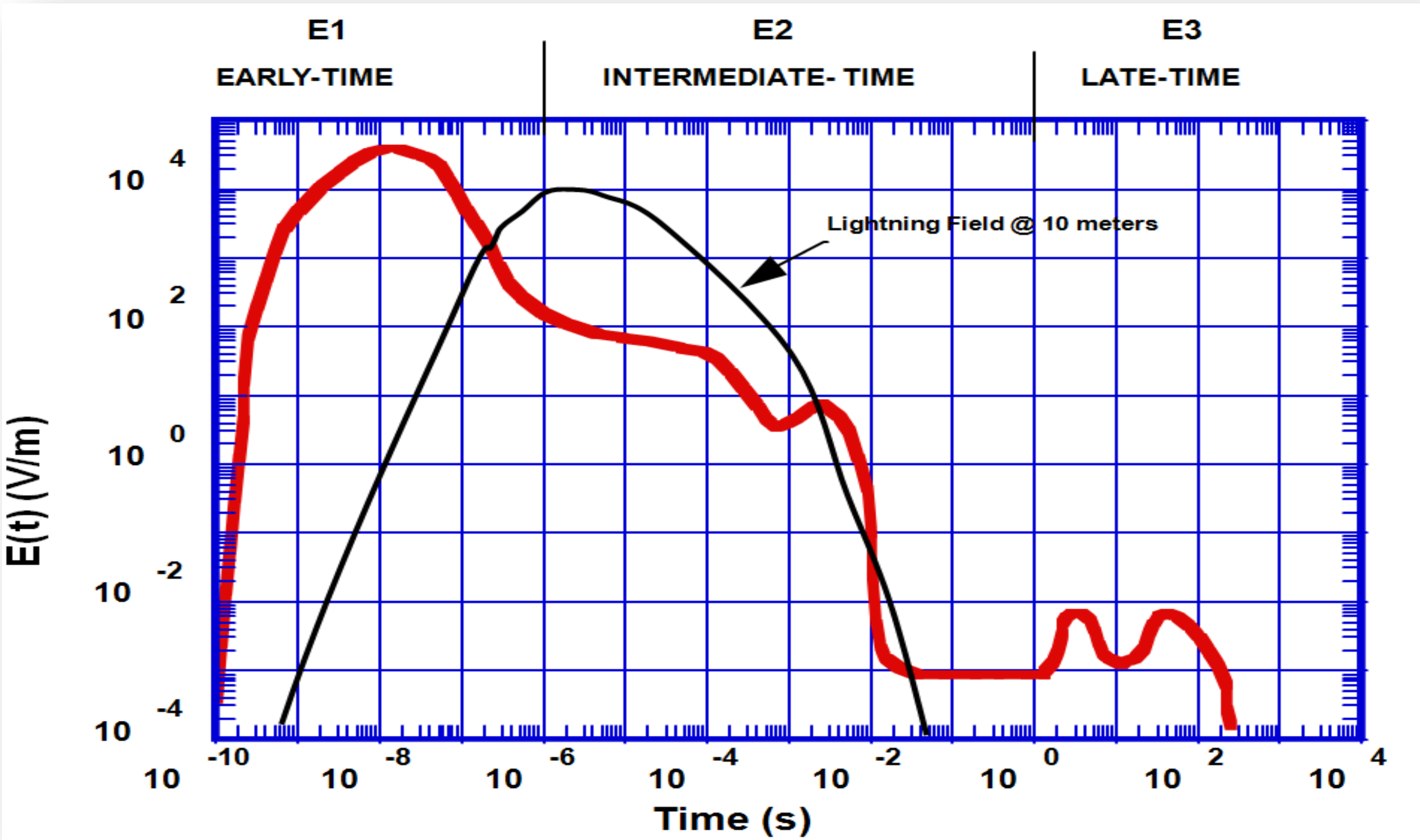
Geomagnetically Induced Currents (GIC)

- Geomagnetically induced DC currents (GIC),that can couple on to power lines and cause saturation in EHV transformers.
- In 1989, a geomagnetic storm energized ground induced currents which disrupted electric power distribution throughout most of the province of Quebec and caused aurorae as far south as Texas.

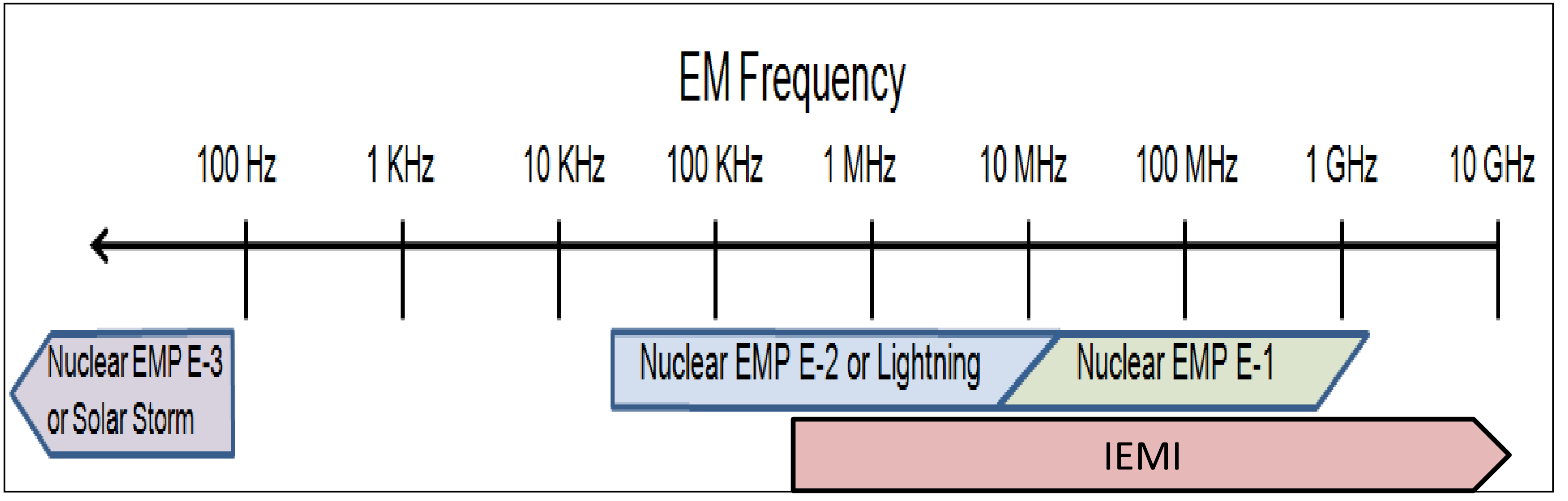
Second Order Harmonics (120Hz)

- As a result of EHV transformers going into saturation they will produce second order harmonics

Terminology



Terminology



An EMP would create a pulse higher than 10,000 V/m.

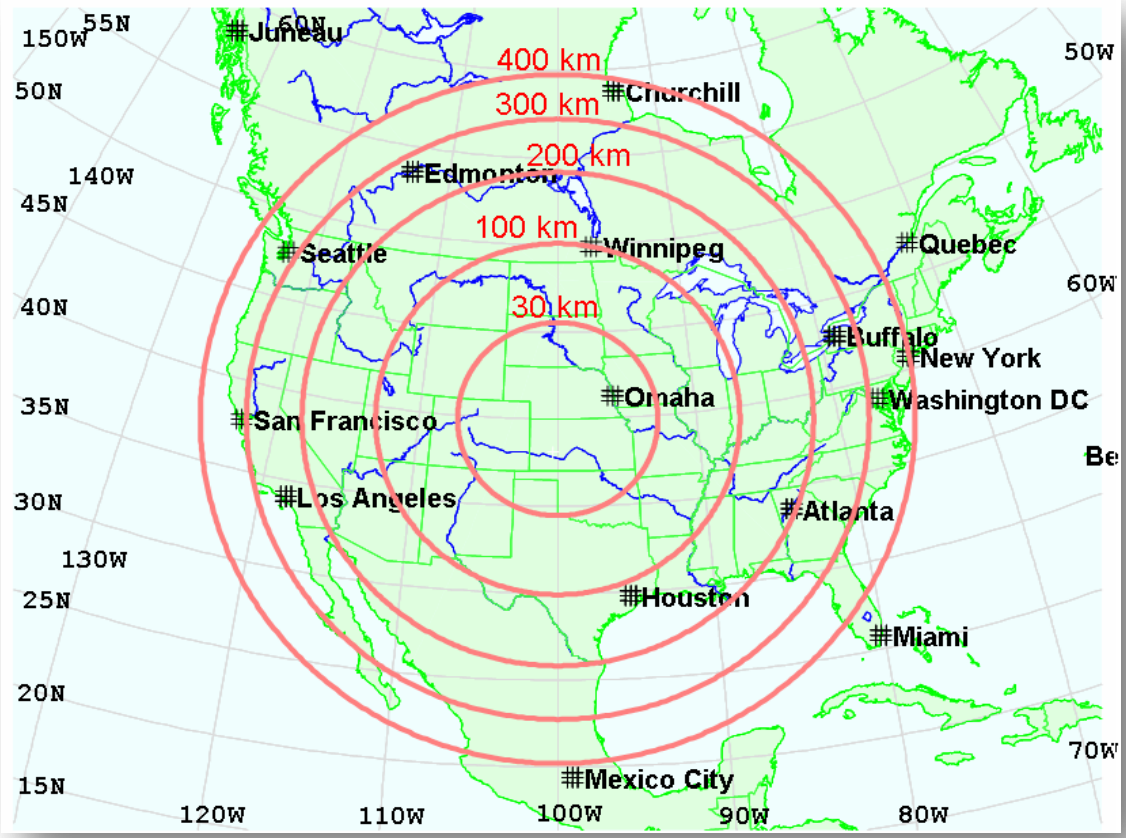
MIL-STD-188-125

TABLE I. Injected pulse characteristics and residual internal stress limits for classes of electrical POEs.

a. Electrical POEs, except RF antenna line POEs.

Class of Electrical POE	Pulsed Current Injection Requirements[1]			
	Type of Injection	Peak Short-Ckt Current (A)	Risetime (s)	FWHM[2] (s)
Commercial Power Lines (Intersite)				
Short Pulse	Common mode	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	2,500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Intermediate Pulse	Common mode	250	$\le 1.5\times10^{-6}$	3×10^{-3}–5×10^{-3}
Intermediate Pulse	Wire-to-ground	250	$\le 1.5\times10^{-6}$	3×10^{-3}–5×10^{-3}
Long Pulse	Common mode	[3]1,000	≤ 0.2	[3]20–25
Long Pulse	Wire-to-ground	[3]1,000	≤ 0.2	[3]20–25
Other Power Lines (Intrasite)				
Unrestricted Lines				
Short Pulse	Common mode	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	2,500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Restricted Lines				
Short Pulse	Common mode	800	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	[4]$800/\sqrt{N}$ or 500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Audio/Data Lines (Intersite)				
Short Pulse	Common mode	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	[4]$5{,}000/\sqrt{N}$ or 500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Intermediate Pulse	Common mode	250	$\le 1.5\times10^{-6}$	3×10^{-3}–5×10^{-3}
Intermediate Pulse	Wire-to-ground	250	$\le 1.5\times10^{-6}$	3×10^{-3}–5×10^{-3}
Long Pulse	Common mode	[3]1,000	≤ 0.2	[3]20–25
Long Pulse	Wire-to-ground	[3]1,000	≤ 0.2	[3]20–25
Control/Signal Lines (Intrasite)				
Unrestricted Low-Voltage Lines[5]				
Short Pulse	Common mode	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	[4]$5{,}000/\sqrt{N}$ or 500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Unrestricted High-Voltage Lines[5]				
Short Pulse	Common mode	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	[4]$5{,}000/\sqrt{N}$ or 500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Restricted Lines				
Short Pulse	Common-mode	800	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Short Pulse	Wire-to-ground	[4]$800/\sqrt{N}$ or 500	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Conduit Shields				
Signal and Low Current Power[6]				
Buried[7]	Conduit-to-gnd	800	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Nonburied	Conduit-to-gnd	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Medium Current Power[6]				
Buried[7]	Conduit-to-gnd	800	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Nonburied	Conduit-to-gnd	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
High Current Power[6]				
Buried[7]	Conduit-to-gnd	800	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}
Nonburied	Conduit-to-gnd	5,000	$\le 2\times10^{-8}$	5×10^{-7}–5.5×10^{-7}

Threats

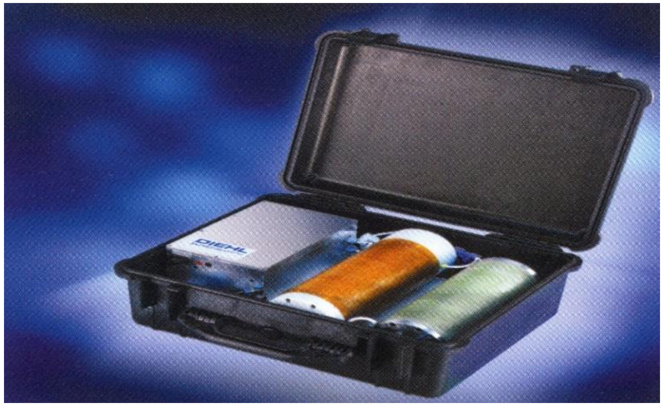


Affected Region vs. Nuclear Burst Altitude

Threats

CHAMP
(by Boeing)

IEMI "Truck Mounted" Weapons



IEMI "Suitcase" Weapons

IEC SC 77C

Objective is to provide voluntary standards for civilian systems to protect against all man made high power EM transients including HEMP and IEMI

- The Secretariat is held by UK, Secretary is Dr. R. Hoad, UK
- The Chairman is Dr. William Radasky, USA

Participating Nations

- China, Egypt, Finland, Germany, Italy, Japan, Korea (Republic of), Mexico, Norway, Pakistan, Poland, Romania, Russian Federation, Sweden, Switzerland, Thailand, United Kingdom and USA

Observing Nations

- Austria, Belgium, Brazil, Bulgaria, Croatia, Czech Republic, Denmark, France, Ireland, Israel, Netherlands, Portugal, Slovakia, Spain, Turkey, and Ukraine (16)

IEC SC 77C

- The IEC has been developing High-altitude Electromagnetic Pulse (HEMP) Standards and reports since the late 1980s
- SC 77C was formed in 1992
- Initial emphasis was to provide the means to protect civilian electronics equipment from the effects of HEMP
- Scope of work in SC 77C expanded in June 1999 to include all
  - High Power EM transient threats (HPEM), including IEMI

High Power generally refers to radiated fields or conducted voltages and currents which have the capability to disrupt electronic systems (e.g. greater than 100V/m and greater than 100V)

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IEC SC 77C

61000-1- (General)	-3 HEMP Effects On Systems -5 HPEM Effects On Systems
61000-2- (EM Environment)	-9 HEMP Radiated Environment -10 HEMP Conducted Environment -11 Classification Of HEMP Environments -13 HPEM Environments
61000-4- (Testing and Measuring Techniques)	-23 Test Methods Radiated -24 Test Methods Conducted -25 HEMP Immunity Tests -32 HEMP Simulator Compendium -33 HPEM Measurement Methods -35 HPEM Simulator Compendium -36 IEMI Immunity Test Methods
61000-5- (Installation and Mitigation Guidelines)	-3 HEMP Protection Concepts -4 Specifications For Radiated Protection -5 Specifications For Conducted Protection -6 Mitigation Of External EM Influences -7 EM Code -8 HEMP Protection Methods For The Distributed Civil Infrastructure -9 System-level Susceptibility Assessments For HEMP And HPEM
61000-6- (Generic Standards)	-6 Generic Standard For HEMP Immunity

US Military Standards

- **Mil Std 464A** – E3 Requirements for systems− Specifies the environment from Mil Std 2169B, also has an unclassified environment
- **Mil Std 461D/E/F** – Requirements for control of EMI (RS105 for HEMP testing equipment)
- **Mil Std 2169B** – Classified HEMP environment Does not give installation design criteria or test methods
- **Mil Std 188-125, Parts 1&2**–Low risk, robust approach for protection of fixed and transportable facilities against HEMP
  - Time-urgent command, control, communications, computer, and intelligence (C4I) functions.
  - Utility, Commercial and Industrial organizations reference MIL-STD 188-125 but consider applying it in a slightly modified form by scaling the protection efforts down and using alternate certified materials and components to achieve equivalent protection

Legislation

U.S. Congress:

- H.R.3410 (Critical Infrastructure Protection Act) (CIPA)
- CIPA directs and empowers the Department of Homeland Security to harden and protect our critical infrastructure including power production, generation, and distribution systems.
- To Amend The Homeland Security Act of 2002 To Secure Critical Infrastructure Against Electromagnetic Pulses, And For Other Purposes
- October 30, 2013
- Referred to the Subcommittee on Cybersecurity, Infrastructure Protection, and Security Technologies
- 12/01/2014 Passed/agreed to in House
- 12/02/2014 Received in the Senate and Read twice and referred to the Committee on Homeland Security and Governmental Affairs.
- June 25, 2015 Passed Committee on Homeland Security

Legislation

Dr. George Baker, Dr. Peter Pry, Michael Caruso Testifying Before U.S. Congress
Photo By Ashton Bingham

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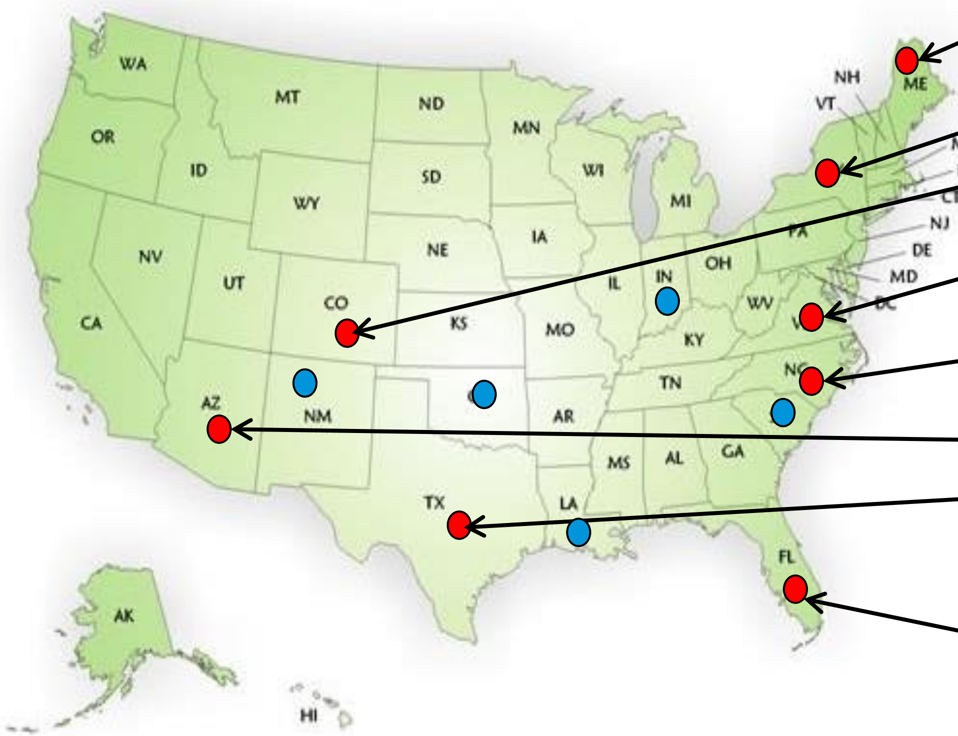
Legislation



- **Maine –** Passed first legislation, has follow-up pending.
- **New York –** working from the local level up
- **Colorado –** focusing on EMP and including study provisions
- **Virginia –** passed emergency preparedness legislation
- **North Carolina –** new legislation pending
- **Arizona –** passed emergency preparedness legislation
- **Texas –** submitted 4 bills; finding funds in State budget, taking issue directly to the utility companies
- **Florida –** trying to work through the Governor's office

***Indiana**, **Oklahoma**, **Louisiana**, **New Mexico**, and **South Carolina** are engaging in initiatives*

Sectors At Risk

Immunity Standards

- IT Equipment - 10 Volts/meter
- Medical Equipment – 10 Volts/meter
- Network Telephone Equipment – 10 Volts/meter
- Aircraft- (HIRF) 7,200 Volts/meter
- Automobiles – 100 Volts/meter
- Military Equipment – 200 Volts/meter

Sectors At Risk

System Type	EMP/E3 or GMD Vulnerability	EMP/E1 Vulnerability	RF Weapon Vulnerability
Grid Power Transmission/Distribution	3	3	1
Electric Power Grid Electronic Control, Monitor Systems	1*	3	3
Long Haul Comm, Data Lines Repeater Systems	3	3	3
Data Center Equipment Rooms	1*	3	3
SCADA, Process Control Systems	1*	3	3
Vehicles, Ships, Aircraft Electronics	0	2	3
Hand-held Electronics	0	2	3

3 – High
2 – Medium
1 – Low
0 – No

Sectors At Risk

Critical infrastructure: assets that are essential for the functioning of a society and economy. (DHS)

- Electricity generation, transmission and distribution
- Gas production, transport and distribution
- Oil and oil products production, transport and distribution
- Telecommunication/Data Centers
- Water supply (drinking water, waste water/sewage, stemming of surface water (e.g. dikes and sluices))

Sectors At Risk

Critical infrastructure: assets that are essential for the functioning of a society and economy. (DHS)

- Agriculture, food production and distribution
- Heating (e.g. natural gas, fuel oil, district heating)
- Public health (hospitals, ambulances)
- Transportation systems (fuel supply, railway network, airports, harbors, inland shipping)
- Financial services (banking, clearing, Insurance)
- Security services (police, military).

Potential Applications

TIER 1 Data Centers

- Small Businesses
- 99.671% Uptime
- 28.8 Hours Downtime Per Year
- No Redundancy

TIER 2 Data Centers

- Medium-size Businesses
- 99.749% Uptime
- 22 Hours Downtime Per Year
- Partial Redundancy in Power and Cooling

Based upon proprietary rating system of The Uptime Institute four-tier ranking system as a benchmark for determining the reliability of a data center.

Potential Applications

TIER 3 Data Centers

- Large Businesses
- 99.982% Uptime
- 1.6 Hours Downtime Per Year
- N+1 Fault Tolerant
- 72 Hour Power Outage Protection

TIER 4 Data Centers

- Enterprise Corporations
- 99.995% Uptime
- 2.4 Minutes Downtime Per Year
- 2N+1 Fully Redundant
- 96 Hour Power Outage Protection

Based upon proprietary rating system of The Uptime Institute four-tier ranking system as a benchmark for determining the reliability of a data center.

Potential Applications

PROTECTION LEVEL 1 (Survival of Data and Equipment)

EMP Protected Environment

- With EMP protected enclosures and treated points of entry, your data and processing equipment will survive. Although the power, cooling, and utilities in an unprotected host facility may not be immediately available, your equipment will remain safe. When power, cooling and utilities and communications are restored, your data equipment will be fully operable.

Potential Applications

PROTECTION LEVEL 2 (Survival & Continuous Operations of Data & Equipment)

<u>Independent Power and Utilities</u>

- If an EMP event occurs, your data and processing equipment will <u>continuously operate</u> with a fully independent and protected power and utility source. This unit may be located inside your suite or outside the existing data center facility. Your data processing and communication will not be interrupted.

Potential Applications

- Determine the “mission” of the facility (New or Existing)
  - Does it need to be up and running 100% of the time?
  - What outage is acceptable and for how long?
  - What equipment can be sacrificed?
- Determine the extent of critical long lead equipment

Servers	Generators	Fire Protection
Storage	Power Distribution	Intrusion Protection
HVAC	Communications	Transportation
UPS	Network Switches	Water

Potential Applications

- New Construction
  - Early planning
  - Most cost effective approach
  - Least schedule impact
  - No down-time
- Retrofit Applications
  - Detailed need analysis
  - Greater cost
  - Greater scheduling impact
  - Coordinated down-time

System Design

Shielded Enclosure Types

ETS-Lindgren Inc.

System Design

Mechanical Room Hybrid System

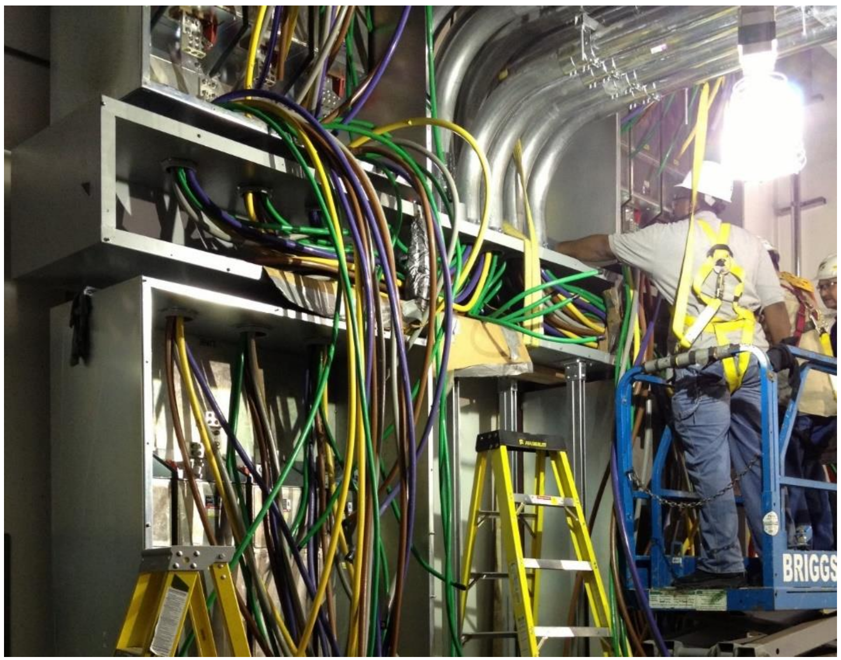
System Design

Modular/Welded Interface

System Design

Before and After

System Design



Service Entrance Power Line Filters
150,000 AIC

System Design

EMP Protected Generator Exhaust

System Design

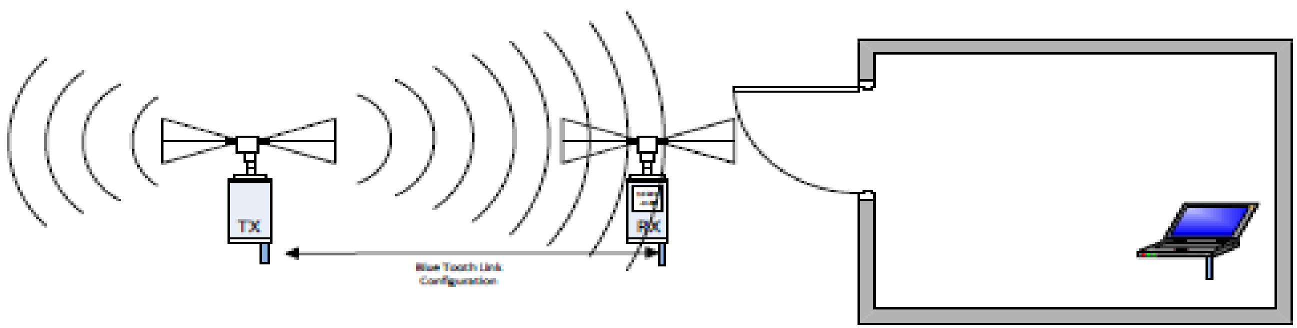
Prefabricated Generator Enclosure
ARMAG Corp.

System Verification

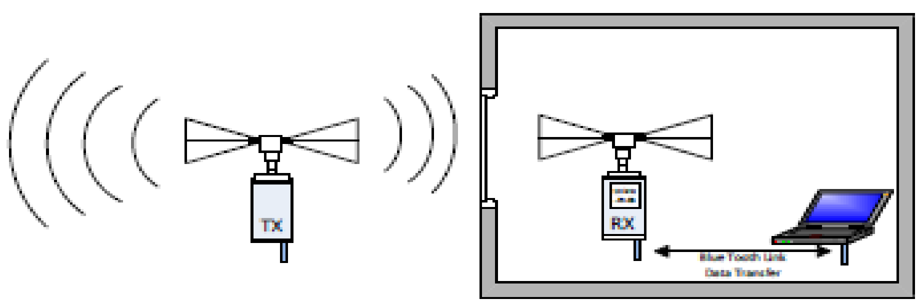
The Little Mountain Test Facility is a state-of-the-art test facility, Air Force Materiel Command laboratory dedicated to simulation testing of nuclear hardness, survivability, reliability and electromagnetic compatibility of defense systems.

System Verification

Step 1 - Reference

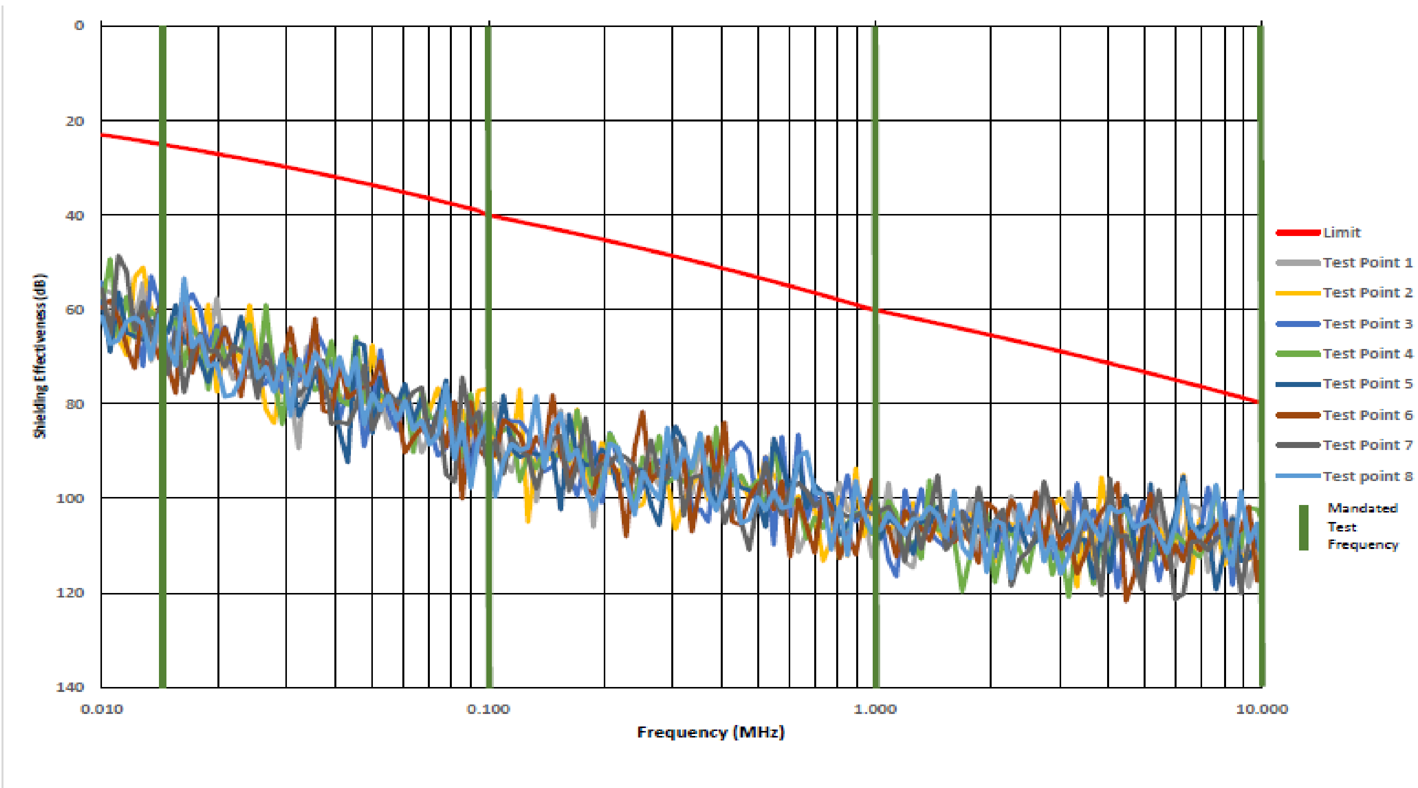


Step 2 - Measurement



Shielding Effectiveness Test

System Verification



Shielding Effectiveness Test

THANK YOU!

Questions?

To contact speaker frank@electronicinstrument.com