TRANSTECTOR

White Paper

EMP - A Burgeoning Threat in Today's Technological World

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Introduction

An Electromagnetic pulse or EMP is a burst of radiation created by a high-altitude nuclear explosion. The range and extent of damage this type of destructive event would cause to commercial networks including utilities, 911 responders and transportation hubs is being evaluate globally by government leaders, military agencies, and scientists.

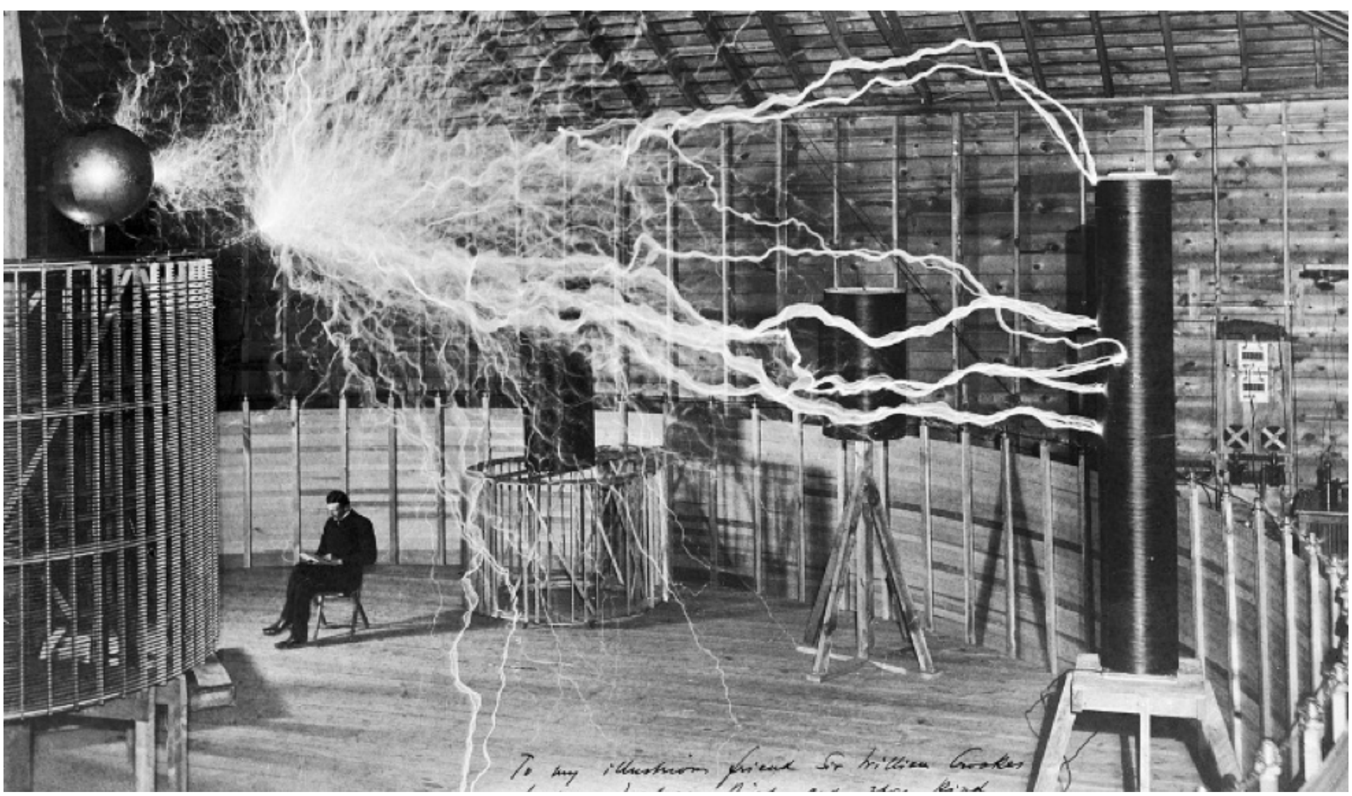
As experts in highly specialized EMP/HEMP filter technology, top defense contractors have relied on Transtector's design experience and patented technology to meet the requirements set by military standards for EMP-EMI mitigation. This proven technology and tested product mix is now being expanded to support commercial network operators as they plan HEMP network threat assessments.

In this white paper, we will discuss various forms of EMP, why these events are devastating to commercial infrastructure, and proactive steps to take in evaluating network threat assessments.

Origins of EMP

Ben Franklin is known as the 'Father of Electricity,' in honor of his early work in electrostatics, and for his famous pioneering experiments with lightning.

Harnessing magnetics, coupled with the flair of a performer, Nikola Tesla should be considered the 'Father of EMP.' His man-made lightning and other high voltage/high frequency experiments in Colorado Springs circa 1900 caused butterflies to become visibly electrified, with blue halos of St. Elmo's fire surrounding their wings. The scientific unit of measure for the strength of a magnetic field is immortalized in his name.



Defined, an electro-magnetic pulse (EMP) is a burst of electromagnetic (EM) energy caused by an acceleration of charged particles, usually electrons. In the modern electrical world, EMP should be considered a category for a broad range of natural and man-made transient electro-magnetic phenomena:

Lightning electro-magnetic pulse (LEMP) – Mother nature provides a visually glorious example of a transient, high-energy, time-varying current of dancing electrons every time a lightning bolt equalizes the diverging potential between charged clouds in the sky and the surface of the Earth. While it is straightforward to understand that practically any object that finds itself in the direct current path of a lightning strike will be thermally vaporized, many are not aware that a great deal of the total damage caused by lightning to electrical equipment is caused by circulating transient surges in other nearby electrical systems, which result due to the coupling and flow of the energy from the LEMP field into their conductive structure.

Geomagnetic disturbance/solar storm (GMD) – The sun cyclically emits shock waves of solar winds from its surface, and when these events are oriented towards our planet, it causes a temporary compression and energization of the Earth's magnetosphere. During the largest recorded GMD in September 1859, electrical shocks were reported by telegraph operators and fires were reported.

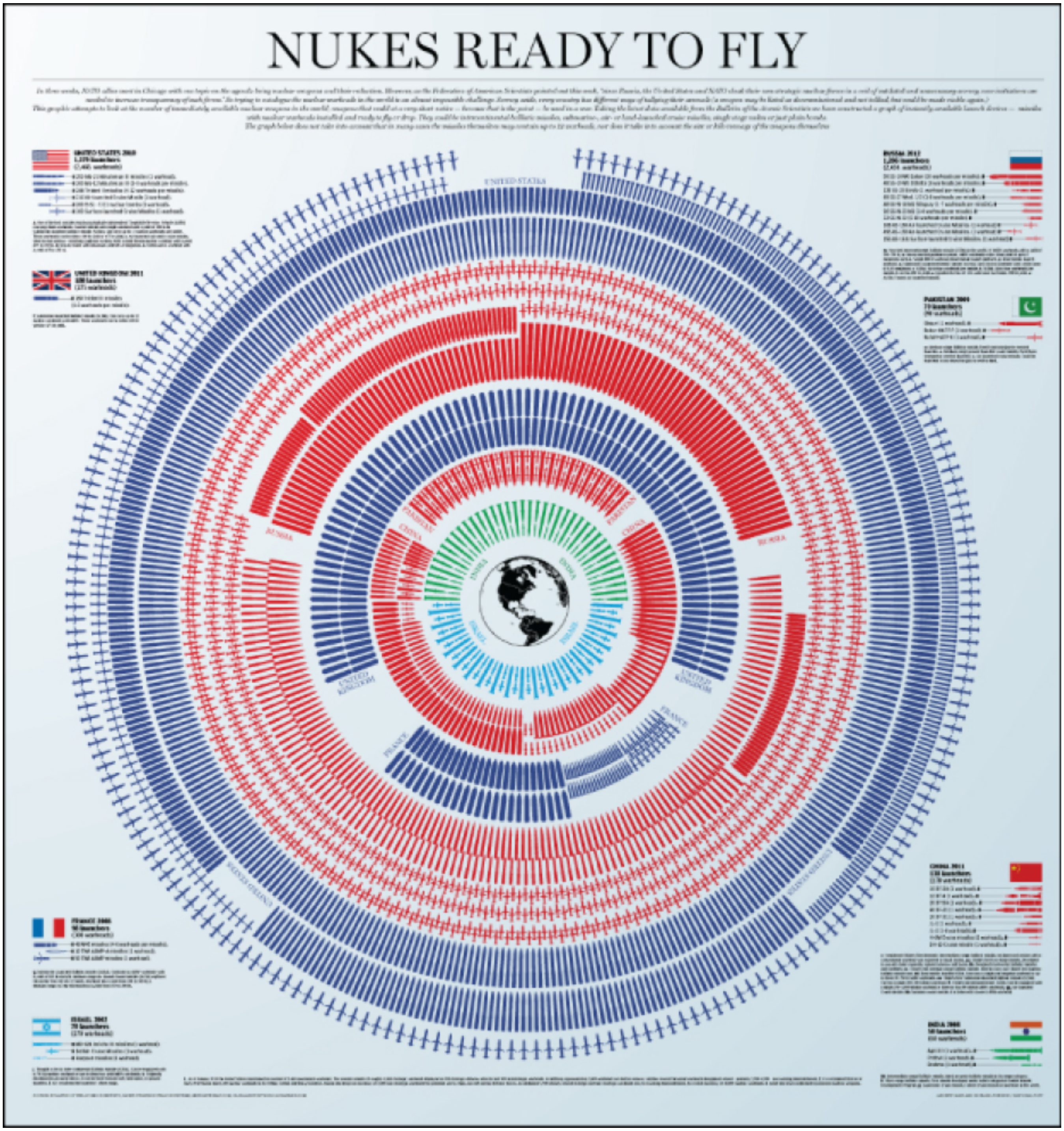
High-altitude electro-magnetic pulse (HEMP) – Capable of influencing the very magnetic field of the Earth, this man-made event is unleashed by detonating a nuclear payload a few hundred kilometers above and oriented towards the Earth's surface. A HEMP event creates three distinct event signatures that together have the potential to wreak havoc on modern electrical systems, large and small.

Source-region electro-magnetic pulse (SREMP) – A cousin to HEMP, this event occurs when a nuclear payload is detonated above the ground, but lower in Earth's atmosphere. The EM energy generated is very high, but covers a smaller footprint on the ground.

Intentional electro-magnetic interference (IEMI), directed energy weapons (DEW) – Man-made, usually created by using a method to rapidly compress the flux in a magnetic field, these EMPs are generally intended for the purpose of damaging or destroying components in a small scale target electrical system.

HEMP Explained

The world's nuclear-armed states possess a combined total of roughly 15,000 nuclear warheads; more than 90 percent belong to Russia and the United States. Approximately 9,600 warheads are in military service, with the rest awaiting dismantlement. All the nuclear weapon states continue to modernize their remaining nuclear forces and appear committed to retaining nuclear weapons for the indefinite future.



National Post Staff, 2012

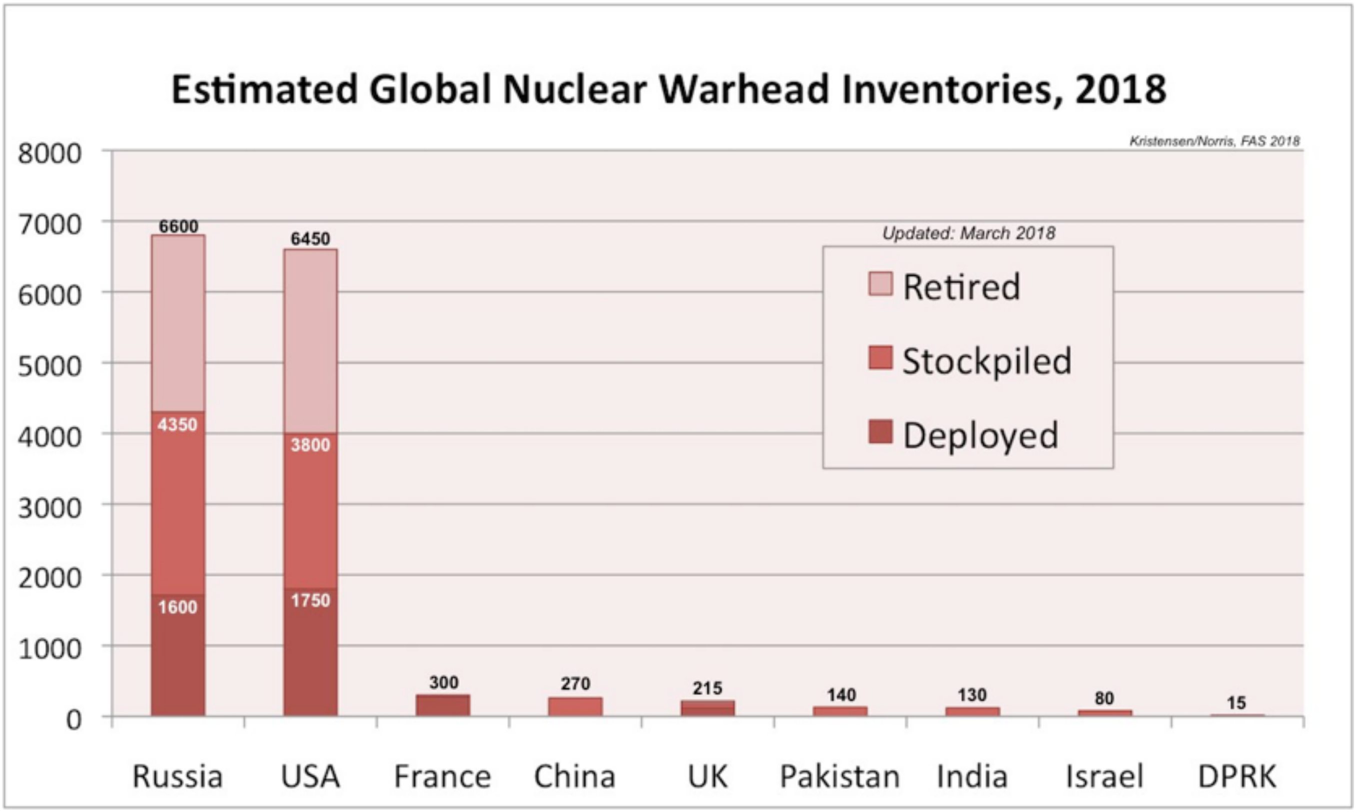


Chart source: https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/

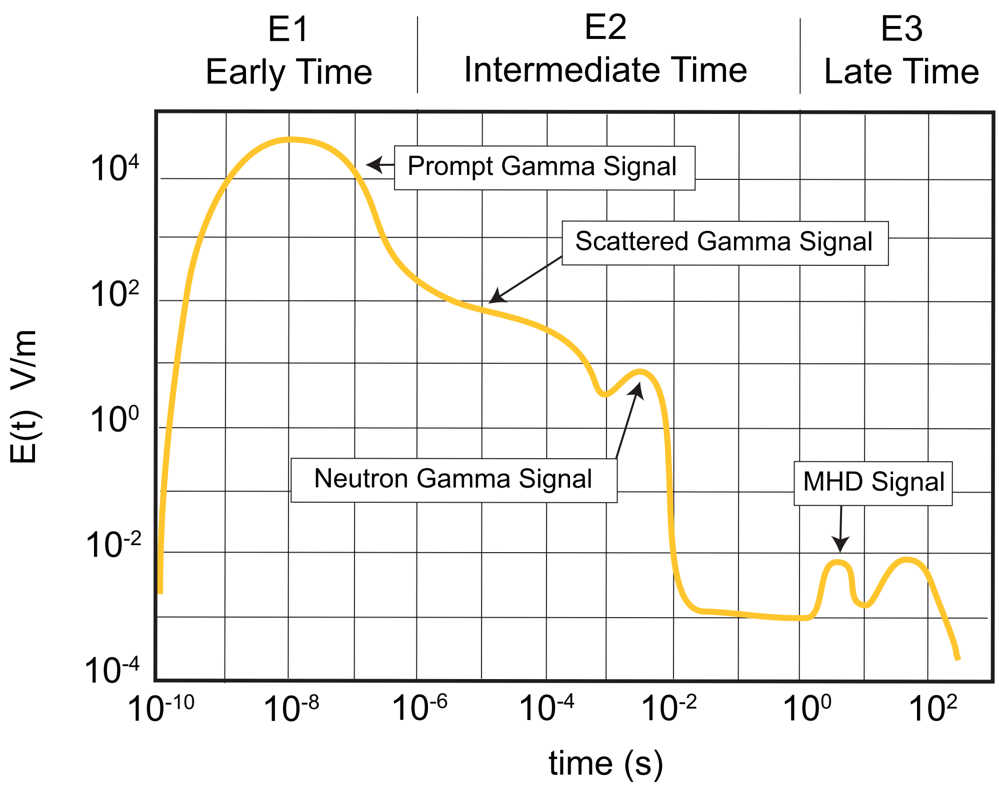
While the EMP effects of a high-altitude nuclear detonation vary based on the yield, altitude and orientation of the weapon, the resulting pulse components of a classic HEMP event are categorized into three time domain regimes (see graph page 6).

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

The Early Time (E1) pulse component results from the bombardment of gamma radiation from the nuclear blast stripping electrons from atoms in the upper atmosphere, sending them speeding downward towards the surface and deflecting off of Earth's magnetic field. This interaction between electrical ions and normal magnetic field causes a very brief, 10's-100's of nanoseconds in length, but very high-intensity, >50kV/m of field strength, EMP over an affected area on the ground, also known as the footprint.

The Intermediate Time (E2) pulse component follows immediately after E1, as a result of scattered gamma rays that are produced by neutrons. The EMP from this effect lasts longer, 1's-1000's of microseconds, and also has the comparative frequency composition of lightning but less energy content than its natural cousin.

The Late Time (E3) pulse component results directly from the distortion of the Earth's magnetic field. This effect is particularly dangerous since the wavelengths of its characteristic frequencies are capable of coupling with large structures such as the distributed power grid in the U.S., and lasts 10's-100's of seconds. Studies are currently being conducted in the U.S. to determine the potential effects of an E3, sometimes compared to the potential effects of a geomagnetic storm or solar flare event, on power transformers and other key power distribution components.



U.S. Department of Defense, 1997

Due to these substantially different time domain characteristics and associated wavelengths, each of the staged events couples or attaches to systems of different physical sizes.

E1 has the shortest wavelength, and attaches most effectively to pieces of individual equipment and generally small electrical systems. The very fast rise time of this pulse can also catalyze damage to electronics in addition to the high voltage and currents derived. Impacted equipment could include desktop and laptop computers, cellular phones, programmable logic controllers, engine control units and automatic transfer switch controllers.

E2 is very similar to lightning, and attaches effectively to wiring in facilities and homes, potentially impacting electronics, telecommunications and control systems.

The E3 event has such a long relative time duration that it is considered a pseudo-DC signal, capable of coupling to large portions of the power grid and causing hotspots in critical transformers. Due to the massive amount of energy involved, protection techniques include blocking tactics such as isolation transformers, reactors and switching devices, since there is far too much energy to attempt to shunt safely away from the system.

Early research by the Electric Power Research Institute (EPRI) suggests that service interruption resulting from E3 would more likely be regional than nationwide. (Howard, 2018)

This event is also often compared to a geomagnetic disturbance (or solar storm) due to its similarities in duration and effects.

Image source: https://www.colocationamerica.com/blog/emp-protected-data-centers

Hardening Against HEMP

After the lessons learned from the atmospheric nuclear tests following World War II, and the ensuing escalating cold war and nuclear arms race with the Soviet Union, the U.S. began implementing protection measures into critical government and military assets, a practice known as 'hardening.'

As described earlier, a HEMP event manifests as a high strength electric field oriented towards the ground. As this radiated field travels to the ground, it couples or 'attaches' to electrical systems and transfers electrical energy to them based on a wide range of factors including field orientation, geometry, soil resistivity and others. This transfer results in very high voltages being developed on system conductors, which in turn drive high electrical currents or arcs within equipment and electronics, and resulting in damage or degradation due to the burnout.

Due to the threats posed to electrical systems both by the radiated field and by the resulting conducted energy, the most effective protection strategy for a HEMP event is a system based design approach whereby shielding, filtering, surge protection and grounding provisions are implemented in coordination with each other to block, distort and shunt the energy safely away from sensitive equipment.

In 1994, the U.S. Department of Defense released MIL-STD-188-125A, containing technical requirements and design objectives for HEMP protection of systems and facilities performing time-urgent command, control, communications, computer and intelligence (C4I) missions. The philosophy behind the standard is to envelope all potentially sensitive equipment within a very well-shielded master volume, and treat all electrical and environmental points of entry (POEs) into the master volume with provisions to block unwanted radiated and conducted EM energy. Towards this end, the standard imposes stringent performance levels on both shielding effectiveness and pulse current injection response into the protected volume. Since this standard applies to the highest level strategic assets, each facility is field-tested to verify hardness characteristics at commissioning and periodically during its service life.

EMP simulator HAGII-C testing a Boeing E-4 aircraft. US DoD, Wikimedia Commons.

In 2016, the Department of Homeland Security released 'EMP Protection and Restoration Guidelines for Equipment and Facilities,' outlaying practical guidelines that can be adopted by any organization desiring to protecting critical systems against HEMP, SREMP, GMDs and IEMI.

The authors developed a series of staged protection levels that are based on the estimated time to recovery after a HEMP event. Specific guidance for implementing shielding and protection measures are given for each level.

Protection Levels

LOW COST
LEVEL 1

Use procedures and low cost best practices to mitigate EMP effects. Unplug power and data line into spare backup equipment. Turn off equipment that cannot be unplugged and that is not immediately needed for mission support. Store one week of food, water and critical supplies for personnel. Wrap spare electronics with aluminum foil or put in Faraday containers. Have back up power that is not connected to the grid (generators, solar panels, etc.) with one week of on-site fuel (like propane/diesel)/ Use GETS, WPS, 7 TSP services; join SHARES if applicable.

HOURS
LEVEL 2

In addition to Level 1, use EMP rated surge protection devices (SPDs) on power cords, antenna and data cables and have EMP protected back-up power. Use SPDs (1 nanosecond or better response time) to protect critical equipment. Use true line/double-conversation uninterruptible power supplies (UPS). Use fiber optic cables (with no metal); otherwise use shielded cables and ferrite/SPDs. Shielded racks/rooms and/or facilities may be more cost effective than hardening numerous cables. Use EMP protected HF radio voice/email if need longhaul nets. Suppress EMP fires.

MINUTES
LEVEL 3

In addition to Level 2, use civil EMP protection standards (like IEC SC 77C). Use EMP shielded racks/rooms and/or facilities to protect critical computers, data centers, phone switches, industrial and substation controls and other electronics. Shielding should be 30-80 dB of protection thru 10 GHz. Use SPDs to protect equipment outside of shielded areas. Can use single-door EMP-safe entryways. Use ITU and IEC EMP standards for design guidance and testing. Have 30 days of back-up power with on-site fuel (or via assured service agreement with EMP resilient refuelers). Use EMP protected HF radio and satellite voice/data nets if need long-range links to support missions.

SECONDS
LEVEL 4

Use Military EMP Standards (MIL-STD-188-125-1 and MIL-HDBK-423), and 80+ dB hardening thru 10 GHz. Use EMP/RFW shielding in rooms, racks, and/or buildings to protect critical equipment. Use EMP SPDs to protect equipment outside of shielded areas. Use EMP protected double-door entryways. Have 30 + days of supplies and EMP protected back-up power (to include on-site fuel) for critical systems. Don't rely on commercial Internet, telephone, satellite, or radio nets that are not EMP protected for communications. Use EMP protected fiber, satellite, and radio links.

U.S. Department of Homeland Security, 2016

Level 4 EMP protection is aligned with applicable military standards for government and defense applications.

EMP protection zones for elements of civil infrastructure that are key to maintaining social order are suggested here.

Suggested Protection

Civil Application	Suggested Protection Zone	Recovery Time
Power Generation, Distribution	3	Minutes
Microgrids	3	Minutes
First Responders	3	Minutes
Telecommunications	3	Minutes
Banking & Finance	3	Minutes
Security	2	Hours
Commerce	2	Hours
Agricultural	2	Hours
Residential	2	Hours

EMP Surge Protection

EMP surge protectors are different from standard lightning surge protectors in that they must also be designed and tested to be effective against the higher frequency E1 pulse for both survivability and response, and also be rated and tested for the E2 pulse that is similar to lightning.

The most important characteristics for EMP surge protectors are a fast response time, a low-inductance surge path to Ground and enhanced shielding characteristics. The use of silicon avalanche suppression diode (SASD) technology is desirable due to its fast response time and non-degrading characteristics, but other technologies such as metal oxide varistors (MOVs) and gas discharge tubes (GDTs) are effective when designed properly. Military grade EMP surge protectors require staged hybrid protection that includes coordinated series impedance elements and/or multiple surge technologies, along with an integral EM barrier to maintain the SE characteristics of the master shield.

Transtector and PolyPhaser provide commercial and military grade EMP surge protectors for a wide range of AC, DC, Network/Signal and RF applications. These products have been tested to the E1 and E2 waveforms as defined in MIL-STD-188-125, and are suitable to support the implementation of Level 2, 3 and in some cases Level 4 EMP protection as outlined in the Dept. of Homeland Security EMP Protection Guidelines for Equipment and Facilities.

For more information contact Transtector or PolyPhaser at 800.882.9110 or visit www.transtector.com or www.polyphaser.com

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